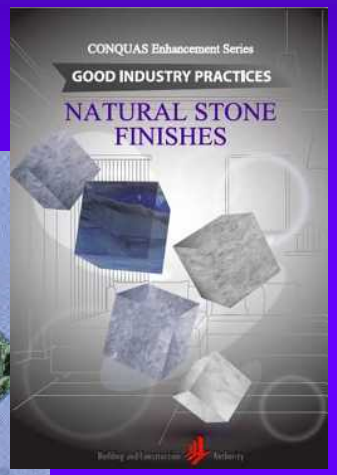
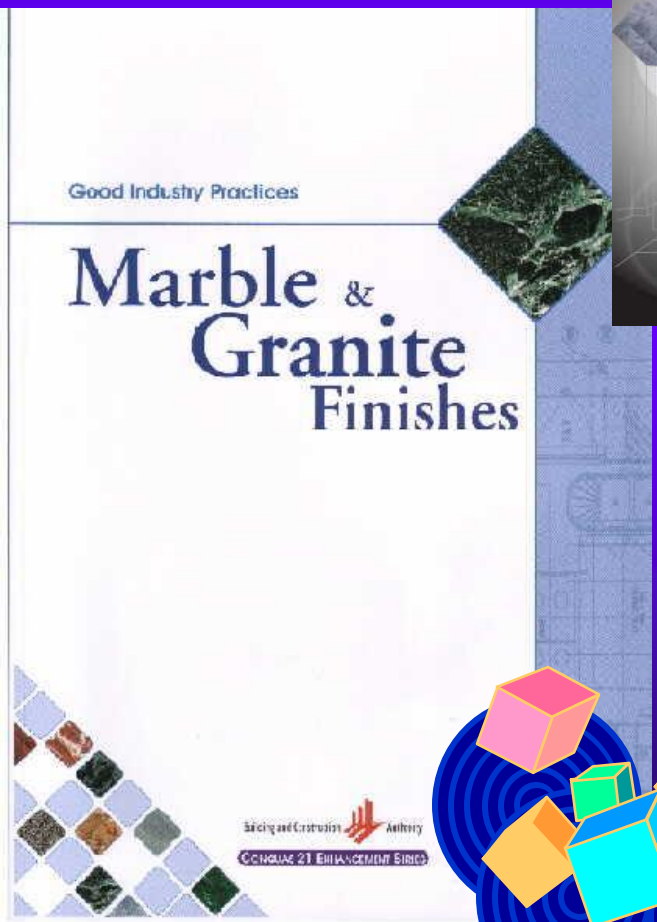
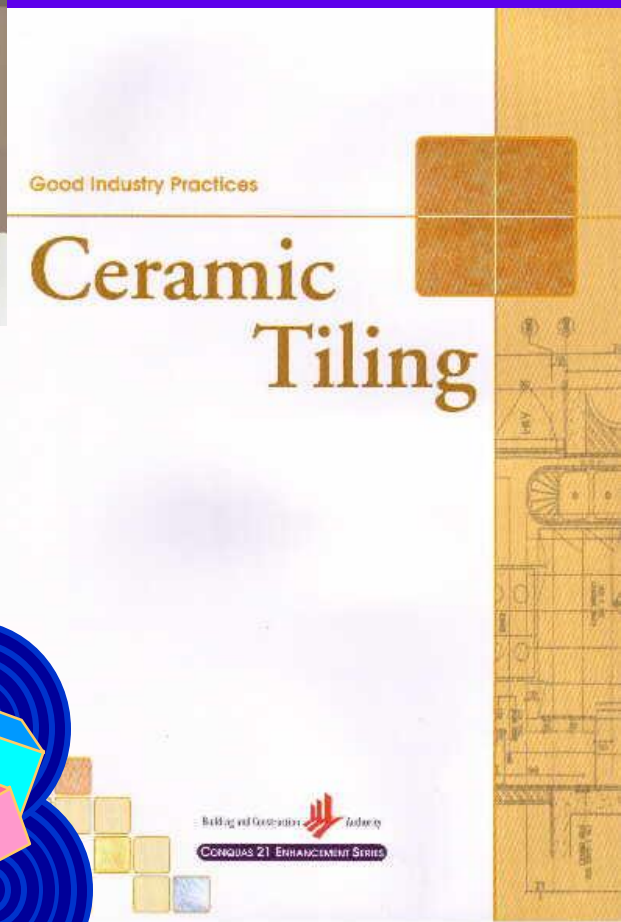
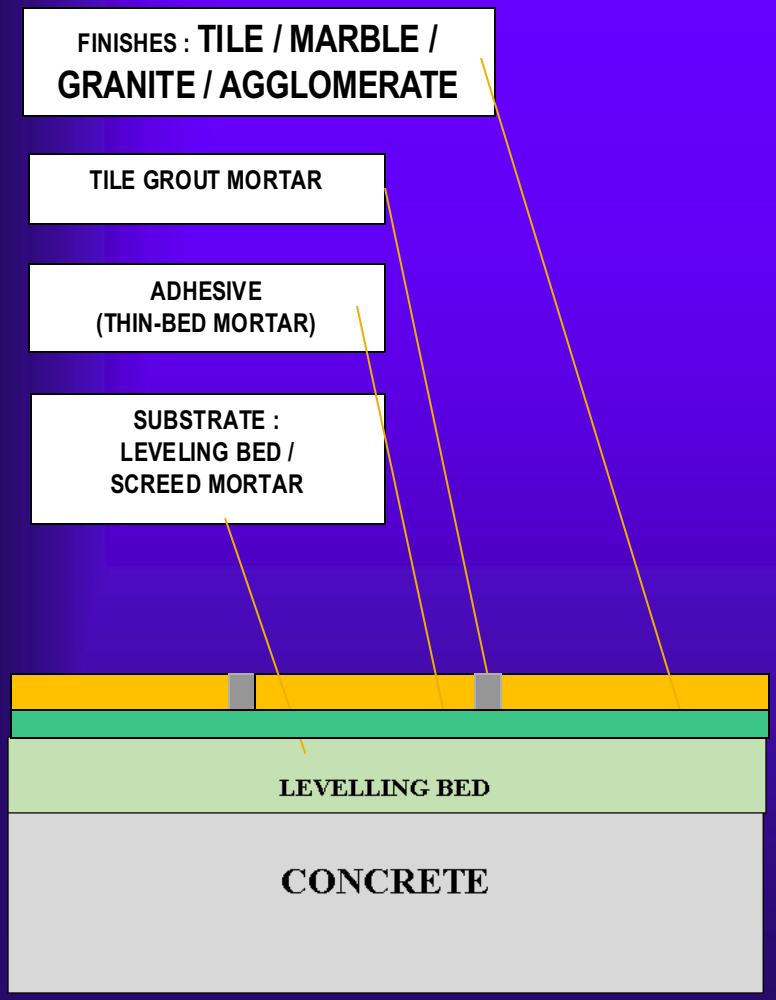
Good Industry Practices
Ceramic Tiling / Natural Stone Finishes







Tiling System & its Components



- All components are equally important
- Must be compatible with one another
- Could only function collectively
- The system is no stronger than the weakest component

Quality Factors

§1 Common Procedures

1.1 Design

- Materials: finishing, bedding, grout
- Details: movement joints, waterproofing
- Layout planning

1.2 Delivery, handling & storage

1.3 Preparatory works

- Surface preparation
- Laying of screed & render
- Setting out

§1 Common Procedures

1.4 Installation

- Levelling Mortar Bed material preparation & Laying
- Adhesive material preparation
- Laying
- Grouting
- Movement joint installation

1.5 Protection

§2 Material Selection

2.1 Ceramic tiles

2.2 Stone finishes

2.3 Agglomerate finishes

2.4 Bedding materials

2.5 Grouting materials

§3 Inspection & Common Complaints

3.1 Inspection of completed works

3.2 Common complaints

- Jointing
- Finishing
- Alignment & evenness
- Cracks & damages
- Hollowness

§1.1 Design - Responsibility

- The designer should consider:
  - Tile layout taking into consideration minimum joint width and tile manufacturing tolerances
  - Material selection – understand material characteristics and compatibility
  - Proper installation
  - Quality control

- The contractor should:
  - understand material characteristics
  - when doubting materials' compatibility:
    - ⇨ check with suppliers on material suitability
    - ⇨ feedback to the designer

<u>Example</u>:
Application of water-based Primer onto Drywall boards first to even out the surface absorbency before tiling works.

But when tiling onto boards that have already been waterproofed (i.e., non-absorbent surfaces), there is <u>NO</u> need to apply Primer prior to tiling.

Caution on “Back-netting” layers

Example:
Specification calls for a coat of penetrating sealer / impregnator to be applied onto the back of the stone.

But if the stone has netting & glue on its back resulting in a non-absorbent surface, applying a sealer may create a film being formed.

Design – Materials

- Finishing
  - ➢ Ceramic tiles
    - ⇨ SS 483 (ISO 13006)
    - ⇨ Traffic & load conditions
  - ➢ Stone finishes
    - ⇨ Finishes & aesthetics
    - ⇨ Installation methods
    - ⇨ Soundness of Natural Stone
    - ⇨ Dimensional stability of Agglomerates
    - ⇨ Confirmation: mock up, pre- & dry-layout

Design – Layout Planning

- Minimum joint width needs to consider:
  - Tiles: manufacturing tolerance, modular format
  - Stones: moisture & thermal movements, processing accuracy
- Aesthetics:
  - Centre of tiling area
  - Minimum cutting

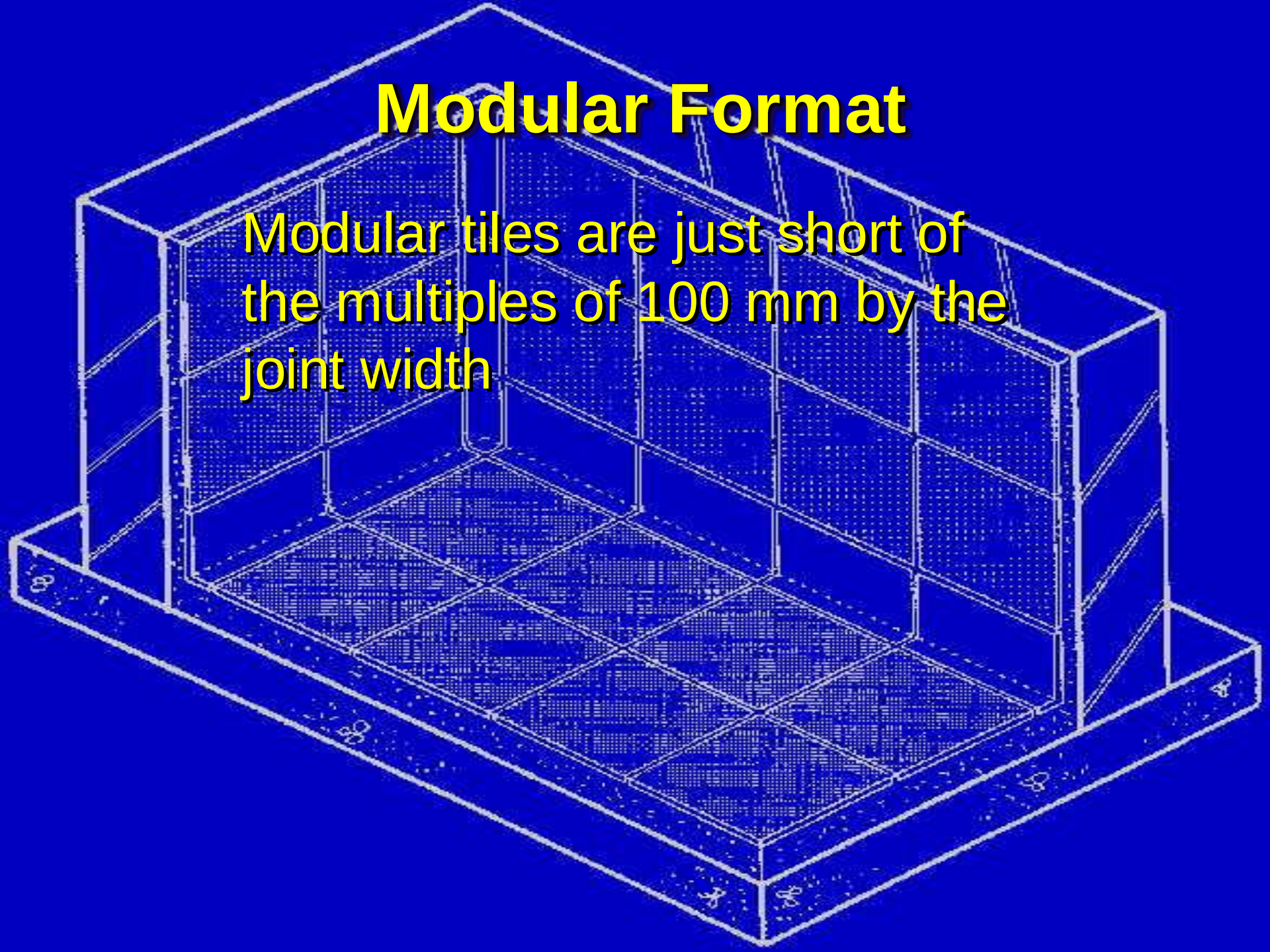
Manufacturing Tolerance

Take 600 × 600 mm tile for example:

- SS 483:
  - Precision extruded: ±2 mm
  - Natural extruded: ±4 mm
  - Dry pressed: ±1.5 mm
- Withdrawn standards:
  - SS 301: ±6 mm
  - SS 57: -0.8/+3 mm

Modular Format

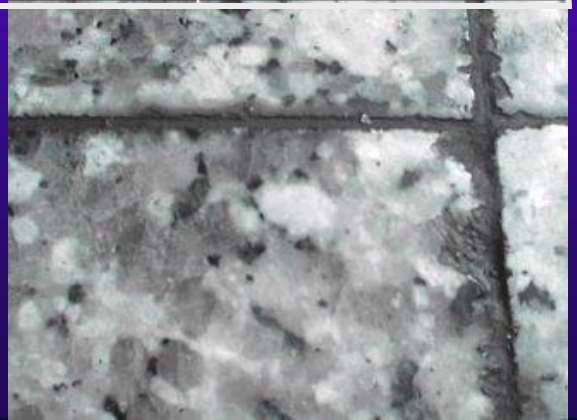
Modular tiles are just short of the multiples of 100 mm by the joint width



Minimum Joint Width

Tile Manufacturing Method	Walls	Floors
Dust pressed ceramics	≥ 1.5 mm	≥ 3 mm
Extruded ceramics	≥ 6 mm	6 ~10 mm

Nature of Stones	Joints
Smooth-finished stones	≥ 1.5 mm
Rough-textured or riven-finished stones	≥ 6 mm

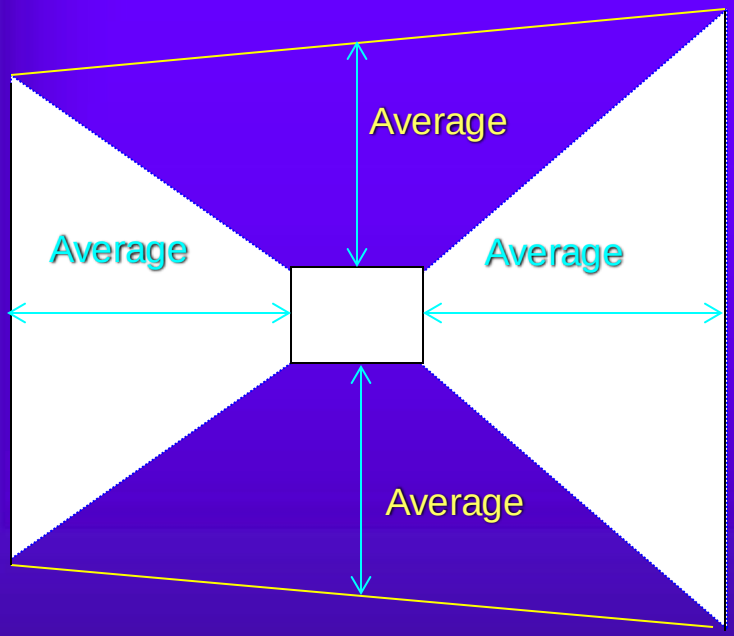


SS 665: 2020 (SS: CP 68) - No Butt Joint

Butt-joint should be avoided.

- Might have problem of breakages due to differential movements
- Cannot be grouted. Joints are open to contamination

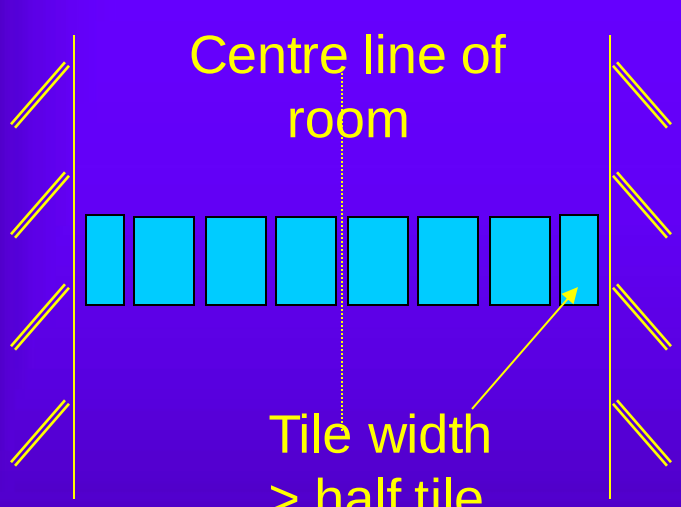
Layout Planning –
Centre of Tiling Area

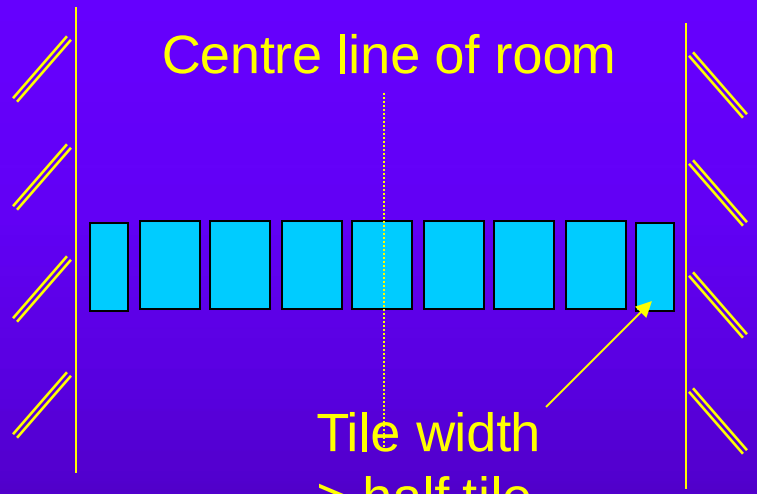


Principle to moderate position of 1st centre tile if room walls are not parallel

Layout Planning – Minimum Cutting

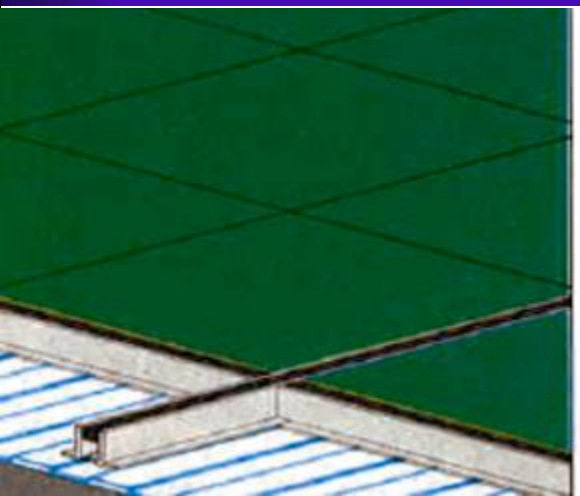
Principle of having cut tiles with width > half tile

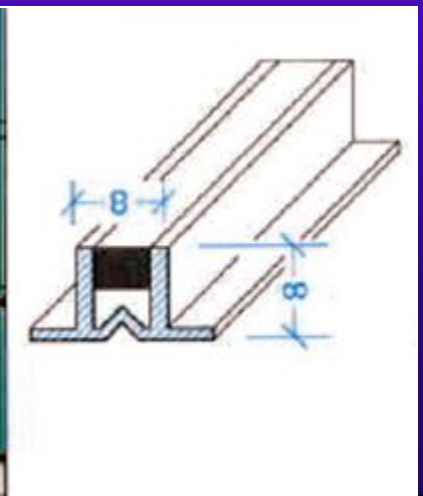


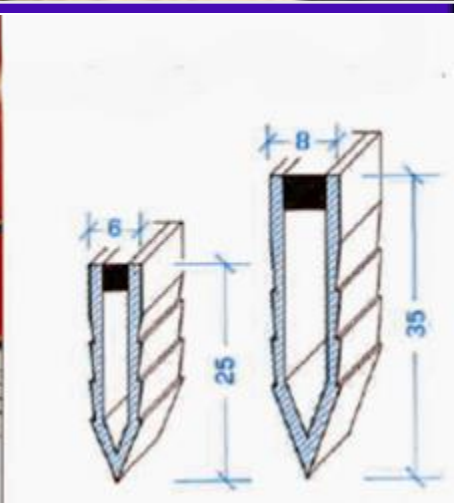


Design – Movement Joints

- In-situ joints are formed during construction
- Prefabricated joints



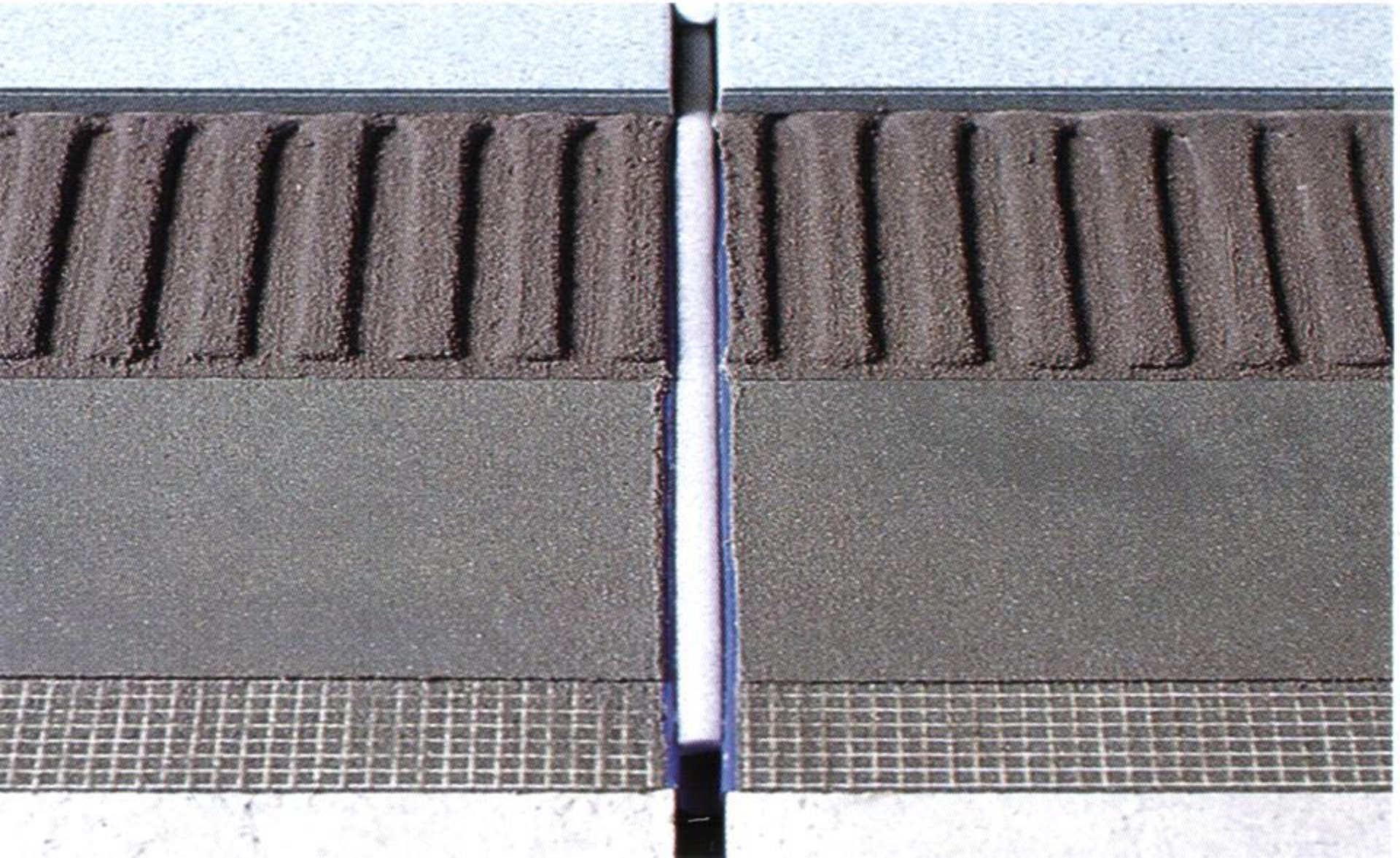




Design – Movement Joints

- Backer-rod: closed pore
- Sealant: adequate Movement Accommodation Factor & durability, application Ratio width to depth;
- Need to waterproof?

Waterproof Movement Joint



Locations & Joint Width

- Carry structural joint through tiling system

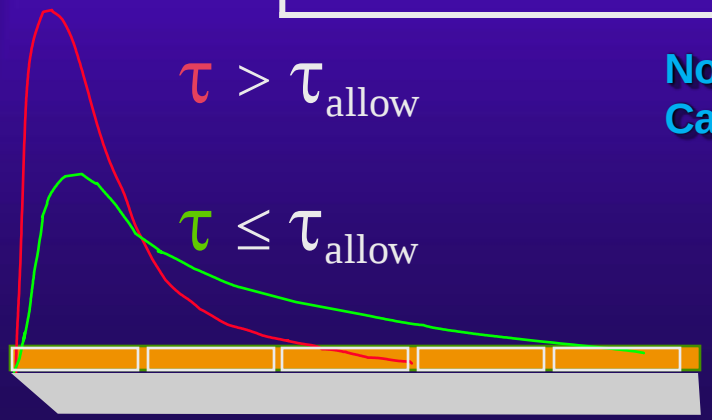
Locations & Joint Width

- Isolate from restraint surfaces: e.g. perimeter wall, column
- At juncture the substrate changes alignments: e.g. corners
- At juncture the substrate changes materials: e.g. concrete column & brick wall

Locations & Joint Width

Divide large continuous tiling system:
e.g. intermediate

Location	Spacing	Width
Interior walls	5 ~ 6 m	3 ~ 5 mm
Interior floors	5 ~ 7 m	≥ 5 mm
Sun-shined Interior	3.6 ~ 7 m	≥ 5 mm
Exterior wall & floor	3 m	10 mm
	5 m	12 mm



Note:
Can also refer to SS 665 (former CP 68) for more details

Locations & Joint Width

- Plan ahead: anticipate all kinds of movements
- What to consider?
  - Long term: tile expansion, mortar shrinkage
  - Short term: temperature, moisture, vibration, etc.
- Provide adequate joints before cracking occurs

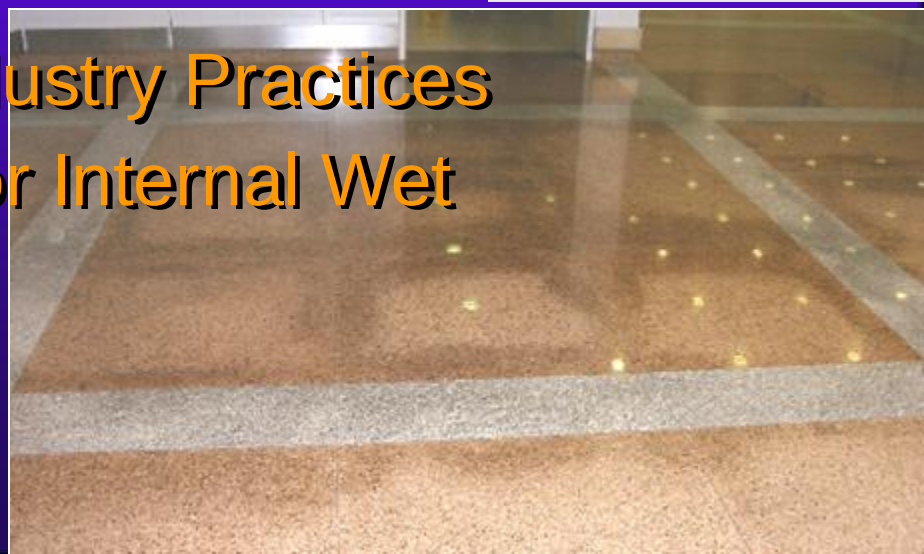
Movement Joints

Plan ahead: Movement Joints can also be incorporated for irregular tile patterns

Design – Waterproofing

Normal protection from damages due to

- Rising damp due to capillary action
  - polyethylene sheet below floor slab
  - damp-proof-course in wall
- Direct contact with water (e.g. shower compartment)
- Details refer to"Good Industry Practices Guide – Waterproofing for Internal Wet Areas"



§1.2 Delivery, Handling & Storage

- Ceramic Tiles
  - Quality: similar to approved sample
  - Country of origin: confirm
  - Appearance: surface appearance, dimensions, no cracking
  - Storage: wrapped in original package on dry, firm & levelled ground

§1.2 Delivery, Handling & Storage

- Large Format Tiles – use of frame may be required for storage and handling to prevent tile warpage

Delivery, Handling & Storage

- Stones
  - Physical criteria: owner defines quantitatively (test methods, etc.)
  - Physical quality: similar to approved sample (type, category, source, tonality variation, etc.)

Delivery, Handling & Storage

- Stones
  - Appearance: check cracks or chips within acceptable time-frame from delivery to avoid dispute between suppliers & contractors
  - Storage: protected with foam materials, wrapped in polyethylene, and kept at clean and dry places

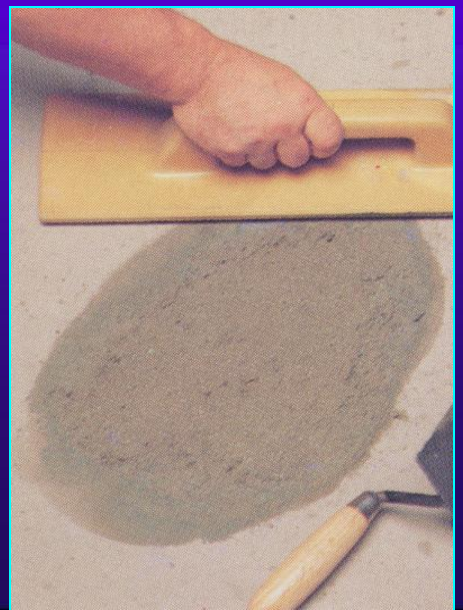
Delivery, Handling & Storage

- Bedding & Grouting Materials
  - Compatibility: check with manufacturer when in doubt
  - Storage: keep original package intact until use; on dry, ventilated and clean place

§1.3 Preparatory Works

- Surface preparation
  - Level/plumb & true to design specification
  - Repair damaged portions & cracks

Undulating surfaces and pot holes must be levelled first prior to the installation of tile & stone with adhesive



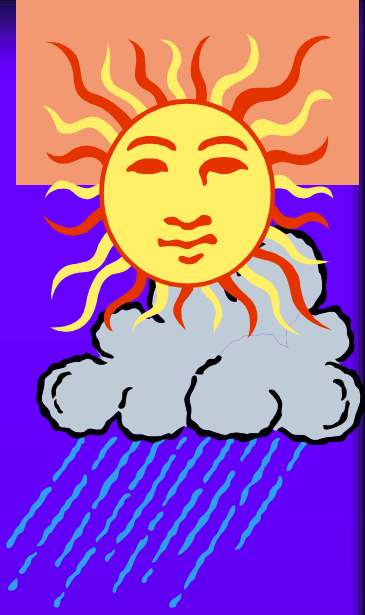
Preparatory Works

Surface preparation

- Substrate sound, stable & free from
  - Loose substances: dust, laitance, etc.
  - Contaminations: oil, form-releasing agent, high/low pH

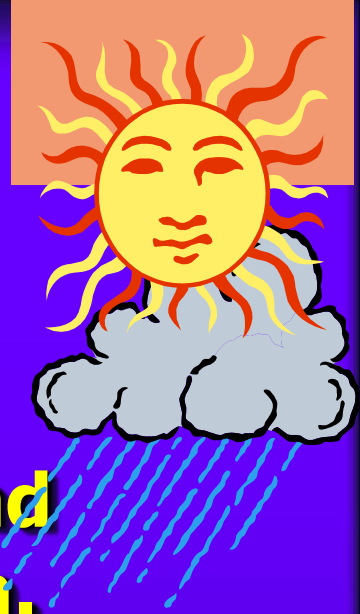
Preparatory Works

- Surface preparation
  - Control environmental conditions
  - Set up shelter when necessary
  - Waterproof, damp-proof on- & below-grade



Protect the substrate and installation work from direct sunshine

Protection & Curing
(especially for pools)



Protect the working area from rain and direct sunshine during the installation. If necessary, erect tentage and maintain temporary drainage system.

Allow installation to cure properly in dry environment.

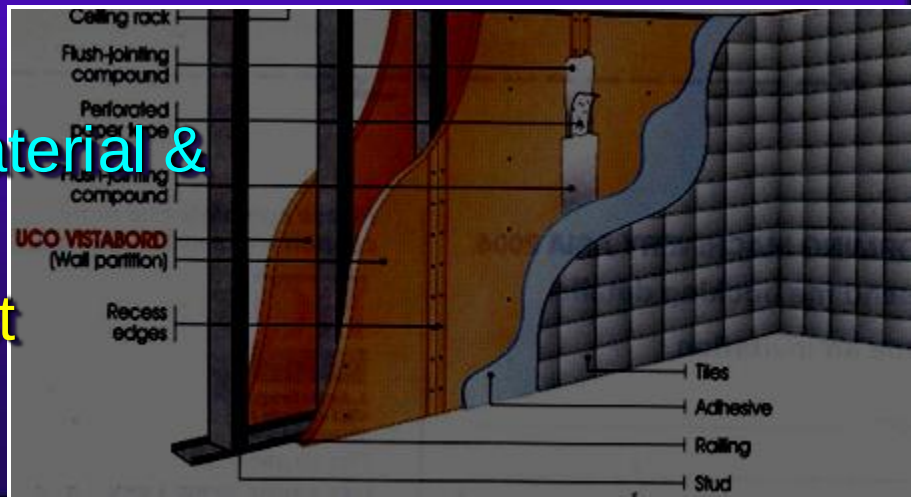
Preparatory Works

- Surface preparation
  - Masonry: nothing special
  - Concrete:
    - ⇨ Cure ≥ 28 days
    - ⇨ Floor: apply slurry coat (no sand) immediately before *screeding*
    - ⇨ Wall: apply splash coat (spatter dash with sand), allow dry for 24 hours before *rendering*

Preparatory Works

- Surface preparation
  - ➢ High-precision (e.g. ALC) blocks:
    - ⇨ Render only when out of alignment
    - ⇨ otherwise, apply a suitable primer before tile/stone installation

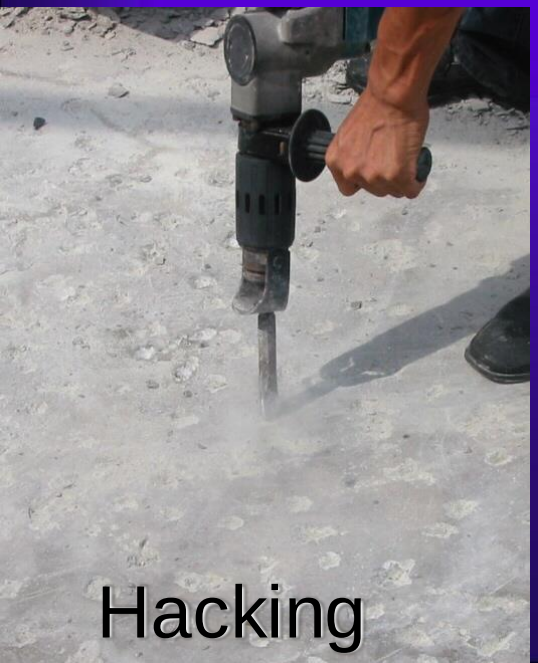
  - ➢ Manufacturer of “dry wall”
    - ⇨ Certifies suitable use
    - ⇨ Specifies supporting material & manner
    - ⇨ Suitable primer to adjust absorption



Preparatory Works

Old surface preparation

additional information not from GPG



Hacking

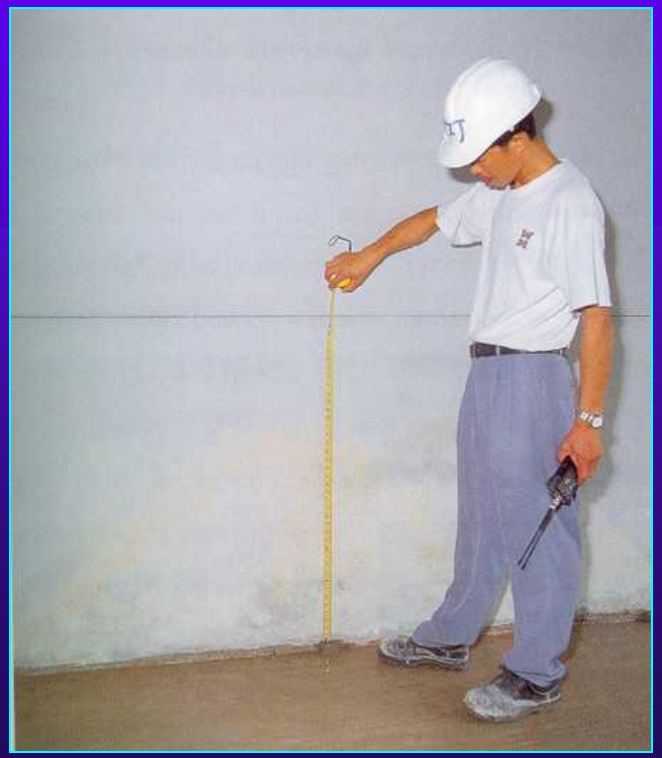
Scarification

Grinding

Sand blasting

Preparatory Works

- Laying of screed & render
  - Setting reference line
  - Dry & porous surface to Saturated Surface Dry

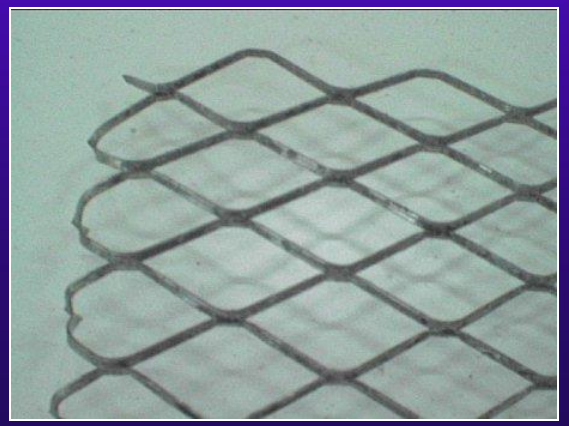


Preparatory Works

- Laying of screed & render
  - Curing:
    - ⇨ Mist spray first 2 days
    - ⇨ Air cure ≥ 7 days
    - ⇨ Detect hollowness & cracks & repair
  - Identify concealed services

Preparatory Works – Applying Render

- Render on walls:
  - 1st coat ≤ 15 mm, roughen,
  - Dry ≥ 24 hours before 2nd coat
- Render thickness:
  - Site batched: total thickness ≤ 30 mm
  - Pre-blended: follow manufacturer's instruction
  - When > 30 mm, insert anchor ribbed metal lathing



Preparatory Works – Floor Screed

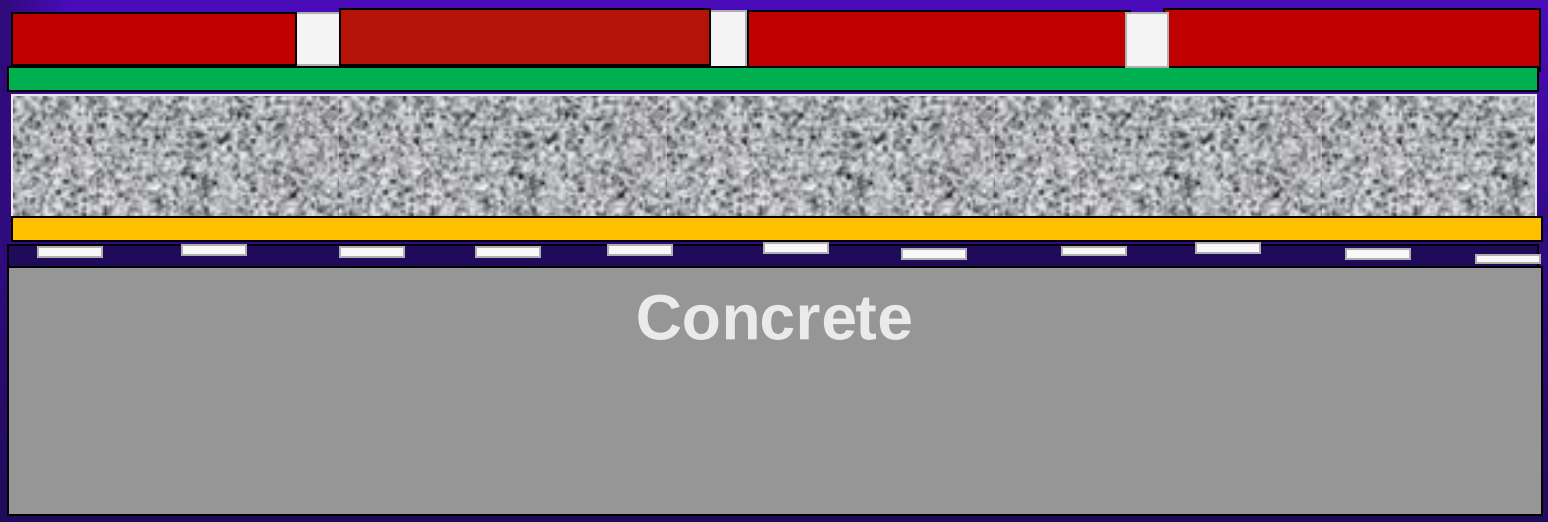
- Screed thickness:
  - Bonded: 40 mm average (minimum 20 mm)
  - Un-bonded: plastic sheet, 75 mm average (minimum 40 mm)
  - When ≥ 40 mm, insert metal mesh in middle
  - Pipes & ducts need additional thickness

Unbonded Floor Screed

Floor Build-up

- Primary waterproofing (for wet areas)
- Separation Layer; polyethelene sheet, drain mat etc
- Floor screed; ≥ 40mm with wiremesh, unbonded
- Lay Tile/Stone Finish with Adhesive (thin-bed)
- Grout tile/stone joint

(Secondary waterproofing over screed – optional)



Unbonded Floor Screed

“Semi-dry” Floor Screed Mortar

Can be Bonded (+ slurry coat) or Unbonded, depending on requirements

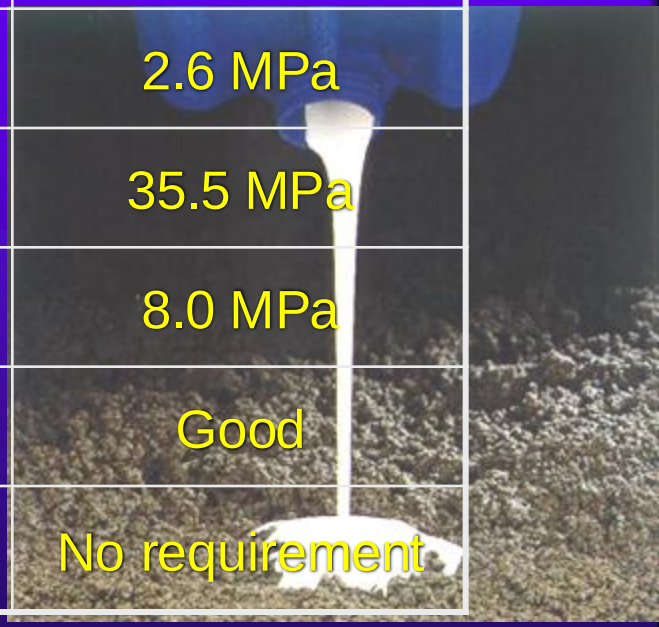
Preparatory Works – Floor Screed

- Screed on concrete floors:
  - Tamp down, remove void, wood-float finish
  - Recommend latex fortification

Preparatory Works

- Laying of screed & render
  - ➢ Effects of adding polymer latex

Performance	C + S	C + S + Latex
Adhesion strength @ 28 day	0.3 MPa	2.6 MPa
Compressive strength @ 28 day	2.8 MPa	35.5 MPa
Flexural strength @ 28 day	Poor	8.0 MPa
Impact resistance	Poor	Good
Minimum thickness	> 20 mm	No requirement



Additional information, not from GPG

Substrate Accuracy

Bedding Material	Walls	Floors
Adhesive	≤ 3 mm	≤ 3 mm
Cement-sand mortar	≤ 6 mm	≤ 5 mm
Semi-dry cement-sand	—	≤ 10 mm

Reference can be made to SS 665:2020 (former CP 68)

Adhesive Thickness & Substrate Flatness

The larger the stone or tile, the flatter the substrate needs to be. Small tiles can follow an undulating substrate. Large stone or tiles cannot.

Check Substrate for Accuracy & Plumbness

Do not lay tile onto undulated surfaces

Not advisable :

It will result in a very thick adhesive application and you cannot obtain a well compacted adhesive bedding.

Undulated surfaces need to be levelled smooth first to achieve required substrate accuracy prior to laying the tile with the adhesive.

When Substrate is not accurate (out of plumb)

Adhesive applied too thick to accommodate alignment resulting in too much air voids in the adhesive bed.

How to do it right?

- Level substrate to plumbness
- Apply adhesive onto substrate and back of tile and then press tile firmly and well compacted into position to remove air voids in the adhesive bed.

Curing of Floor Screed/Wall Render

Allow curing to take place – 7 days for every 10mm thickness of mortar.

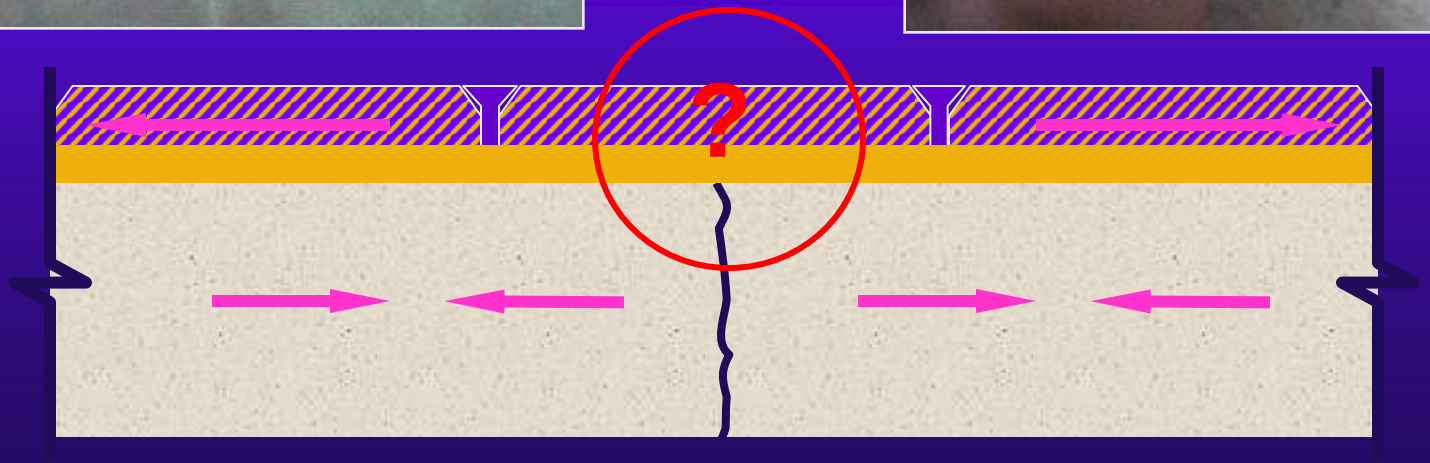
- **Screeds will shrink as they dry out and may produce sufficient compression forces to break the adhesion between the tile and the adhesive bedding mortar.**

- **Allow mortar to achieve low level of residual moisture content.**

Laying stone by “Traditional Mud Bed” or “Wet-Method” :

NB: Thick-bed mortar & uncured screed mortars :
- Moisture in bedding has difficulty to dry out

Site Condition



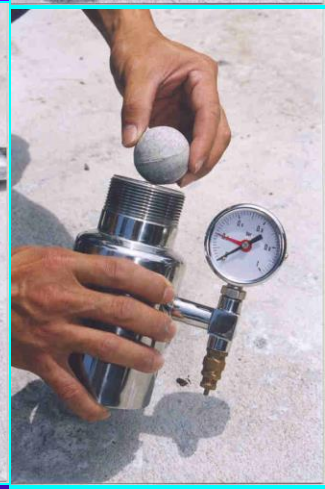
Stress from Shrinkage cracks

Surface Preparation

Check substrate to confirm that there is NO hollowness before commencing the installation of tile or marble.

Preparatory Works

- Preparing for stones
  - Check moisture content in substrate using calcium-carbide test kit for Group II & III stones (Appendix A)



Preparatory Works

- Check moisture content with moisture meter

Preparatory Works

- Setting out tiling
  - Minimize cutting
- Preparing stone
  - Water-repellent impregnator on 5 (NOT 6!) faces of absorbent stones
  - Adequate adhesive & vapour barrier to prevent watermark & efflorescence

Preparatory Works

Impregnators / Penetrating Sealers :

- Water-based vs Solvent Based

- Water-repellent vs
  Water & Oil repellent

- Original Intent of Impregnators

“Water Repellency” Effect from Sealers & Its Negative Impact on adhesion

Caution

- Water-beading"

- Sealer Residue on the back of the marble

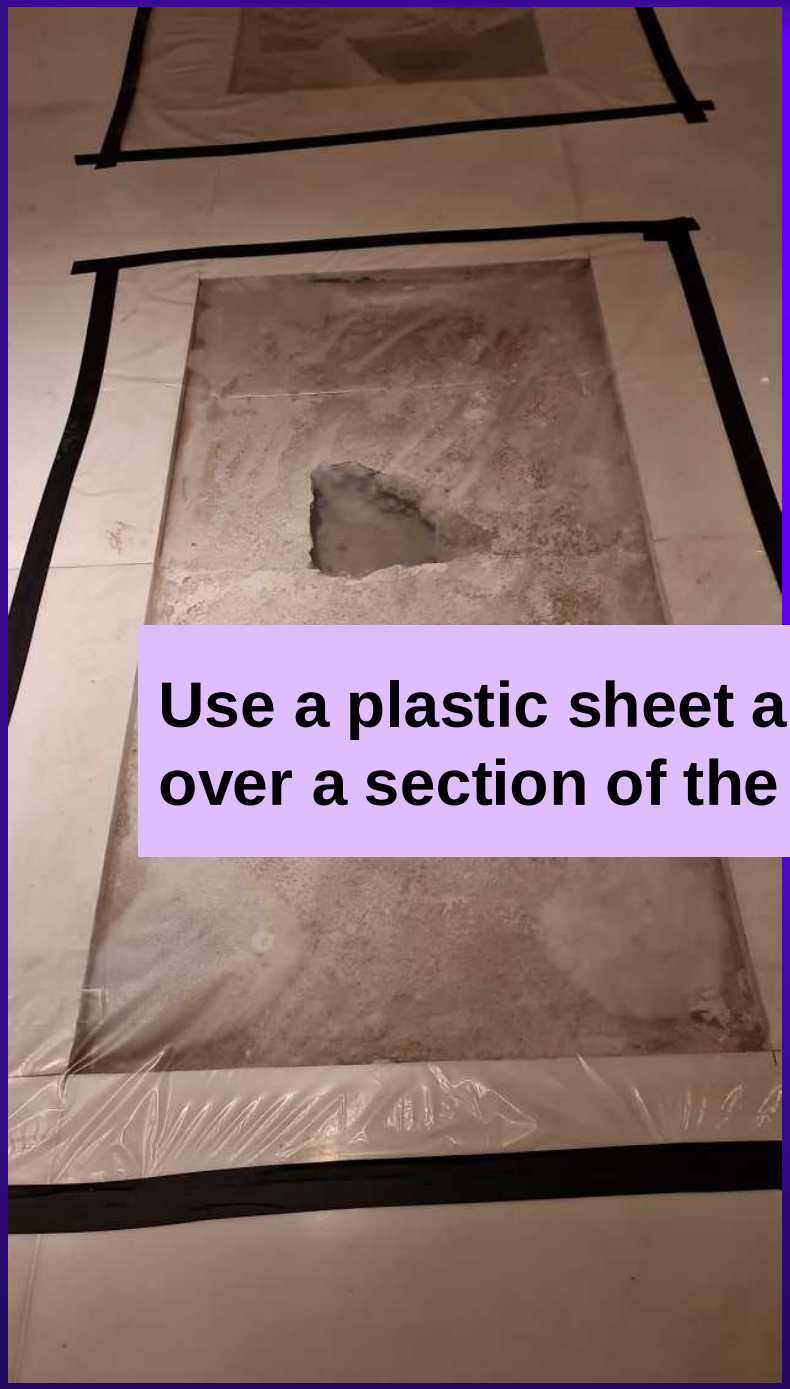
Does the Back-Sealing of the stone really prevent the stone from stains?

What can still go wrong?

- Not thoroughly sealed
- Stone's porosity is not always homogeneous
- Residual Moisture from the screed is still high

Discoloration after installation

What could have happened?



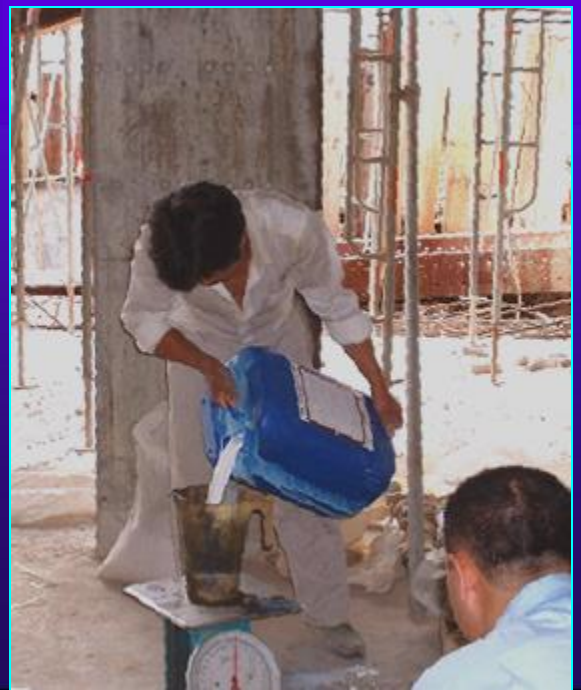
A simple quick check on site can also be done over a 24-hour period to verify if screed mortar has High Moisture Content.

Use a plastic sheet and seal over a section of the floor.

Water droplets are visible which implies presence of moisture in this floor substrate.

Installation

- Bedding material preparation
  - ➢ Mix proportion:
    - ⇨ Site-blending: consistent proportions
    - ⇨ Pre-blended: follow manufacturer instruction



Installation

- Bedding material preparation
  - Mechanical mixer
  - Clean container
  - Potable water
  - Right order and timing

Installation

- Bedding material preparation
  - High-speed mixing ⇒ entrapped air
  - Large quantity, early mixing, long transport distance ⇒ exceeded pot life
  - Re-tampering ⇒ reduced performance

Site Mixing of Cementitious Adhesive:

Pour Liquid into clean bucket , and then pour the Powder component and mix it with a mechanical stirrer.

Installation

- Laying tiles
  - **C + S mortar**
    - ⇨ Dampen substrate
      adjust suction
    - ⇨ Soak porous tiles
      avoid water lost
  - Adhesive
    - ⇨ Dampen substrate?
    - ⇨ Observe Open Time

Installation

- Laying
  - Press with firm pressure & fully compacted
  - Tap uniformly
  - Use plastic spacer for consistent joint width
  - Check level
  - Random check bedding coverage

Installation

- Cleaning back of tile to remove dirt and dust before laying

- Apply adhesive onto substrate with steel notched trowel

(*observe "Open Time"*)

- Apply adhesive onto the back surface of tile

Installation

- Use rubber mallet to tap on tile for good coverage, contact and compaction

- Check randomly adhesive coverage and compaction during work in progress

- Check for evenness and lippage

Installation

- Wipe clean the “bond” side of the stone

- Apply adhesive onto the surface with a steel notched trowel

- Tapping on stone for better adhesive contact, coverage and compaction

What is the correct method of troweling?

Multi-Directional?

One Directional?

Direction for Troweling

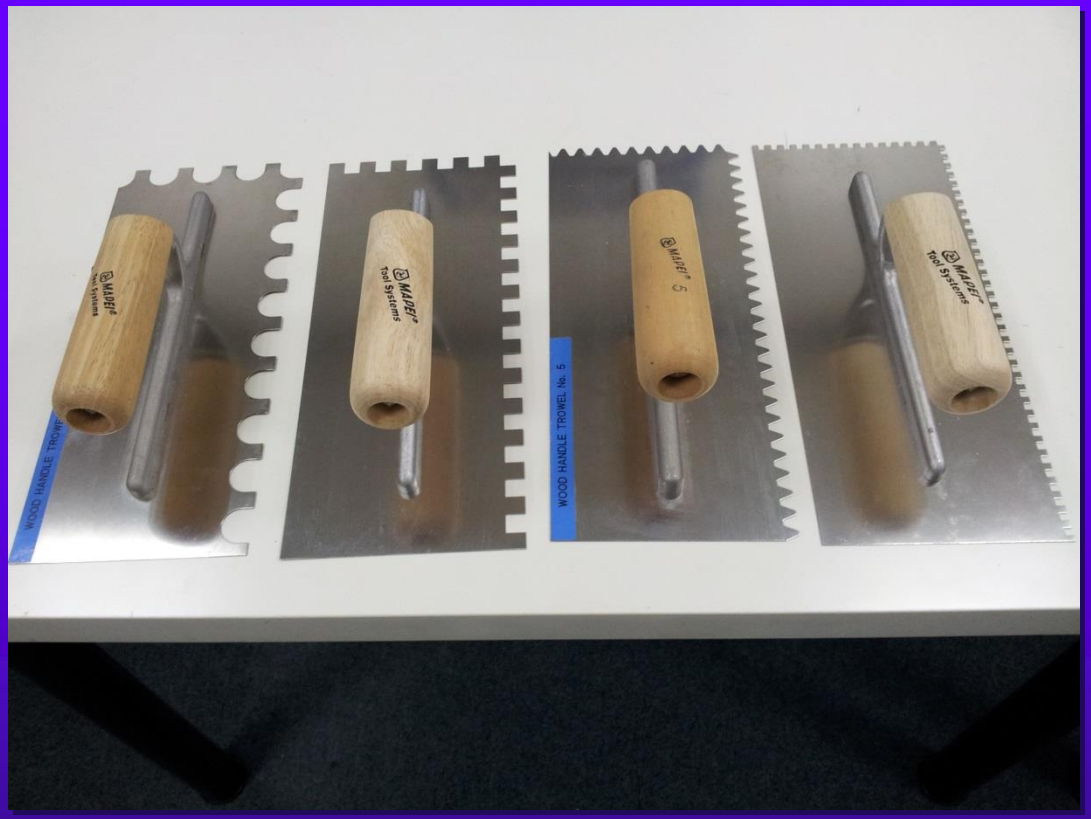
Installing Thin tiles :
Adhesive will be applied thin and it is recommended to have adhesive ribs parallel to each other to flatten properly and help push the air out.

Tiles >8mm thickness:
Same concept but negative impact of multi-directional not so great. Thus, multi-directional is still acceptable.

Serpegiante

1000x300x20mm
Internal
Toilet Wall
Marble
Installation
using Improved
Performance &
Flexible
Adhesive

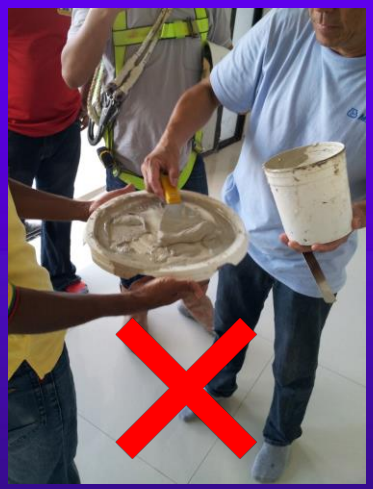
Steel Notched Trowels for Installation



Different notched sizes to achieve different adhesive thicknesses e.g.
4mm x 4mm notched trowel - for installation of glass mosaics
6mm x 10mm notched trowel – for 300 x 600mm size tile/stone
KF Trowel for installation of 600 x 600mm size tile/stone

Installation – Tile Grout

- Grouting
  - Mix like bedding material
  - No“dry”or“semi-dry” method
  - Proper mixing container
  - Fill joint completely
  - Colour consistency: apply in 1 operation
  - Hold rubber trowel at 45^{o} angle



Installation

- Preparation before Grouting
  - Remove excess mortar in the joints
  - Remove dirt & contaminants
  - If necessary, vacuum out the contaminants
  - Clean off dirt on tile surface with clean damp sponge & clean water

Installation

- Grouting
  - Time before cleaning
  - Clean thoroughly
  - Time before allowing foot traffic
  - Time for full curing

Application & Cleaning of Tile Grout

Apply grout mortar with firm rubber trowel.
Excess grout mortar to be removed using the rubber trowel.
Use a damp sponge to clean the surface.
Do not use too much water to clean the grout residue.

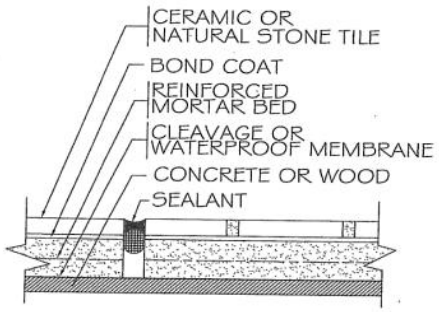
Installation

- Movement joint installation
  - Control depth
  - Close-pore backer rod
  - or bond breaker tape
  - Sealant application:
    - Self-levelling
    - Gun-grade

Sealants in Tile Work

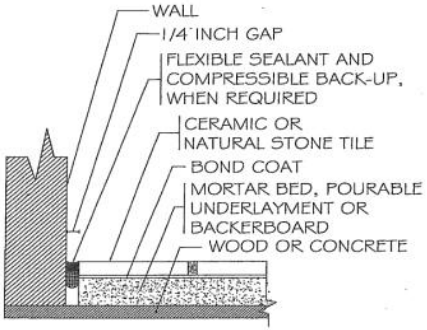
EJ171C-16

- **Expansion Joint**



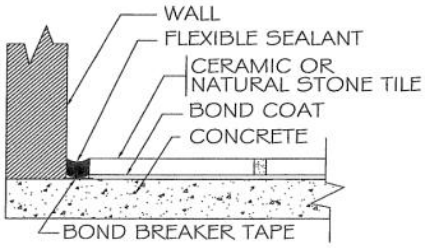
EJ171I-16

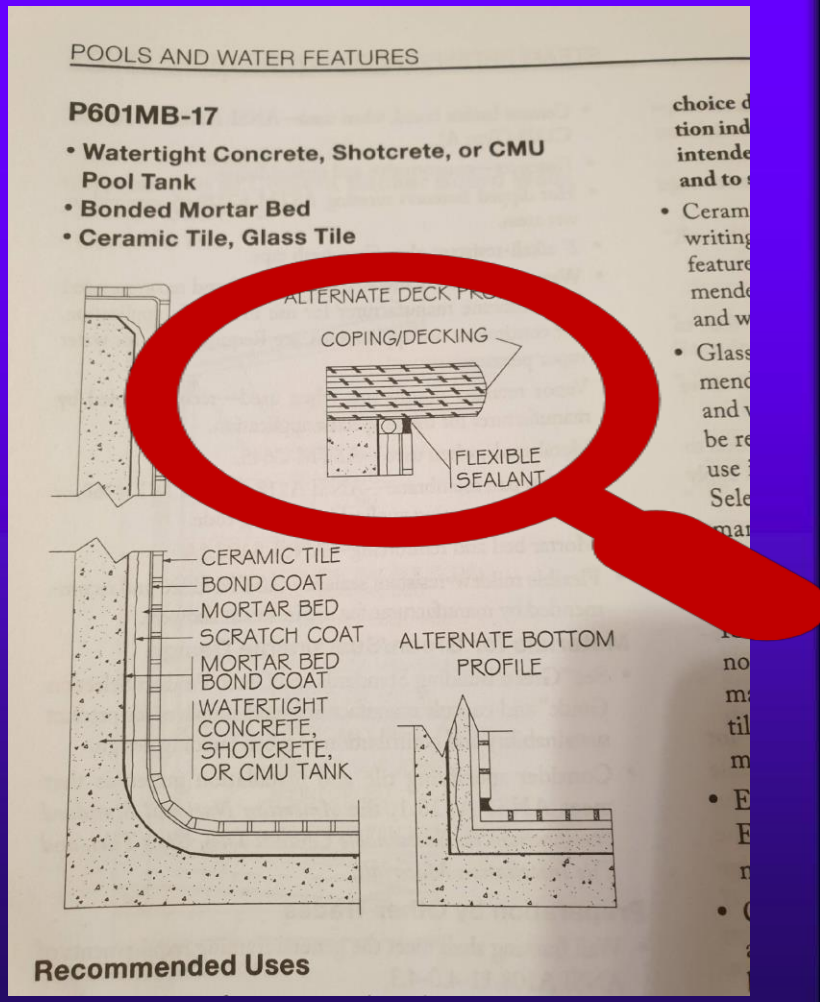
- **Perimeter Joint**



EJ171G-16

- **Perimeter Joint**

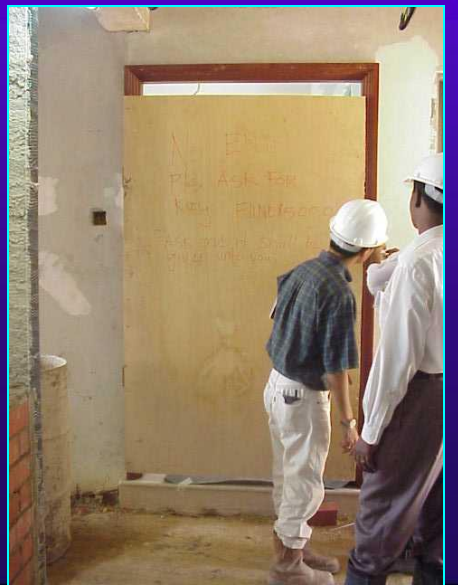




NB: Reference taken from TCA Handbook

Protection

- Site control of environmental condition (SS 665:2020; former CP 68)
- Coordinate among construction trades to:
  - Prevent damage & rework
  - Identify party responsible for damage



Protection

- Immediately after completion of tile installation
  - Floors protected by cleaning & covering
    - ⇨ 0 ~ 4 day: NO traffic
    - ⇨ 5 ~ 14 day: Light foot traffic
  - Walls protected from impact from
    - ⇨ Adjacent
    - ⇨ The other side

Protection of Completed Works

- *Protection with an upturn*

Allow marble and adhesive to dry out properly before covering the floor with protection.

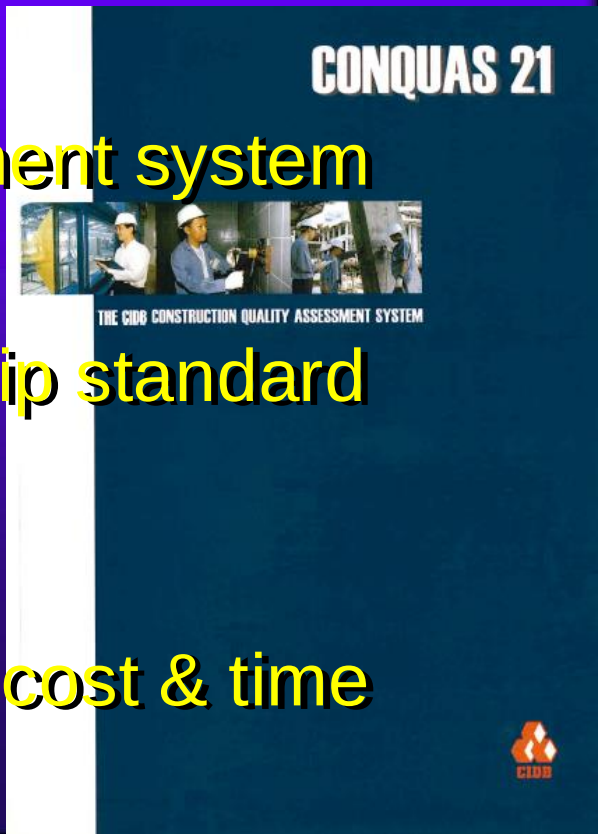

WORKS COMPLETED
项目完成
வேலை முடிவுற்றது
NO ENTRY
EXCEPT AUTHORISED PERSONS ONLY
不准进入，闲人免进
அங்கீகரிக்கப்பட்ட நபர் தவிர
அனுமதி இல்லை

Installation

- Inspection of completed works
  (§3 Inspection & common complaints)

QUALITY MARK / CONQUAS

- To have standard Quality Assessment system
- To make QA objective by:
  - Measuring against workmanship standard & specification
  - Using sampling approach
- To carry out QA within reasonable cost & time



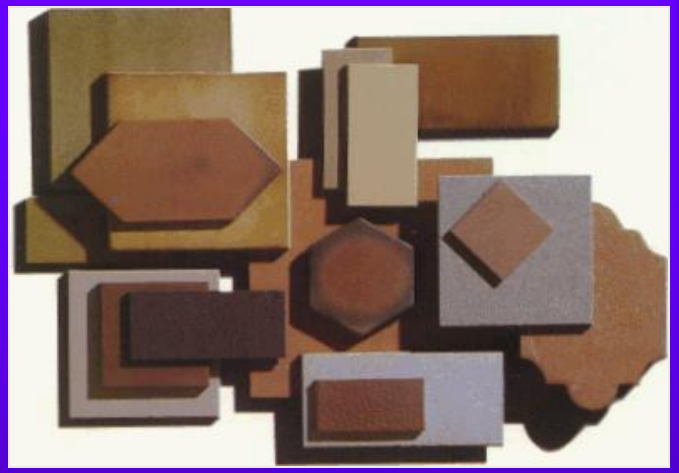
PART 2
Material Selection in Tile & Stone Works

Contents

- Tile selection
  - SS 483 (ISO 13006)
  - Traffic & load conditions
- Stone selection
  - Finishes & aesthetics
  - Installation method: adhesion or anchorage
  - Soundness & Dimensional stability
  - Confirmation: mock up, pre- & dry-layout
- Bedding materials
- Grouting materials

Ceramic Tile

- Made from
  - Clay (plasticity)
  - Quartz sand (strength)
  - Feldspars (fluxing)
  - Glaze (decoration)



Ceramic Tile

Types of Tiles:

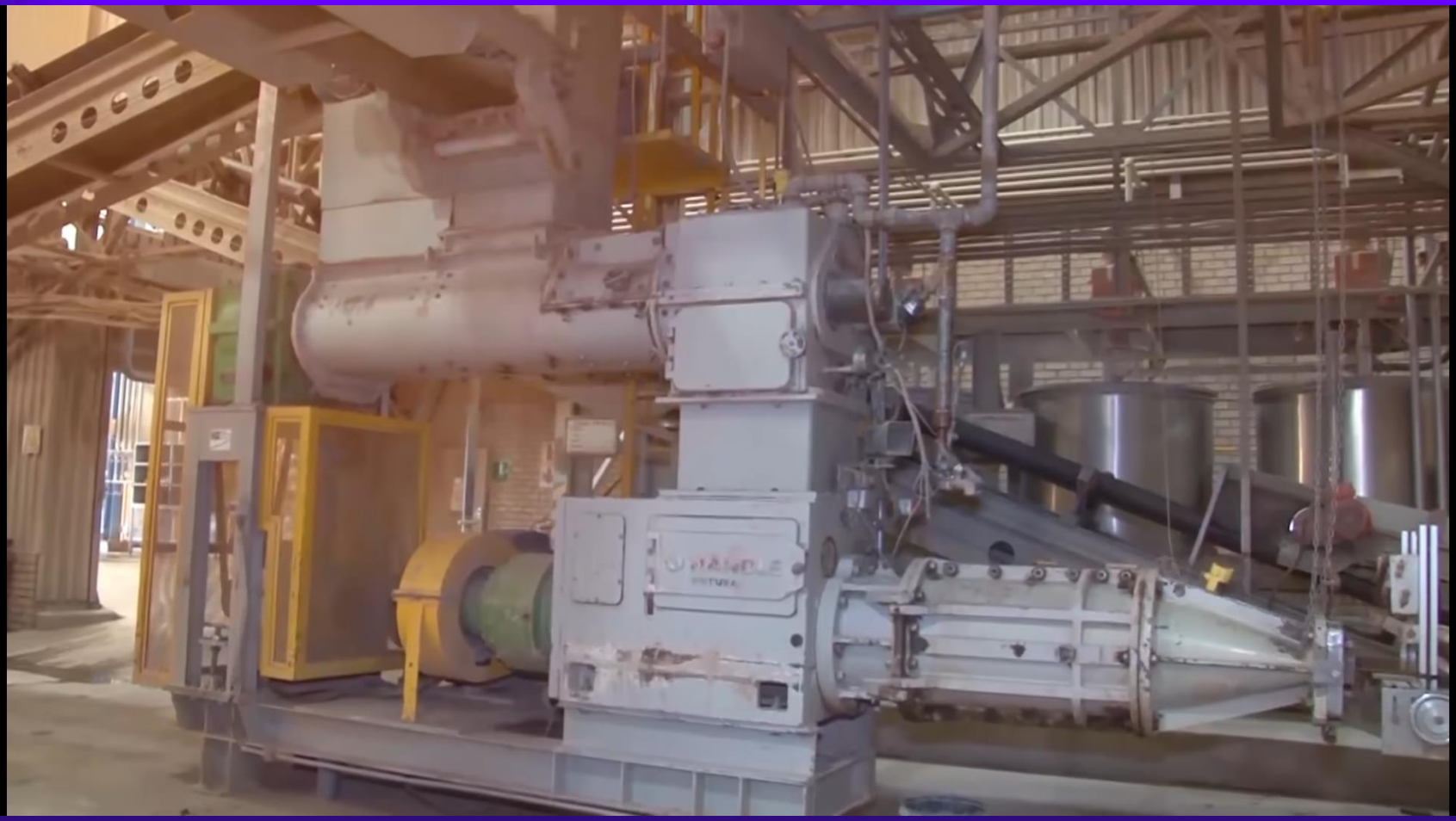
- Ceramic Tile (Glazed & Unglazed)
- Porcelain Tile
- Rectified Tile
- Quarry Tile
- Klinker Tile etc

Ceramic Tiles

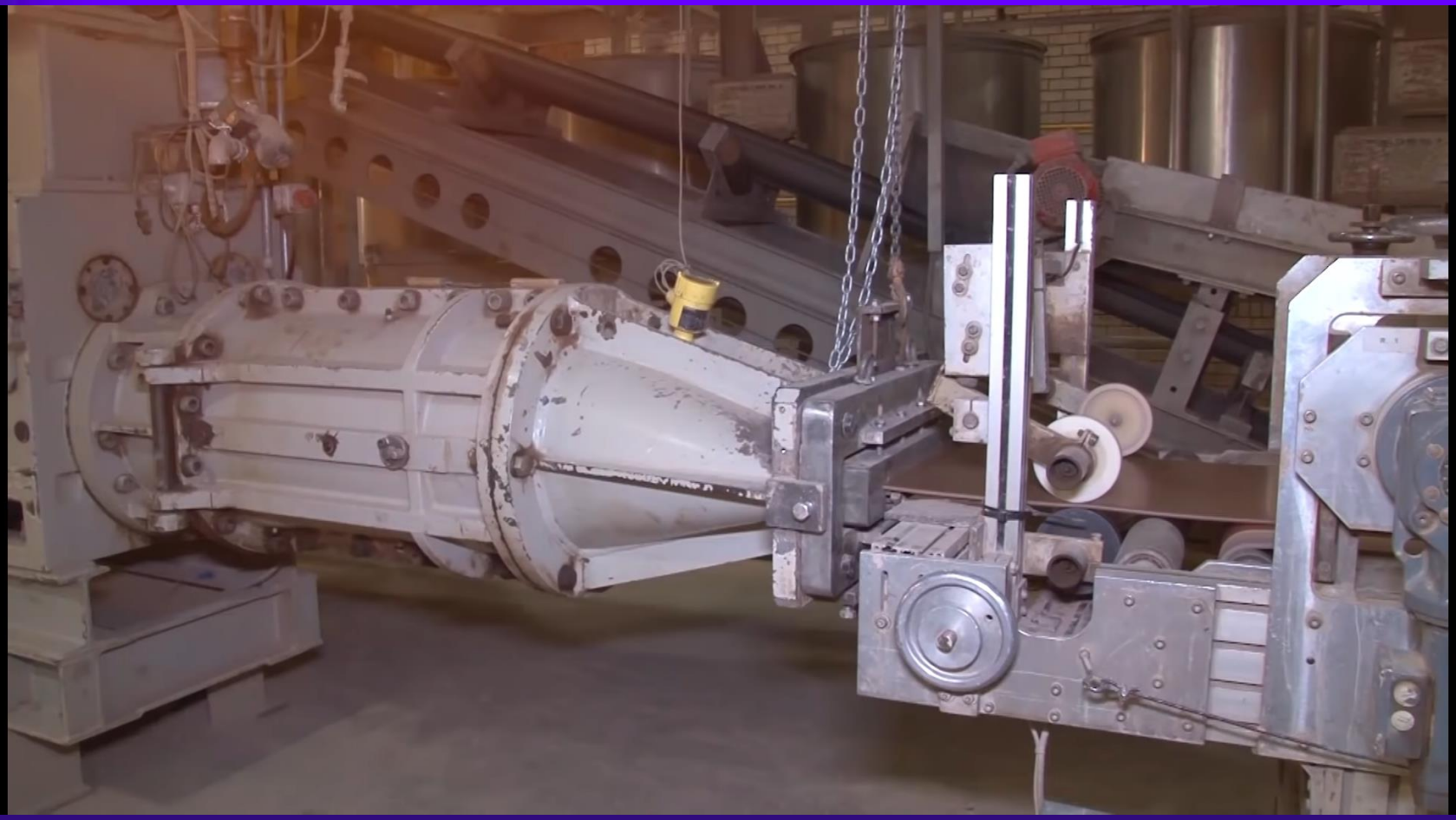
- Shaping methods:
  - Powder + 4 ~ 7% moisture ⇒ pressed
  - Paste with 15 ~ 20% water ⇒ extruded
  - Other processes:
- Fired at high temperature (950 ~ 1200°C)

Tiles Produced by “Pressed” Process

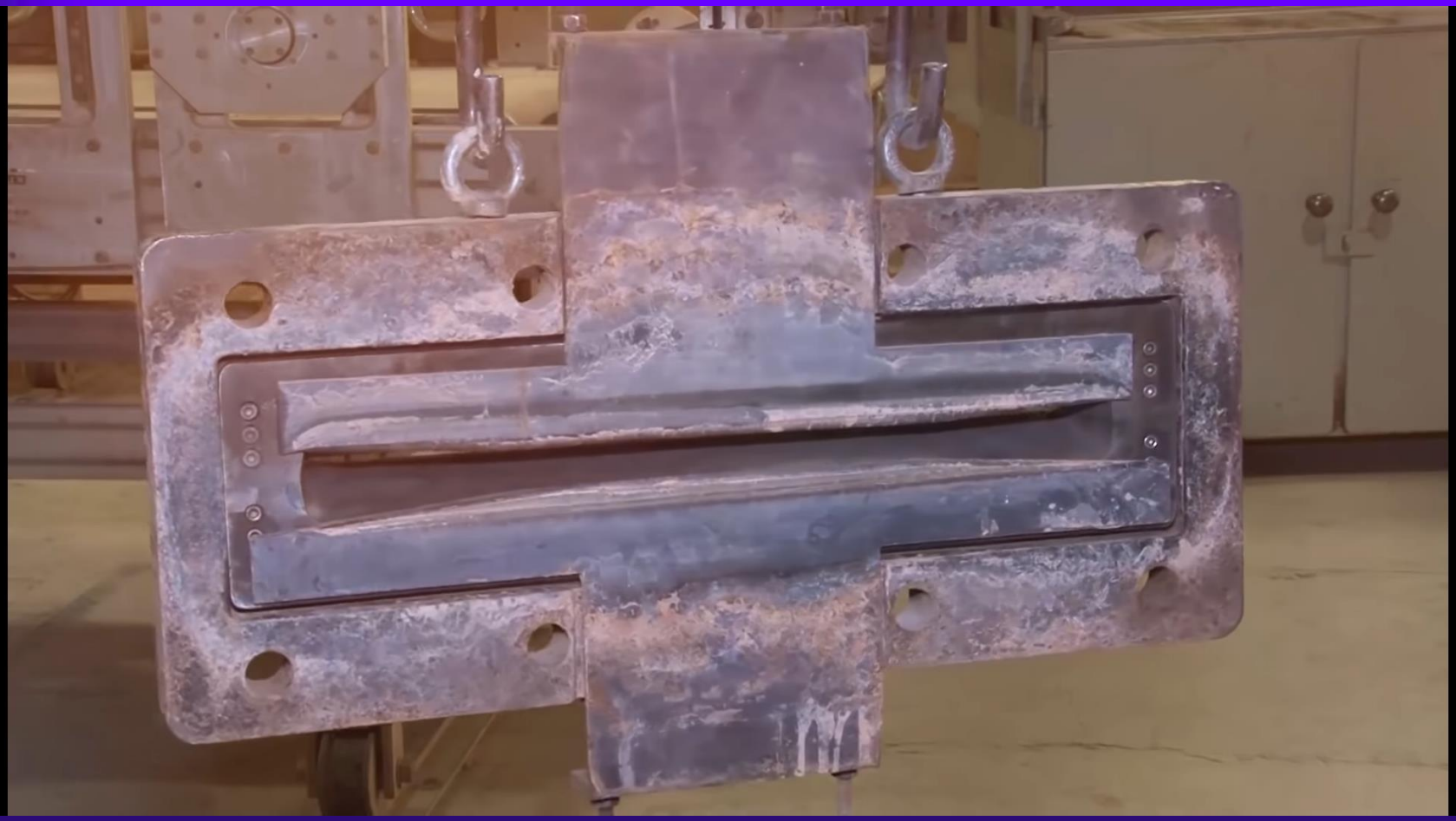
Tiles Produced by “Extrusion” Process



Tiles Produced by “Extrusion” Process



Tiles Produced by “Extrusion” Process



Tile Selection – SS 483: 2000

Shaping	Group I $E \leq 3\%$	Group II_a $3\% \leq E < 6\%$	Group II_b $6\% \leq E < 10\%$	Group III $E > 10\%$
A: Extruded	Group AI	Group AII_{a1}	Group AII_{b1}	Group AIII
		Group AII_{a2}	Group AII_{b2}	
B: Dry Pressed	Group BI_a $E \leq 0.5\%$	Group BII_a	Group BII_b	Group BIII
	Group BI_b $0.5\% \leq E < 3\%$			
C: Other Processes	Group CI	Group CII_a	Group CII_b	Group CIII

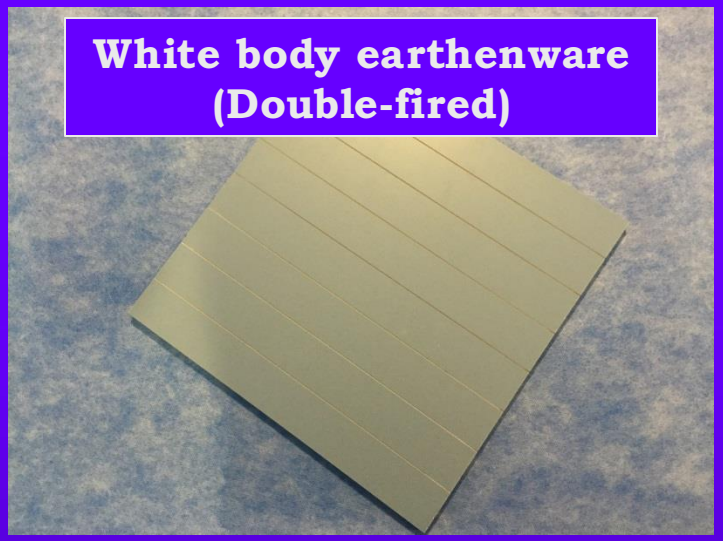
NB: Other reference standards for Ceramic Tiles – ISO 13006; EN 14411

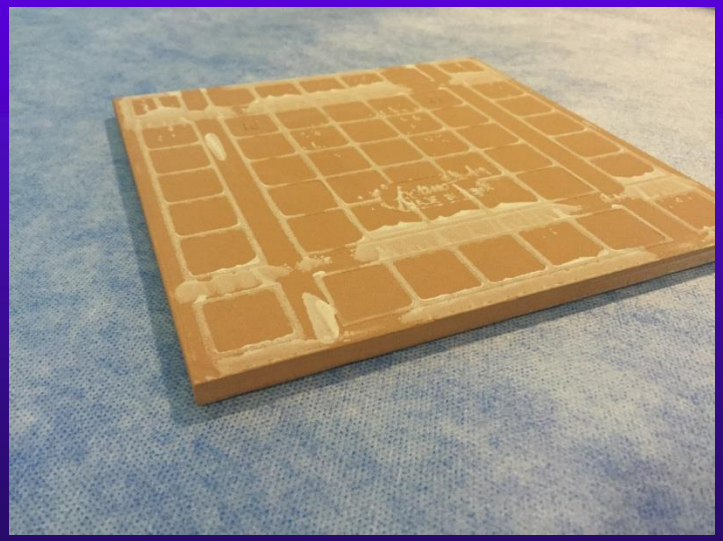
ITALIAN CERAMIC FLOOR AND WALL TILE (According to Product Type)

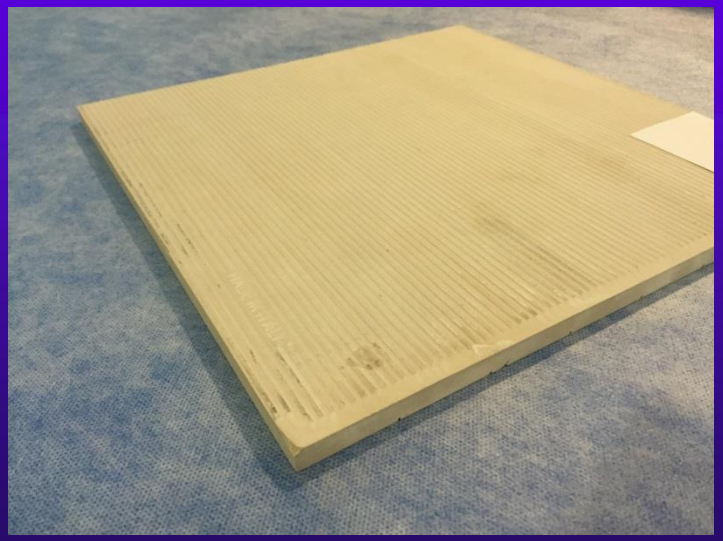
	TYPE	WATER ABSORPTION (%)	SHAPING METHOD	MAIN USE
GLAZED	MAJOLICA	15-25	PRESSING	Wall Tile (internal)
	COTTOFORTE	4-15	PRESSING	Floor Tile (internal)
	SINGLE FIRED WHITEWARE	0-6	PRESSING	Floor Tile (internal & external)
	SINGLE FIRED REDWARE	0-12	PRESSING	Floor tile (internal & external)
	EARTHENWARE (WHITE BODY)	6-25	PRESSING	Wall Tile (internal)
	KLINKER	0-7	EXTRUSION	Wall Tile (external) Floor Tile (internal & external)
UNGLAZED	COTTO	3-15	EXTRUSION	Wall Tile (internal)
	RED STONEWARE	0-4	PRESSING	Floor Tile (internal & external)
	PORCELAIN STONEWARE	0-0.5	PRESSING	Wall Tile (internal) Floor Tile (internal & external)
	KLINKER	0-7	EXTRUSION	Wall Tile (external) Floor Tile (internal & external)

Source: Publication by C.Palmonari, G. Timellini

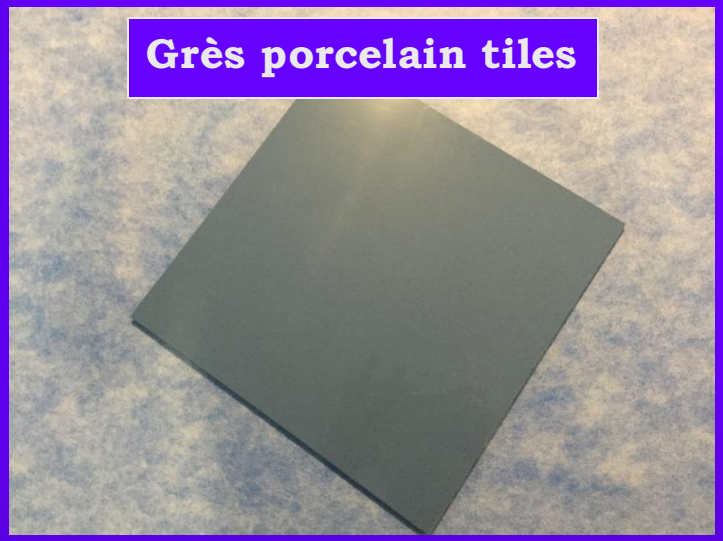
Type of tiles

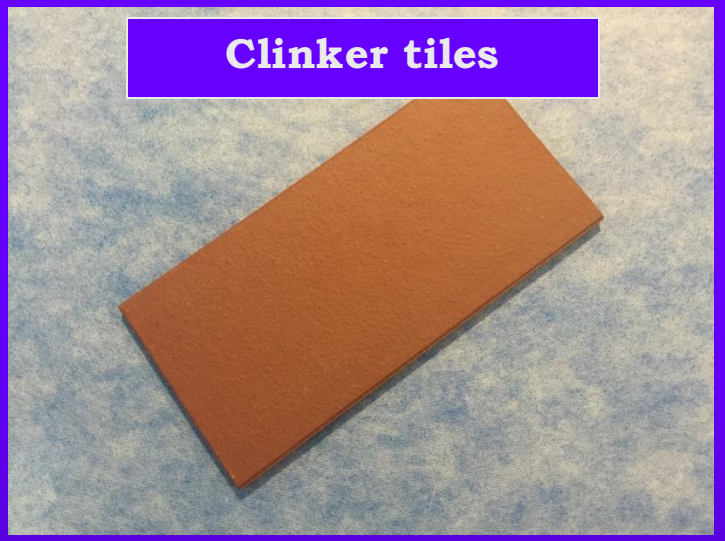


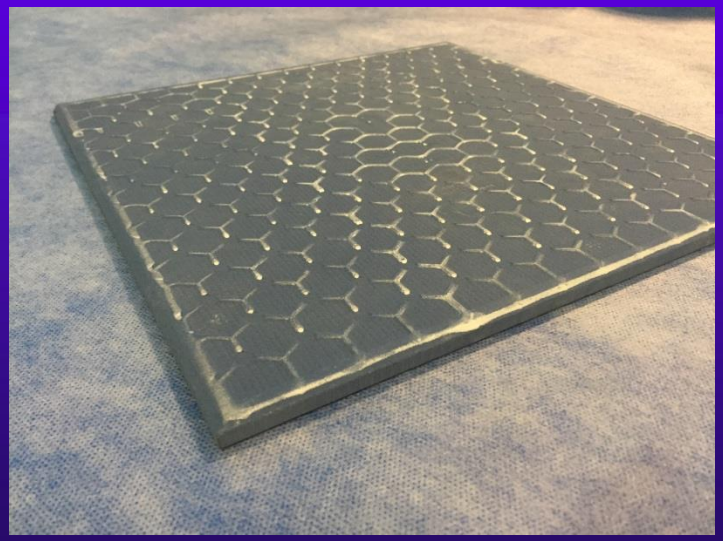


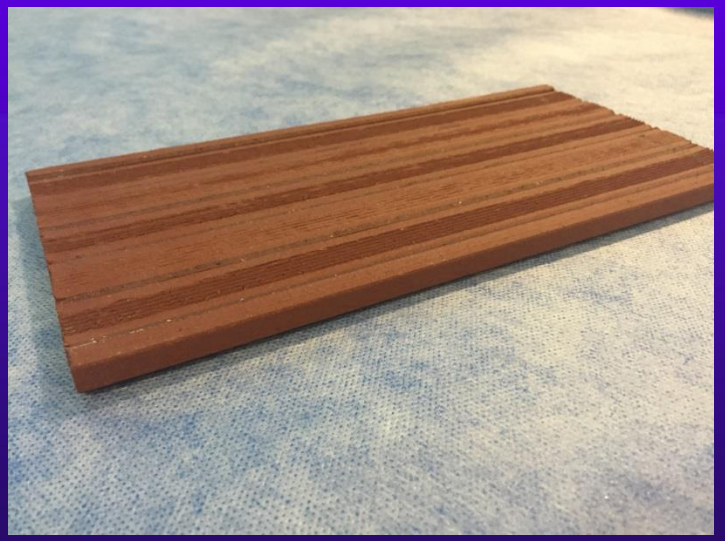


Type of tiles



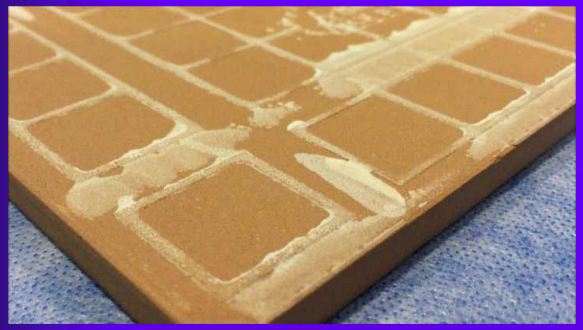


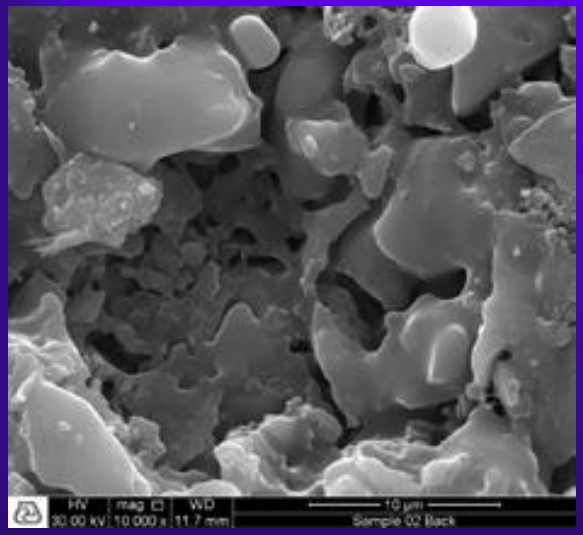


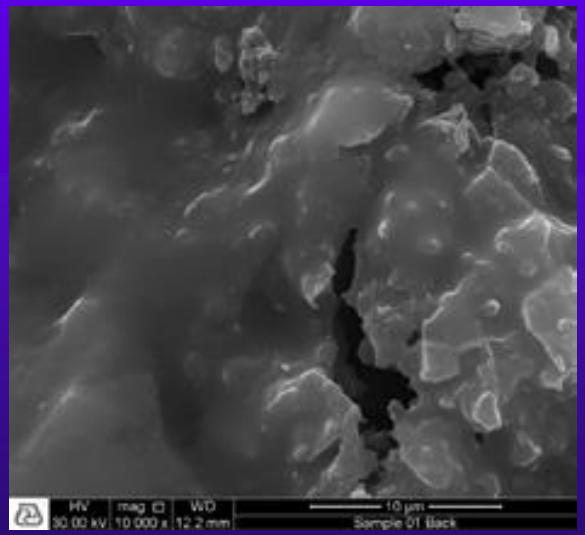


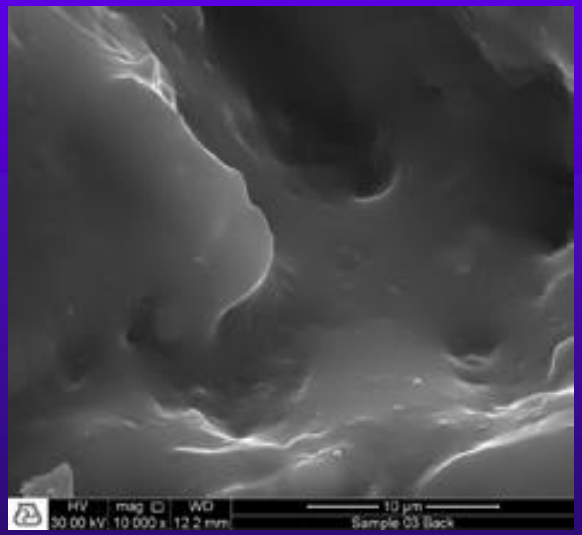
Different tile water absorption body

Double-fired tiles	Single-fired tiles	Grès porcelain tiles

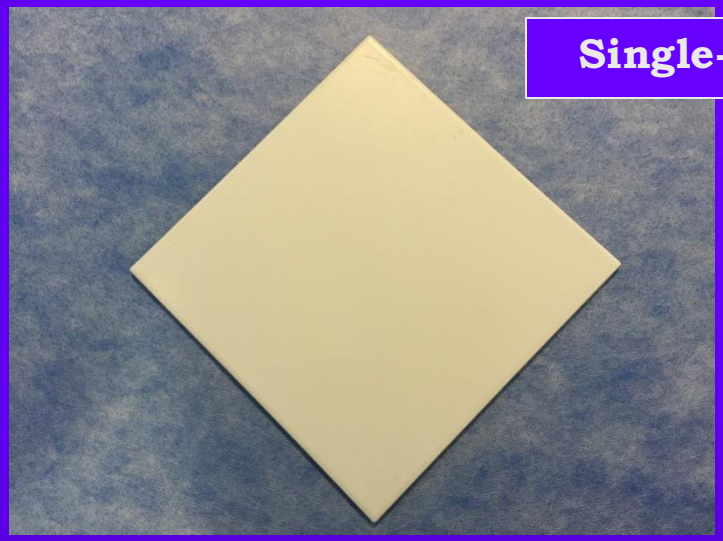




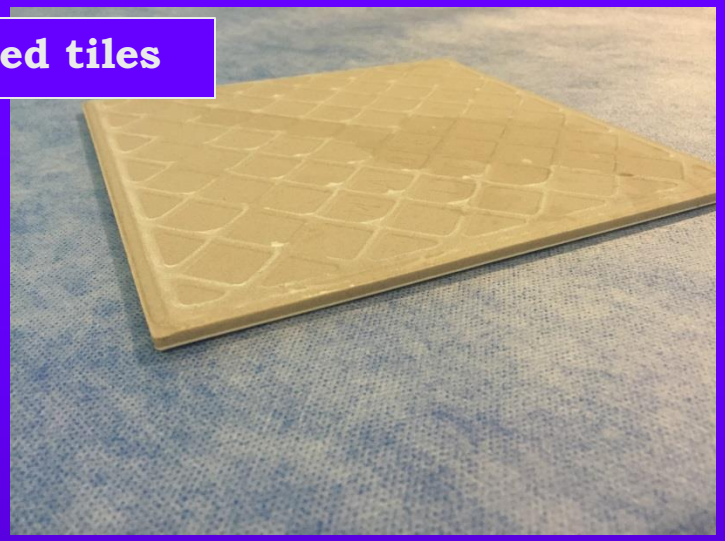




Type of tiles



Single-fired tiles

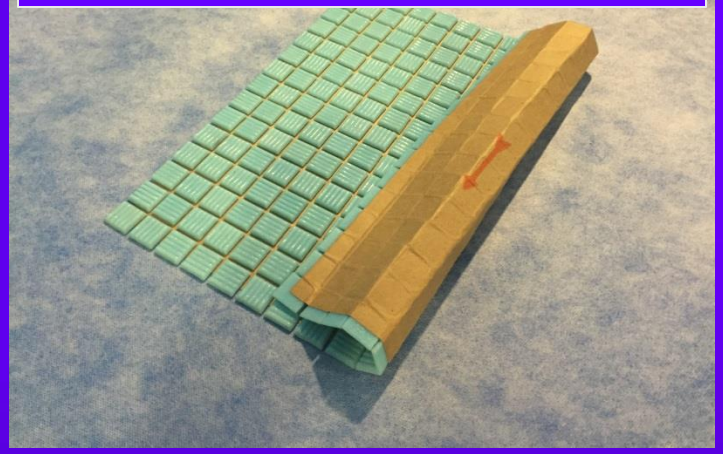


Cotto tiles

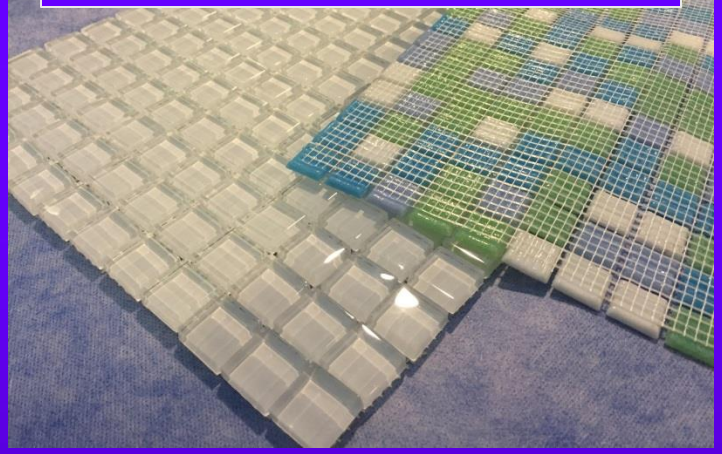
Ceramic mosaic tile on mesh

Other type of tiles... glass tiles

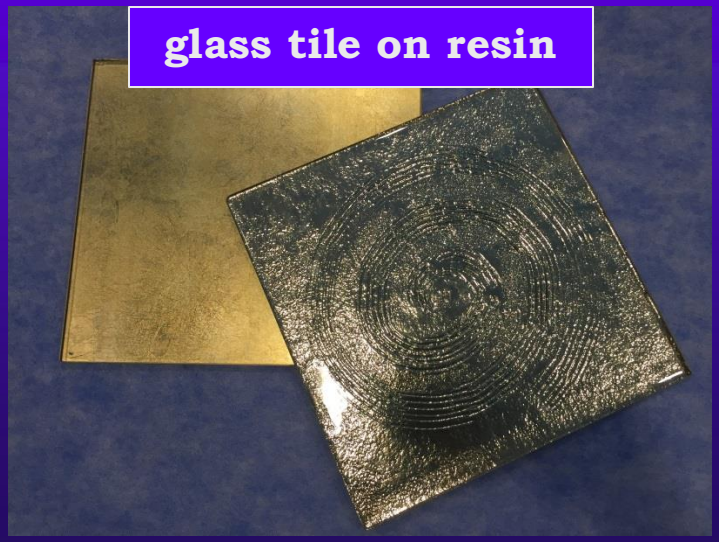
glass mosaic tile with paper



glass mosaic tile on mesh



glass tile on resin



Withdrawn SS 301& SS 57

Application	Floor		Wall	
Glazing	Unglazed	Glazed	Unglazed	Glazed
Abrasion resistance	Extra heavy	A		SS 57
	Heavy	B		
	Medium-heavy	C		
	Medium	D		

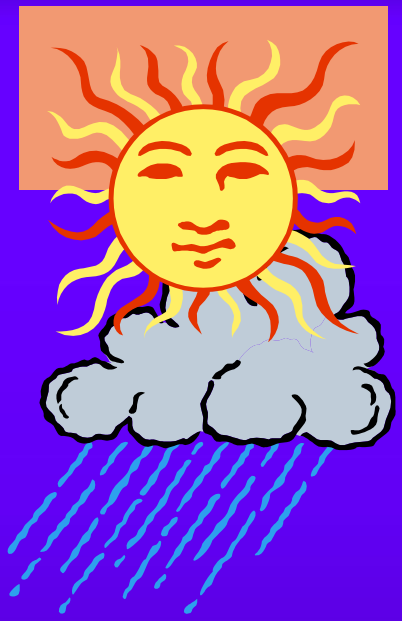
Tiles – Selection Criteria

ISO 10545	Test Method	Related
Part 2	Dimensions & surface quality	SS 301/57
Part 3	Water absorption (boiling & vacuum)	SS 301/57+
Part 4	Modulus of rupture & breaking strength	SS 301/57+
Part 5	Impact resistance	New
Part 6	Deep abrasion of unglazed tiles	SS 301
Part 7	Surface abrasion of glazed tiles (PEI)	SS 301-
Part 8	Thermal expansion	New
Part 9	Resistance to thermal shock	SS 301/57
Part 10	Moisture expansion	New

Tiles – Selection Criteria

ISO 10545	Test Method	Related
Part 11	Crazing resistance (at 5 bars)	SS 301/57*
Part 12	Frost resistance	New
Part 13	Chemical resistance	SS 301/57+
	Acid resistance	SS 301.K
Part 14	Stains resistance	SS 301/57?
Part 15	Lead & cadmium release of glazed tiles	New
Part 16	Small colour differences	New
	Colour fastness	SS 301.H
Part 17	Coefficient of friction	SS 485+-
	Scratch hardness of surface	SS 301.G

Tiles – Some "Small" Issues



- Expansions due to temperature (ISO 10545.8) and moisture-content variations (ISO 10545.10) are in small units (10^{-4} mm/mm)
- But they are BIG issues in performance of tile works
- Long term irreversible movements due to creep, "growth" and settlement are also significant

Tiles – a "Large" Issue

- Many new considerations:
  - Tile flatness & adhesive thickness
  - Application procedure & adhesive open time
  - Lateral support

Tiles – Some Safety Issues

- ISO 10545.15 limits mass extracts (mg/cm^2) of Lead & cadmium release by glazed tiles
- SS 485: 2001 specifies slip resistance classification of public pedestrian surface materials:
  - Wet pendulum
  - Dry floor friction (Tortus)
  - Wet/barefoot ramp
  - Oil-wet ramp

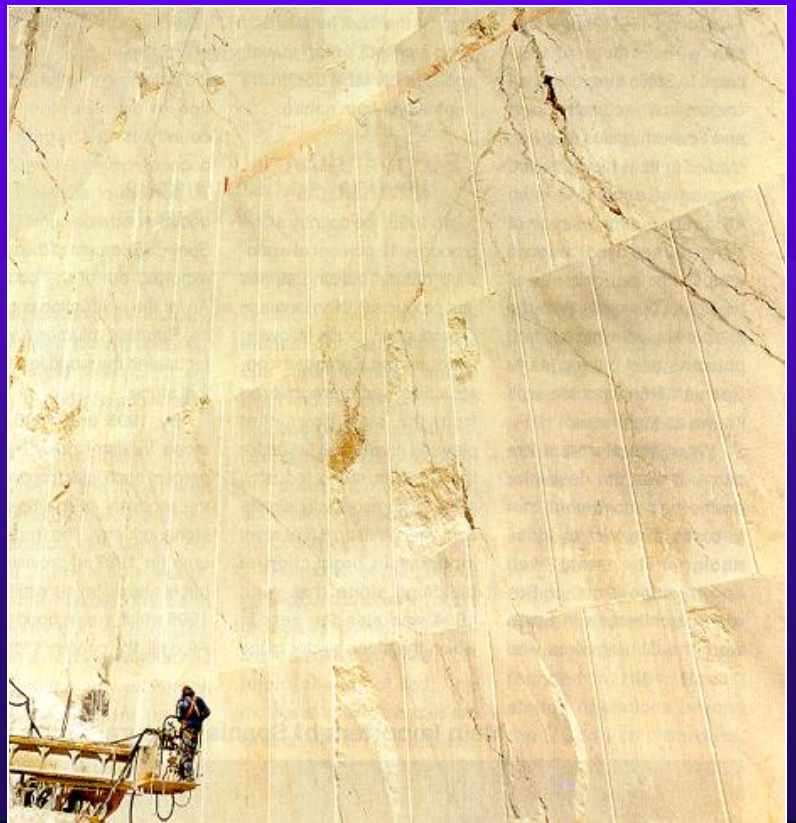
Tiles – Selection Criteria

- Traffic & load conditions:
  - Light loading: low-density human traffic
    ⇒ all suitable
  - Heavy loading: high-density human traffic & physical loads
    ⇒ sufficient adhesion, compaction, no separating layer

Marble, Granite & Natural Stone

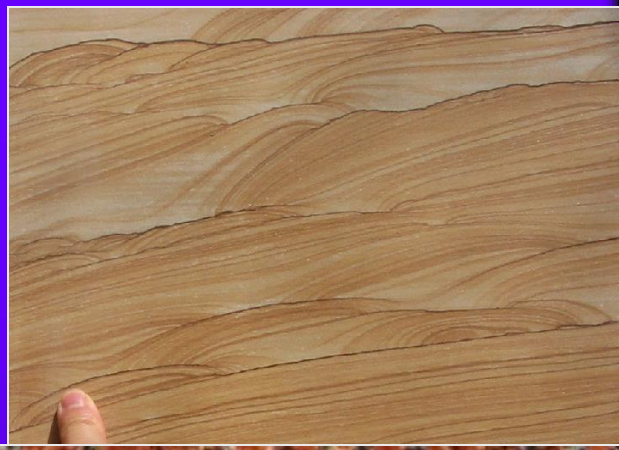
Stone Formation

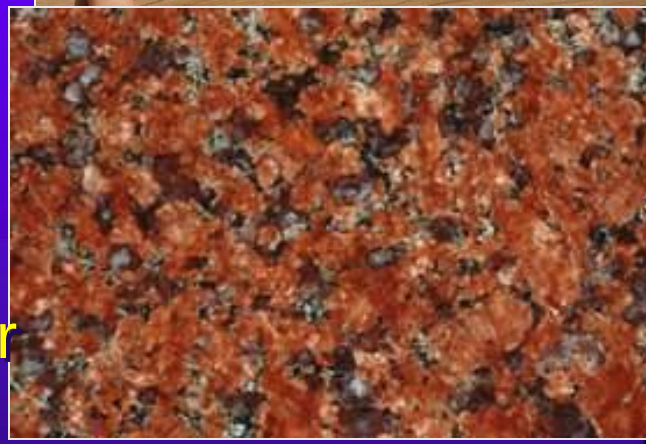
- Naturally formed under varying conditions ⇒ NO 2 pieces bear same composition & appearance

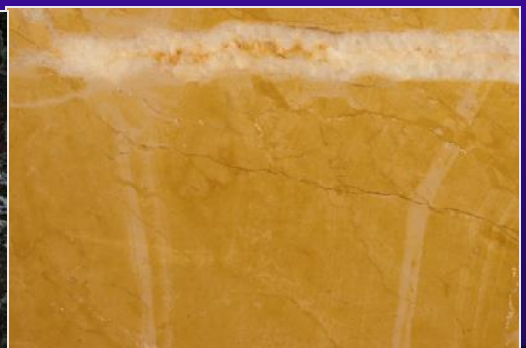


Stone Formation

- Geological types:
  - Sedimentary: formed from sediments deposited in rivers or glaciers and consolidated to form rock beds (limestone, sandstone are examples)
  - Igneous: formed from volcanic material such as magma which cooled & solidified (e.g. granite)
  - Metamorphic: Originated due to transformation of existing rocks under very high heat & pressure (marble, slate, …)







Stone Finishes

- Polished
- Honed/ abrasive
- Sandblasted
- Flamed: only for granites
- Riven: only for slates

Stone – Installation Methods

- By adhesion: similar to tile installation

- By mechanical anchorage when
  - Unit weight > 40 kg/m^2
  - Stone size > 1 m^2
  - Refer to BS 8298

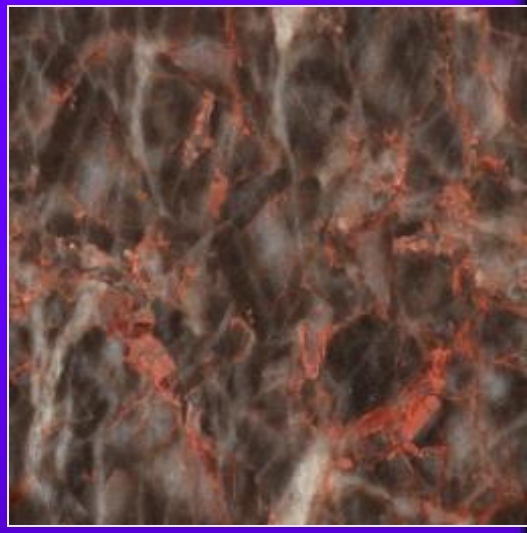
Stone – Installation

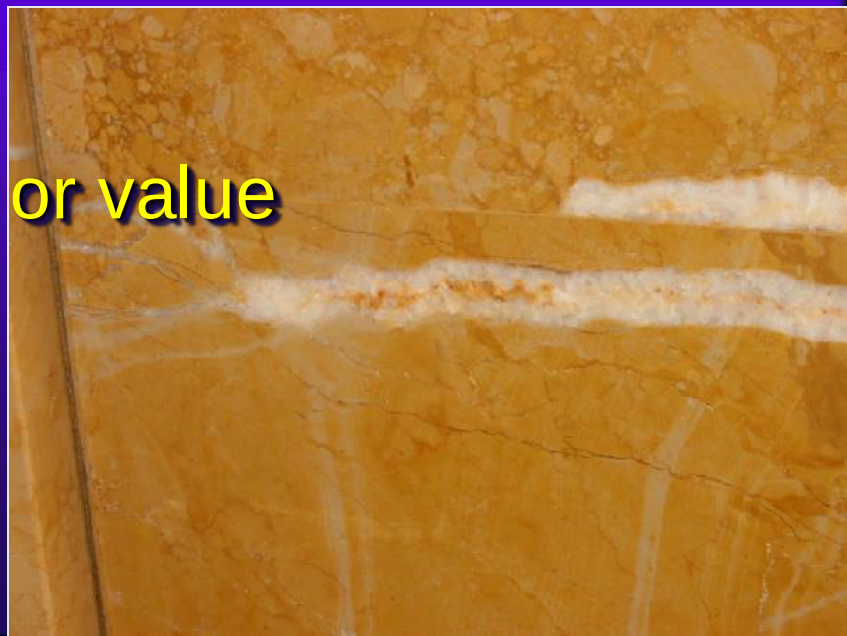
- Standards for cementitious adhesives do not differentiate "tile adhesives" and "marble adhesives"

- Determine performance of C2 or C1 for suitability in the respective installations (whenever necessary, properties of "F", "E" "S1" and "S2" shall apply)

Natural Stone – Soundness

- 4 groups (A, B, C & D) by Marble Institute of America (MIA)
- Related to fabrication methods:
  - Waxing
  - Sticking
  - Filling or cementing
  - Reinforcing
- Nothing to do with merit or value





Natural Stone – Soundness

Natural Stone – Soundness

Natural Stone – Soundness

Stone Confirmation

- Mock up
  - Installed, grouted & cleaned with designed materials
  - Approved by all concerned parties
  - Retained as standard throughout stone work

Stone Confirmation

- Pre laid at factory
  - Best blend of patterns & colour tones
  - Owner marks before sent to site
- Dry layout at site
  - Final adjustment before installation

Agglomerated Stones

Agglomerated stones are artificial stones made of composite materials produced by binding stone, marble & quartz chips with specially formulated resin.

- Physically less porous and harder than many types of natural marble and stone

- Uniform internal body structure

Agglomerated Stones

Different types of resins are used by different manufacturers. Epoxy and polyester resins are binders that are commonly used to produce the agglomerate stones.

Some polyester resins are not completely UV stable and therefore agglomerated stones may not be suitable for external applications.

Agglomerated Stones

Agglomerated stones are normally available in thicknesses of 15mm, 12mm and sometimes 10mm. Thicker agglomerated stones are available for heavy duty conditions.

Agglomerated Stones

Characteristics to consider:

* Dimensional tolerances – EN 14617-16
* Determination of dimensional stability – EN 14617-12
* Water Absorption (%) – EN 14617 -1
* Bending strength (MPa) – EN 14617-2
* Abrasion resistance (mm3) – EN 14617-4
* Chemical resistance (in % gloss loss) – EN 14617-10
* Slip resistance – SS 485:2011 or EN 14231:2003
* Impact resistance – EN 14617-9
* Thermal shock resistance – EN 14617-6
* Coefficient of linear thermal expansion – EN 14617-11

EN 14617 – 12
Agglomerated Stone
Determination of Dimensional Stability

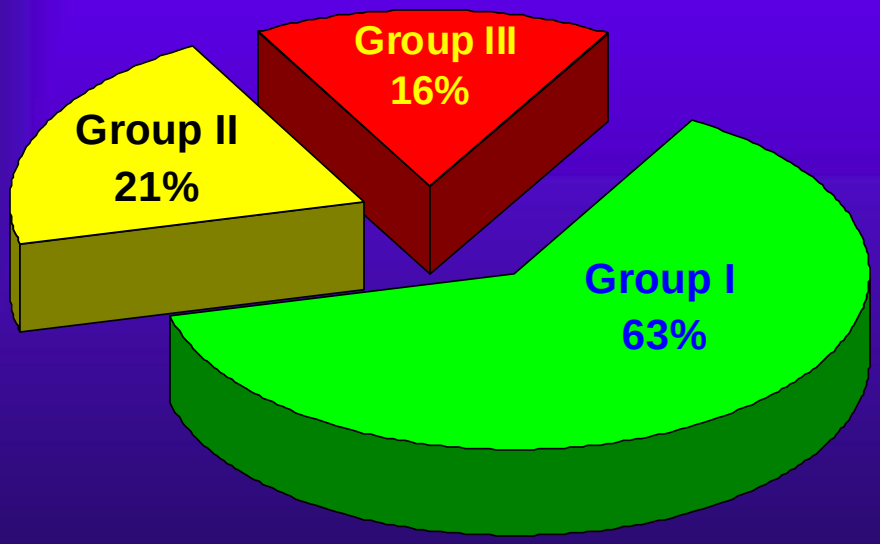
Stone – Dimensional Stability

- Some thin stone veneers are moisture sensitive – warp during installation when in contact with water
- Cementitious adhesives contain water
- Reaction-resin adhesive
  - No water, but
  - Very expensive

Dimensional Stability Testing Apparatus

Stone Stability – Statistics

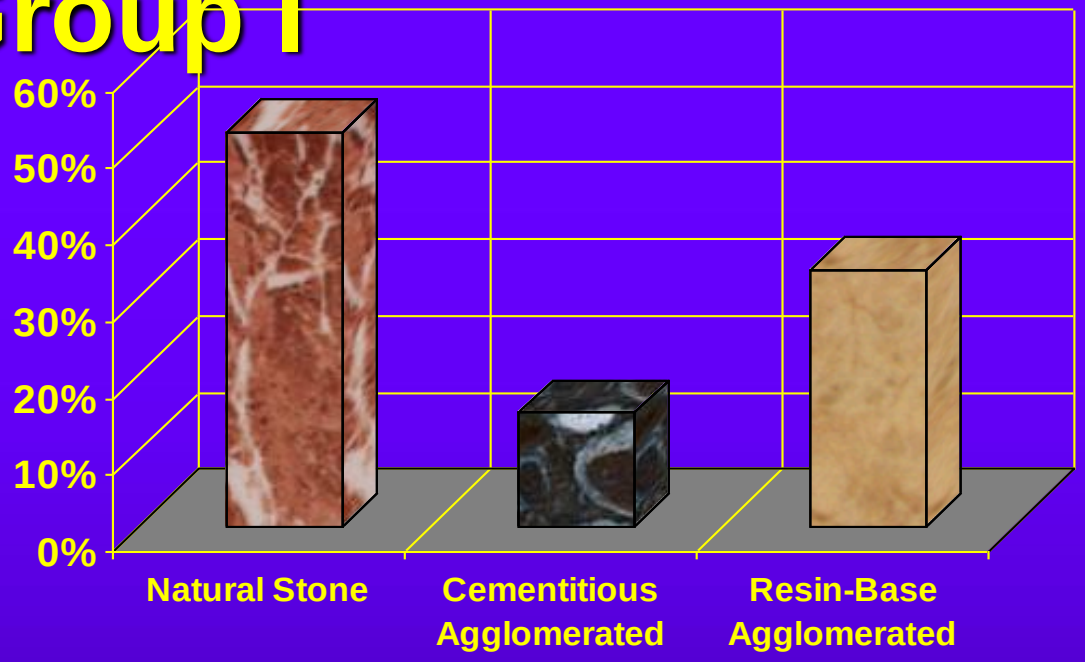
- Over 1300 entries, most 300 × 300 mm
- Measure out-of-plane movement continuously
- Classify based on movement at 6 hours



Stone Stability – Group I

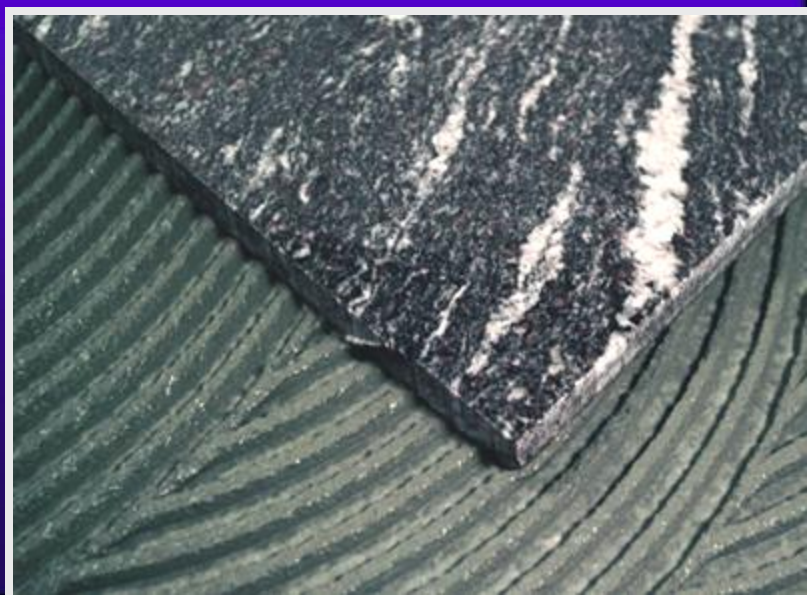
- Moisture stable
  < 0.3 mm

- Adhesive consideration:
  - Substrate
  - Loads
  - Time frame



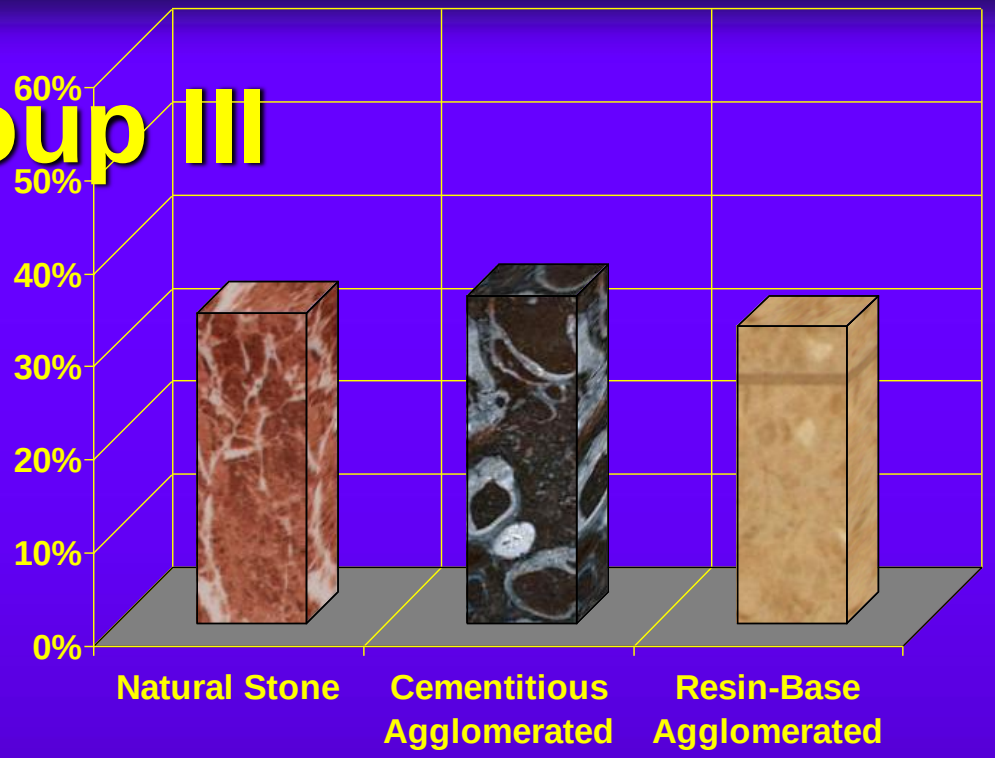
Stone Stability – Group II

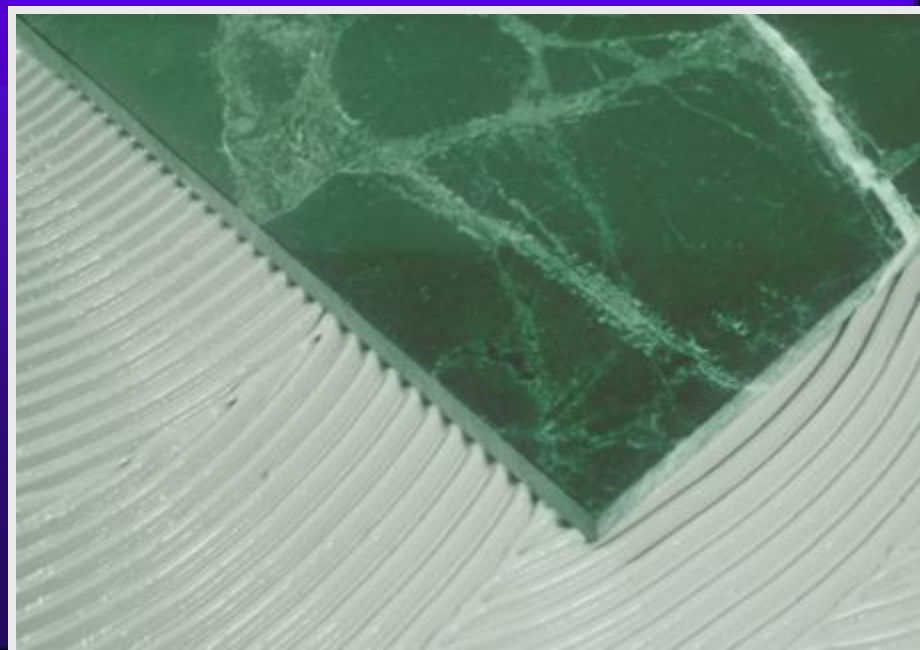
- Slight moisture sensitive (0.3 ~ 0.6 mm)
- Adhesive selection:
  - Special fast hardening
  - Early grip
  - Low moisture



Stone Stability – Group III

- Highly moisture sensitive (> 0.6 mm)
- Adhesive selection:
  - Water-free reaction-resin





Dimensional Class of Stone

Dimensional Stability Class	Deformation	Adhesive Type to Use
Class A	d < 0.3mm	Normal-setting or Fast-setting Cementitious
Class B	0.3 ≤ d < 0.6 mm	Fast-setting Cementitious
Class C	d ≥ 0.6 mm	Reaction-resin (epoxy-based or (PU-based)

Bedding Mortars

- Thick-bed Mortars
- Thin-bed Mortars / Thin-set Mortars

Bedding Mortars

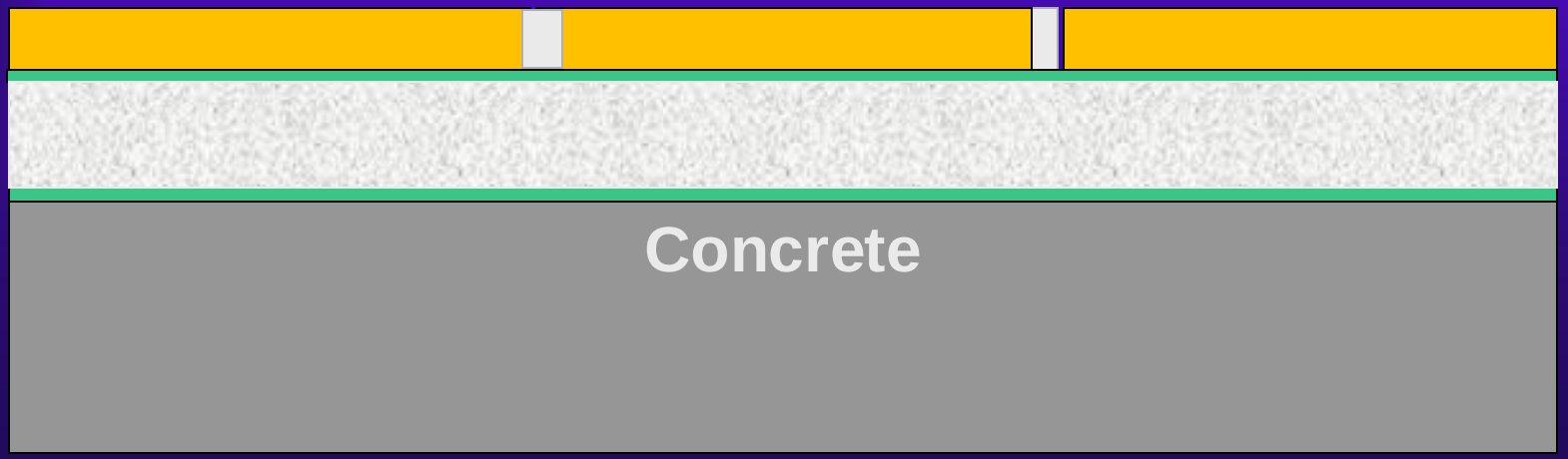
- **Thick-bed**
  - Refers to tile and stone installation carried out by the traditional mud bed method; commonly known as wet method of laying.
  - Is not considered an adhesive and the standards of EN 12004 & ISO 13007-1 do not apply.

Installation by Thick Bed Method

Traditional Mud Method, "Wet-method" (1:3 or 1:4) (minimum thickness 20mm)

Application to be done in 1 operation:

- Slurry coat onto concrete surface
- Thick bed mortar (laid wet-on-wet)
- Slurry coat onto mortar surface (wet-on-wet)
- Lay tile/stone immediately and tamp into the bed



Bedding Mortars

- **Thin-bed / Thin-set**
  - Historically, liquid latexes are added to the Portland Cement and Fine Silica Sand mix (1:1), in replacement of water.
  - It is also a bedding mortar but normally applied thin and the mix consistency is “creamy” and soft - Dry method of laying.
  - Can bond tile & stone directly onto substrate.

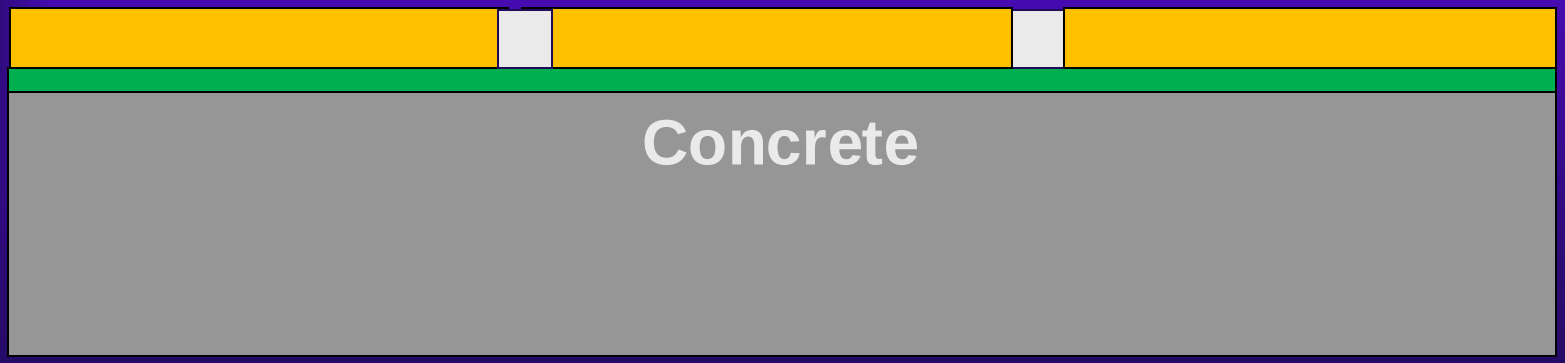
Tiling System by Thin Bed Method

Tile can be bonded directly to the concrete surface, i.e., without levelling screed or render……. But,

Thin-bed applications require substrate to be accurate, plumb and true.

Screed is required when:
i) Substrate is not accurate
ii) Need to increase level to fulfil "Final Floor Finish"

NB: Screeding & Tiling done in 2 separate operations

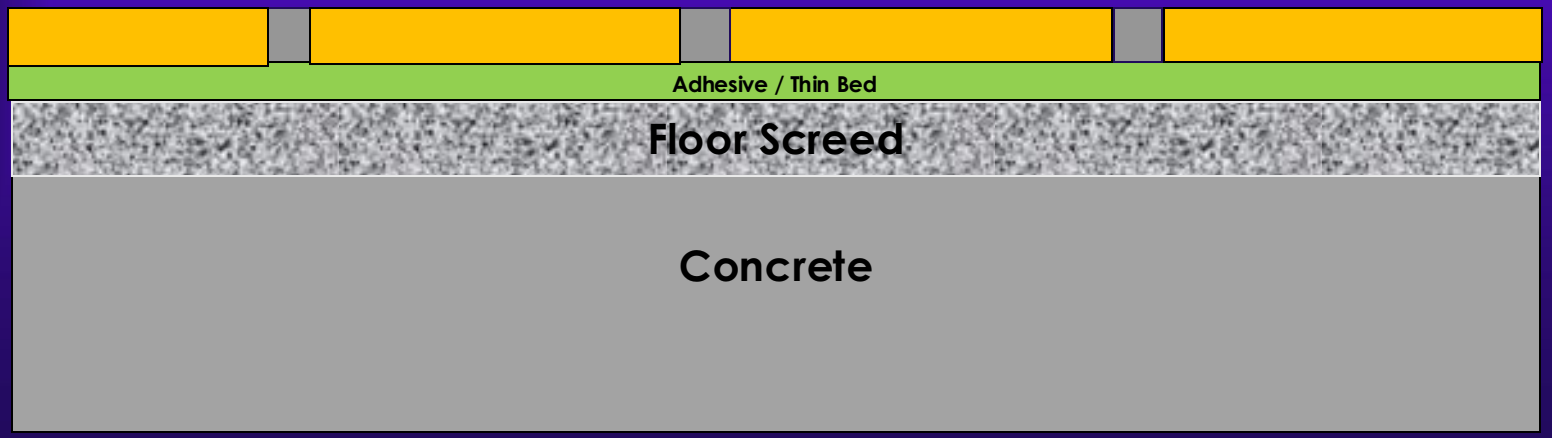


Tiling System by Thin Bed Method

When concrete substrate is not accurate, a screed mortar will be required to be laid to required level and allowed to cure. (tolerance 3mm in 2 metres – Ref.BCA).

Thereafter, tile to be laid with adhesive (Thin-bed).

Application to be done in 2 operations.



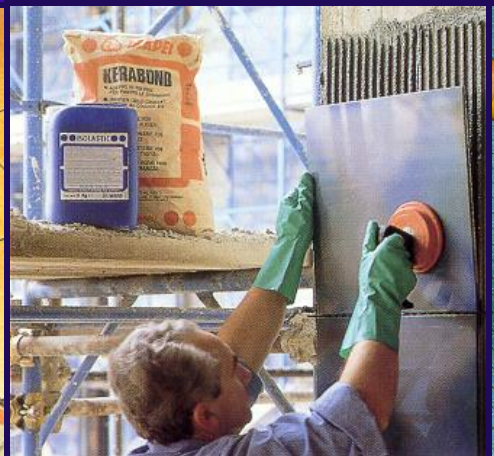
Bedding Mortars

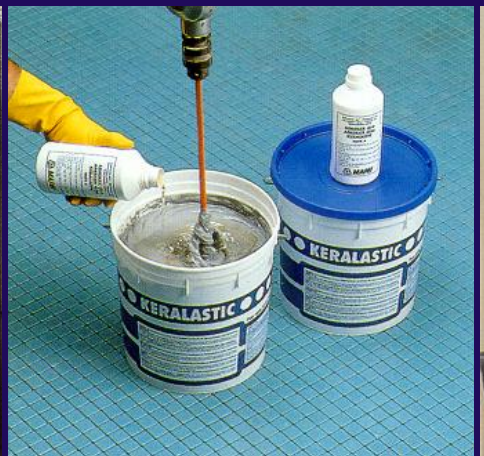
- Mortar:
  - Cement (SS 26) + sand (SS 31)

- Adhesive:
  - Cement + sand
  - + polymer for cohesion, adhesion, toughness, flexibility, water-resistance, etc.
  - + admixtures for water retention, setting time, thixotropy, etc.

Adhesive Classification

Adhesives	EN 12004 ISO 13007-1	BS 5980	ANSI
Cementitious (1-component)	C	Type 1	A118.1
Cementitious (2-components)		Type 3	A118.4
Reaction-resin (multi-components)	R	Type 5	A118.3
Dispersion (water-based) *(DIY)*	D	Type 2	A136.1





Adhesive Classification
Cement-Based Adhesive

Basic characteristic

- Class C1： Normal adhesive

Additional characteristic

- Class C2： Improved adhesive

- Optional characteristics：
  - F : Fast-setting
  - T : Slip-resistant
  - E : Extended open time
  - S : Deformable

CLASSIFICATION OF CEMENT-BASED ADHESIVES

The Class 1 adhesives (Normal adhesives) must have tensile adhesion strength :

- **after 28 days**
- **after heat ageing** **≥ 0.5 N /mm²**
- **after water immersion**
- **after freeze-thaw cycles**

and open time with tensile adhesion strength after 20 minutes **≥ 0.5 N /mm²**

The Class 2 adhesives (Improved adhesives) must have tensile adhesion strength : **≥ 1 N /mm²**

EN 12004 and ISO 13007-1
Cement-Based Adhesives

Classification	Characteristics	Requirement
C1 - Normal	Tensile Adhesion Strength Open Time : Tensile Adhesion Strength	≥ 0.5 N/mm^2 ≥ 0.5 N/mm^2 After not less than 20 mins
C2 - Improved	High Tensile Adhesion Strength Open Time : Tensile Adhesion Strength	≥ 1.0 N/mm^2 ≥ 0.5 N/mm^2 After not less than 20 mins
F – Fast setting	Early Tensile Adhesion Strength after 6 hrs Open Time : Tensile Adhesion Strength	≥ 0.5 N/mm^2 ≥ 0.5 N/mm^2 After not less than 10 mins
T – Slip (No Vertical Slip)	No Vertical Slip	≤ 0.5 mm
E – Extended Open Time	Extended open time : Tensile Adhesion Strength	≥ 0.5 N/mm^2 After not less than 30 mins
S1 – Deformable S2 – High Deformable	Transverse Deformation	≥ 2.5mm < 5mm ≥ 5mm

EN 12004 & ISO 13007-1

Chemical composition of the adhesive		C cementitious	D dispersion	R reactive resin
Fundamental classes	Normal adhesive			
	Improved adhesive			
	Fast setting adhesive			
Optional classes	Slip resistant adhesive			
	Extended open time adhesive			
Deformability classes	Deformable adhesive		—	—
	Highly deformable adhesive		—	—

Bedding Selection

Adhesive Choices:

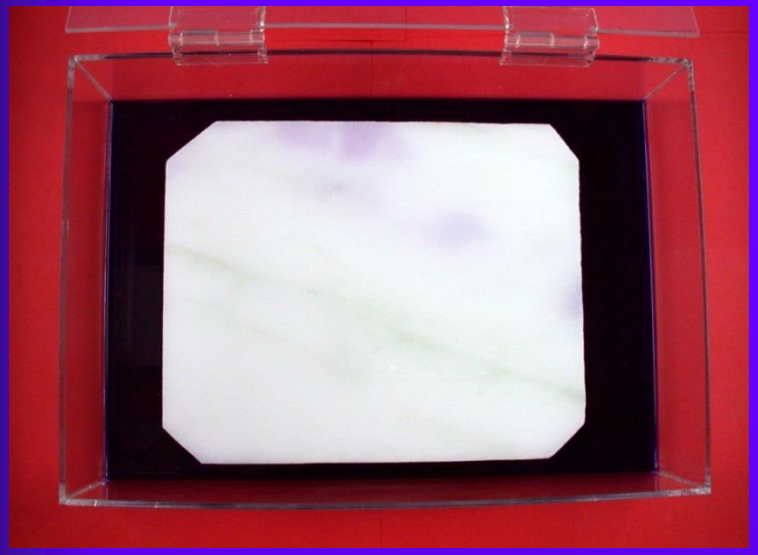
Normal vs. Improved Performance

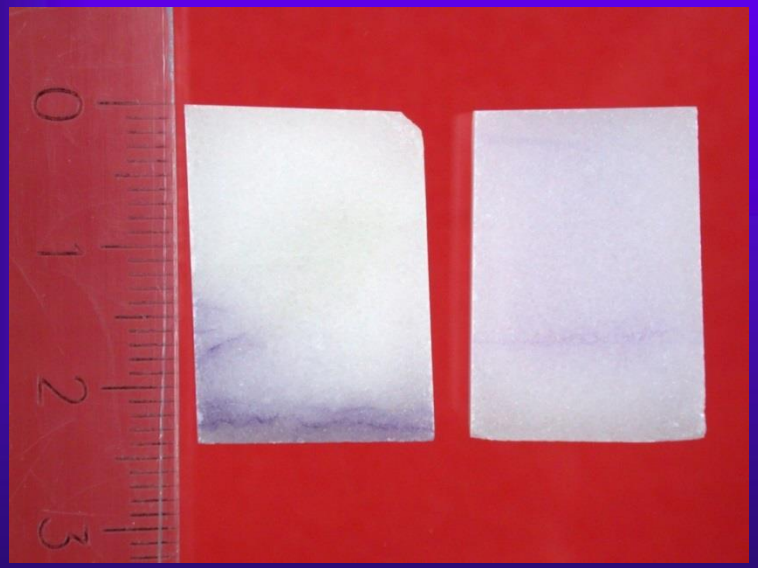
- One-component (mix with water)
- Two-component (powder & latex)
- Flexible/Deformable Cementitious
- Fast-setting with rapid hydration property

Bedding Selection

Options Available To overcome moisture mark stains of highly porous marble & granite

- **Select Two-component (less water in the mix & better water retentivity characteristic)**
- **Select Fast-setting adhesive with rapid hydration property**
- **“R” type of products that do not contain water**





Capillary porosity of the stone is not uniform.

Note the heterogeneous distribution of the blue-violet stains

Since all stones are natural products, when in doubt. advisable to do site trials to compare normal-setting vs. fast-setting adhesives

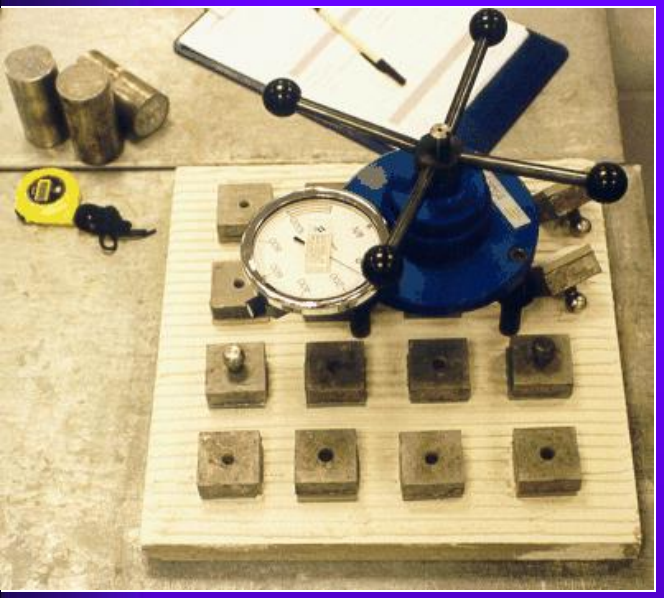
Stone Sensitive to Moisture During Installation

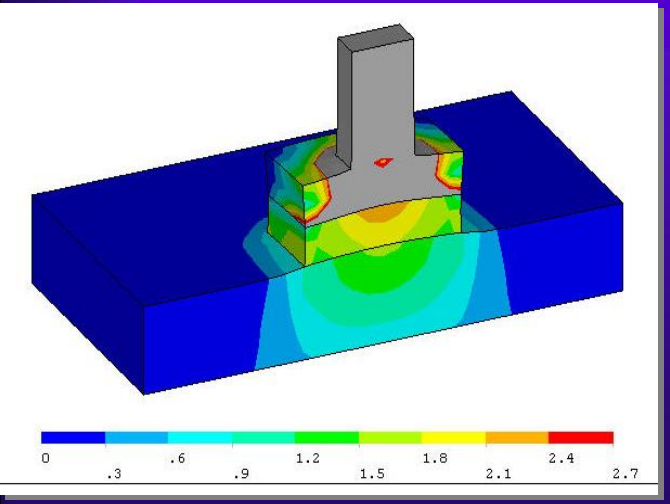
Solution: Use fast-setting adhesives with rapid hydration property

Installation of White Marble

Fast-setting cementitious adhesive vs. Normal-setting

Final Properties - Tensile Adhesion Strength



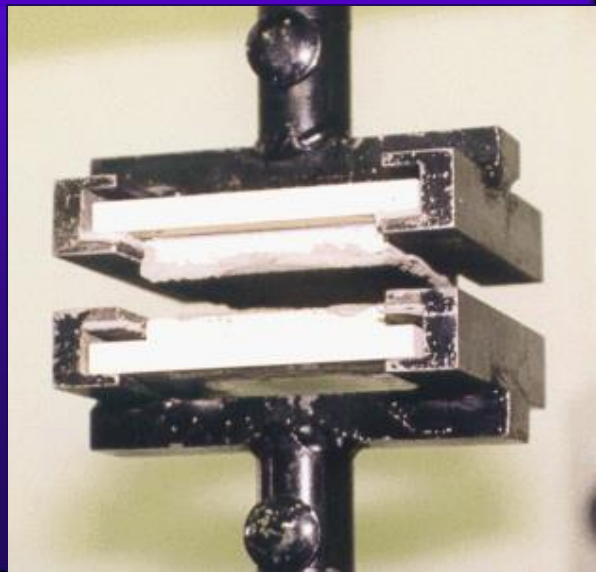


EN 12004-2 (EN 1348):

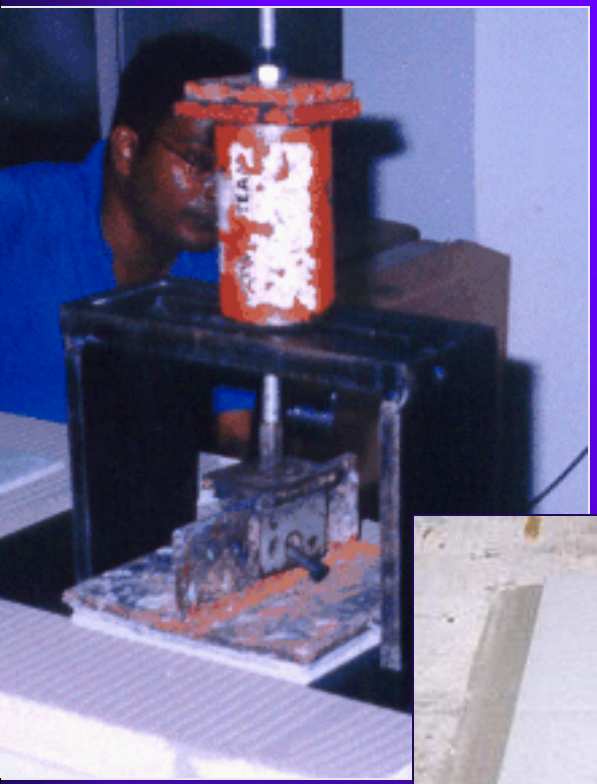
- "C1" $\sigma_{28} \geq 0.5$ MPa
- "C2" $\sigma_{28} \geq 1.0$ MPa
- Job-site use possible

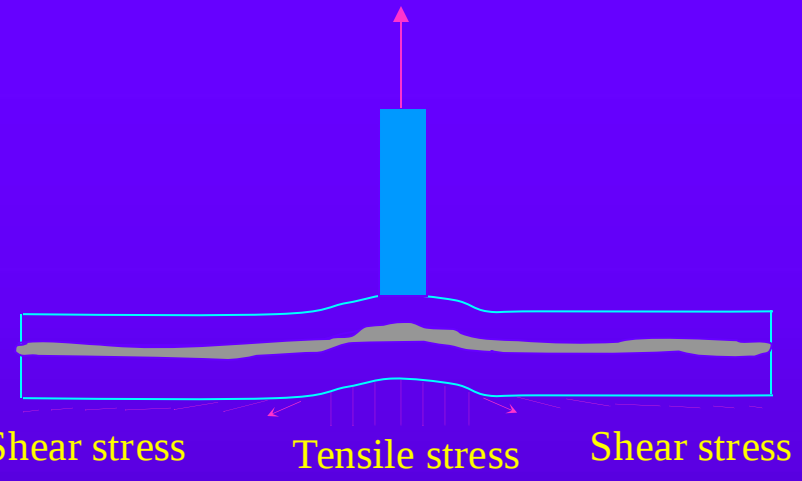
BS 5980:

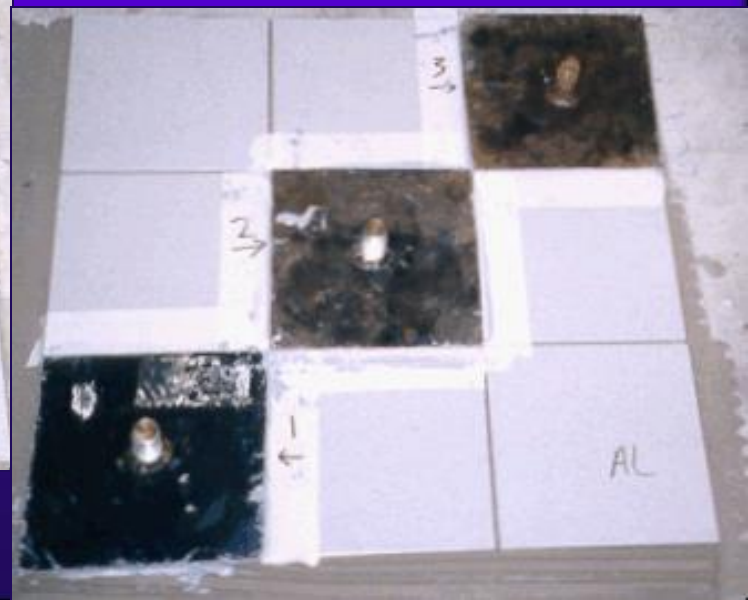
- $\sigma 14 \geq 0.17$ MPa
- Only conducted in laboratory



Common Scene at Job Site

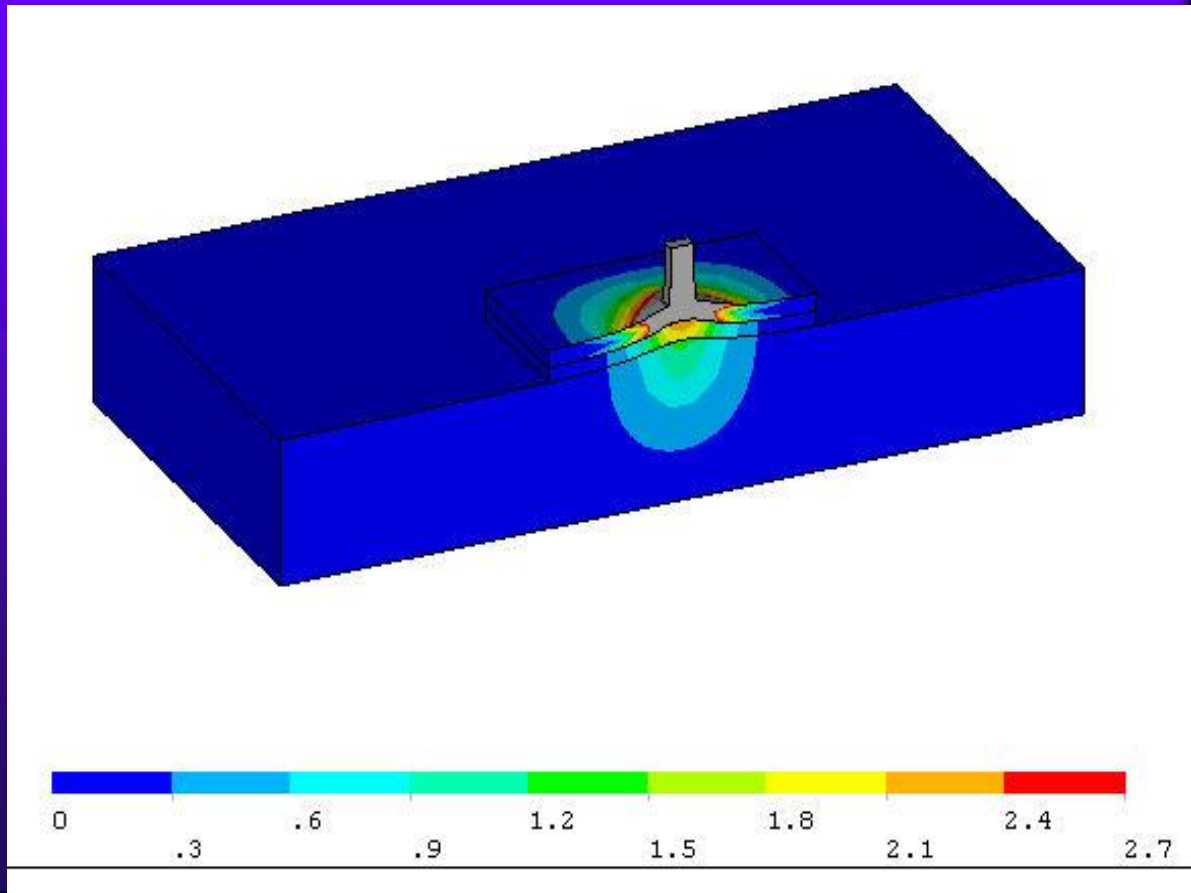




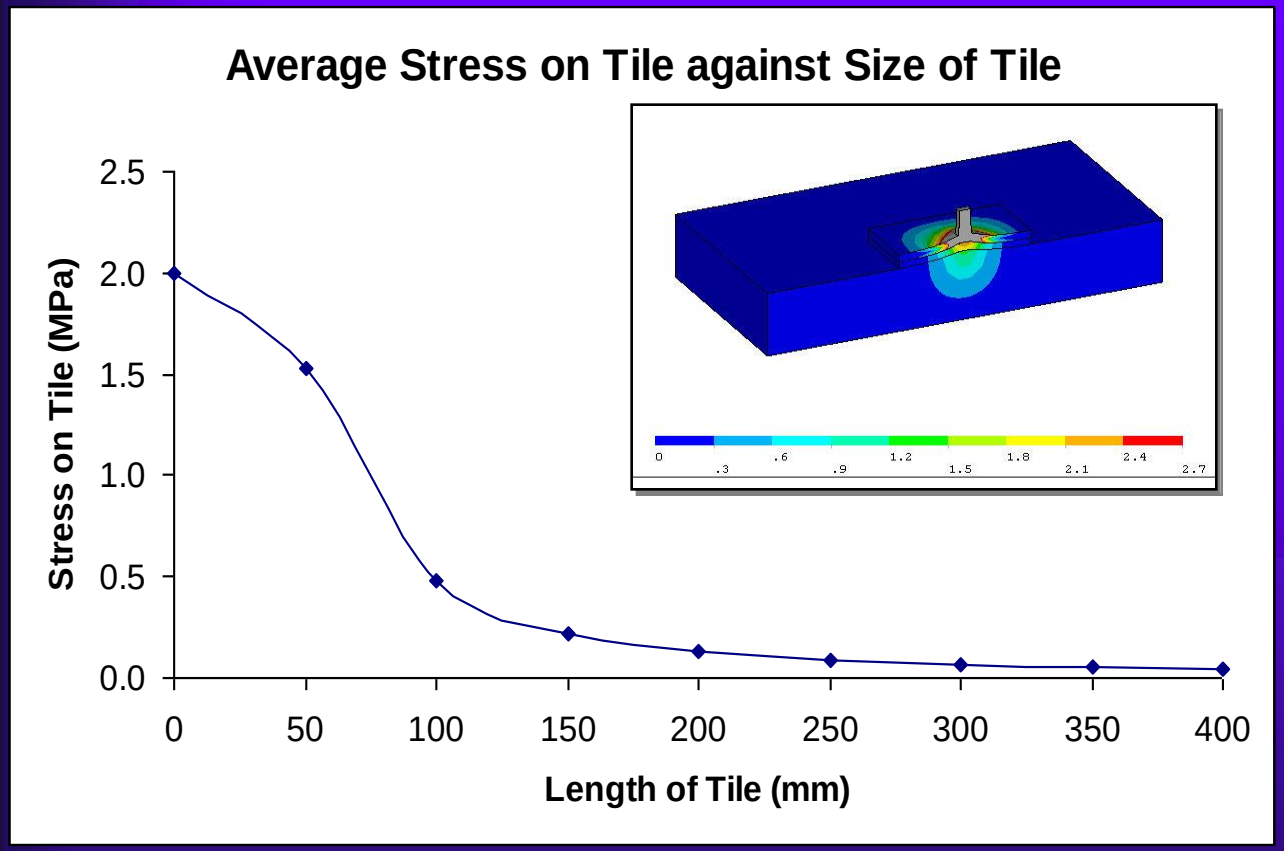


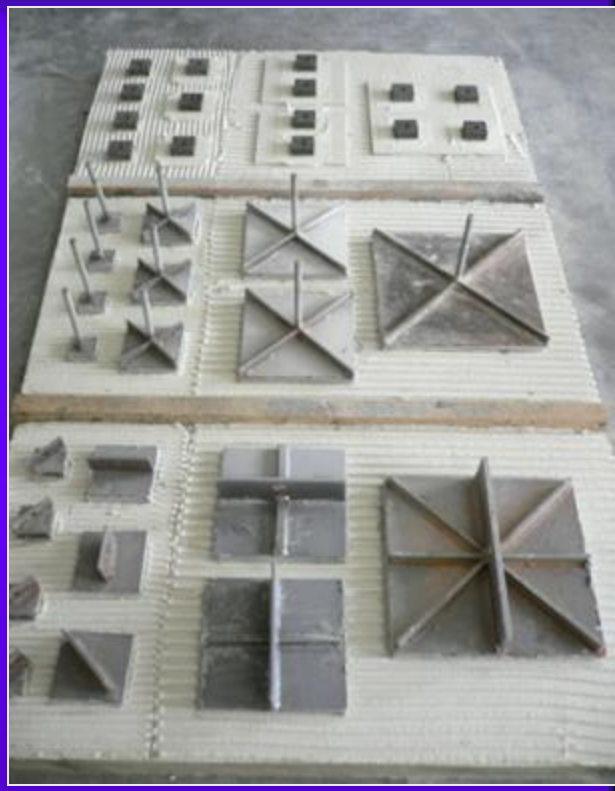
Common Scene at Job Site

- Incorrectly calculated by Force/Area

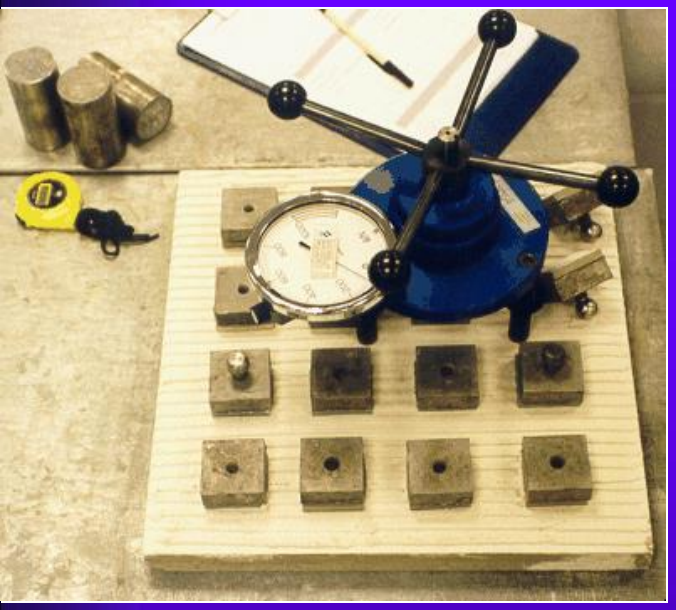


Controversial Method





Application Properties – Open Time



- EN 12004: maximum interval after application of adhesive at which tiles can be embedded & achieve tensile strength 0.5 MPa (Normal: ≥ 20 min, “E”: ≥ 30 min)

- ANSI A-118: longest time tile retained on wallboard after being twisted 90º with a special tool (Normal ≥ 50 min, high-temp ≥ 20 min)

ANSI A118 Standards

ANSI standards were established by the American National Standards Institute and are used mainly in the United States and Canada.

- **Shear Bond Strength**
  - **118.1 : Dry Set Mortar**
  - **118.4 : Latex Modified Portland Cement Mortar**

ANSI Standard Tests on:

- **ANSI 118.15 – Improved Latex Modified Portland Cement Mortar**

New Special Characteristics

- **A118.15F : Fast-setting**
- **A118.15E : Extended Open Time**
- **A118.15T : Nonsag**

Application Properties –

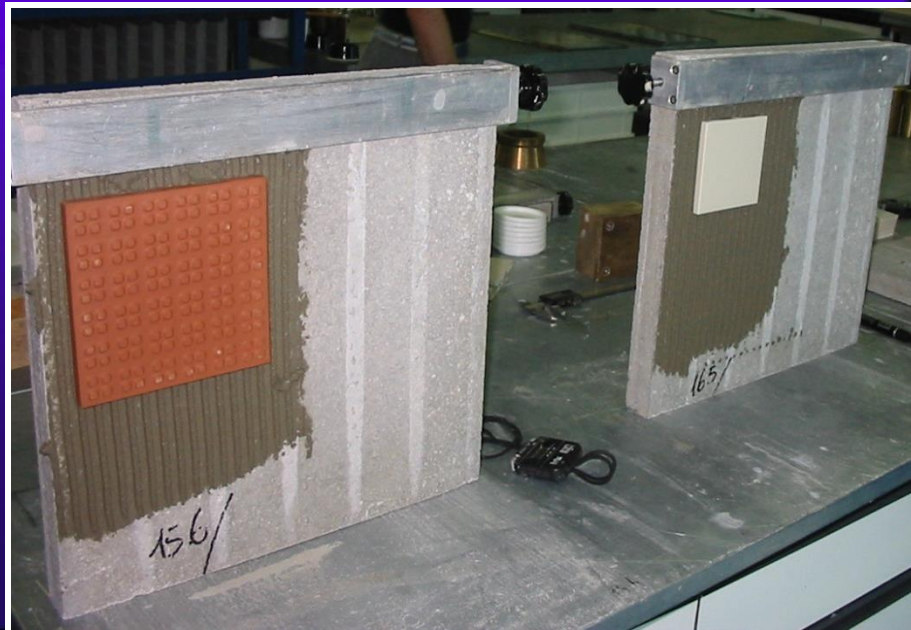
Wetting Capability

EN 12004-2 (EN1347):

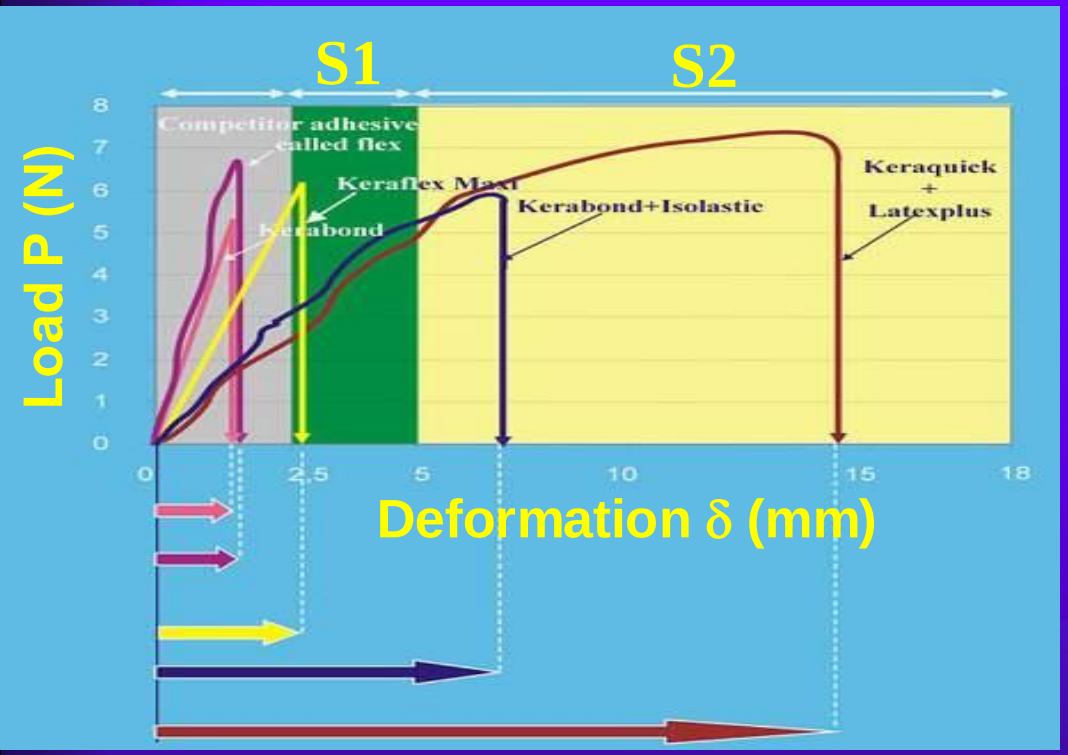
ability of a combed adhesive layer to wet the tile

Application Properties – Slip Resistance

EN 12004-2 (EN1308): downward movement of tile applied to combed adhesive on vertical or inclined surface ("T" ≤ 0.5 mm)

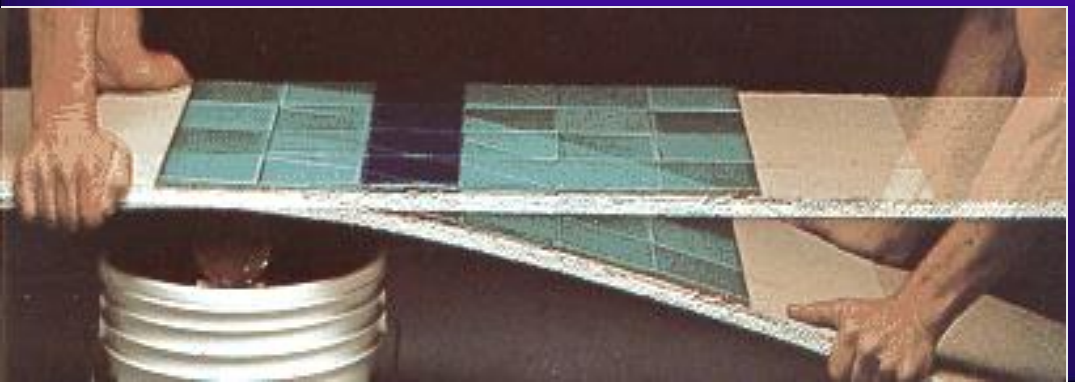


Final Properties – Transverse Deformation



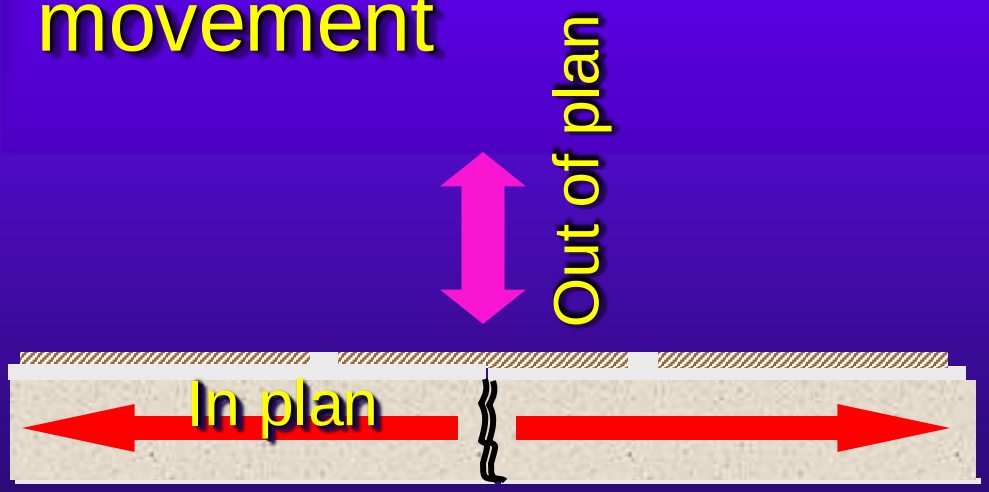
EN 12004-2: 2017 “deformable (S1) ” & “highly deformable (S2)”

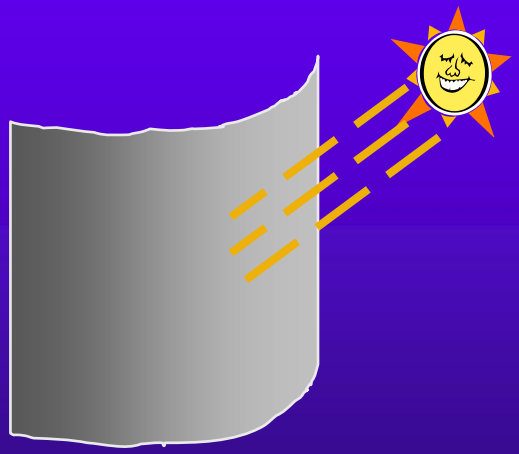
- Environments
- Dynamic loads
- Shrinkage

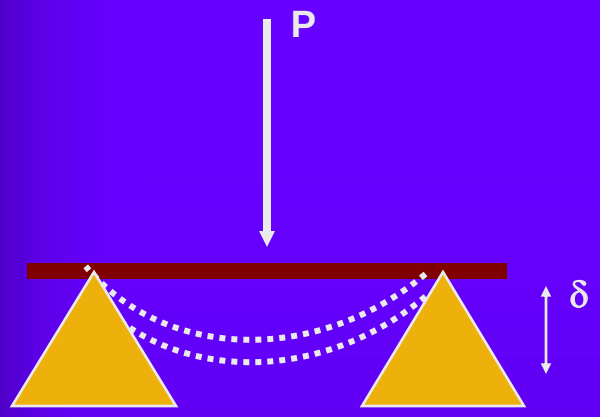


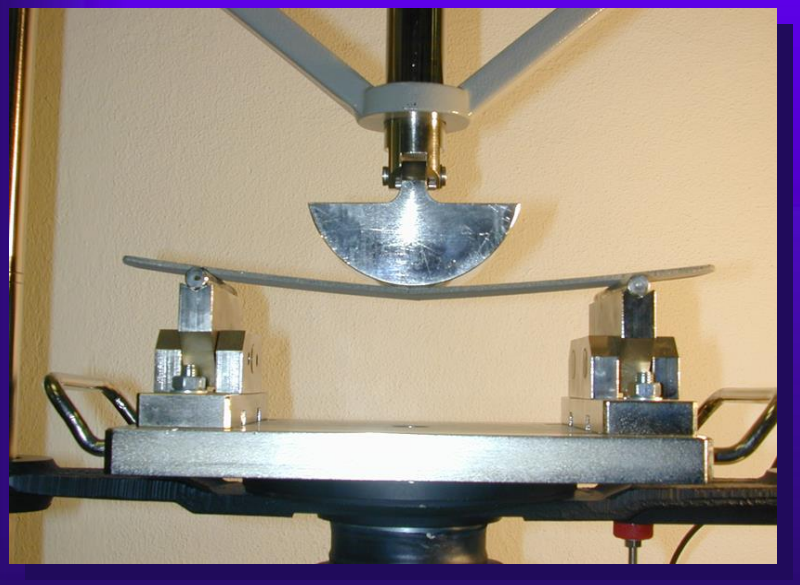
Deformability Caters for

- Environmental stresses due to temperature & moisture cycles
- Substrate vibration, dynamic impact
- Substrate cracks & differential movement



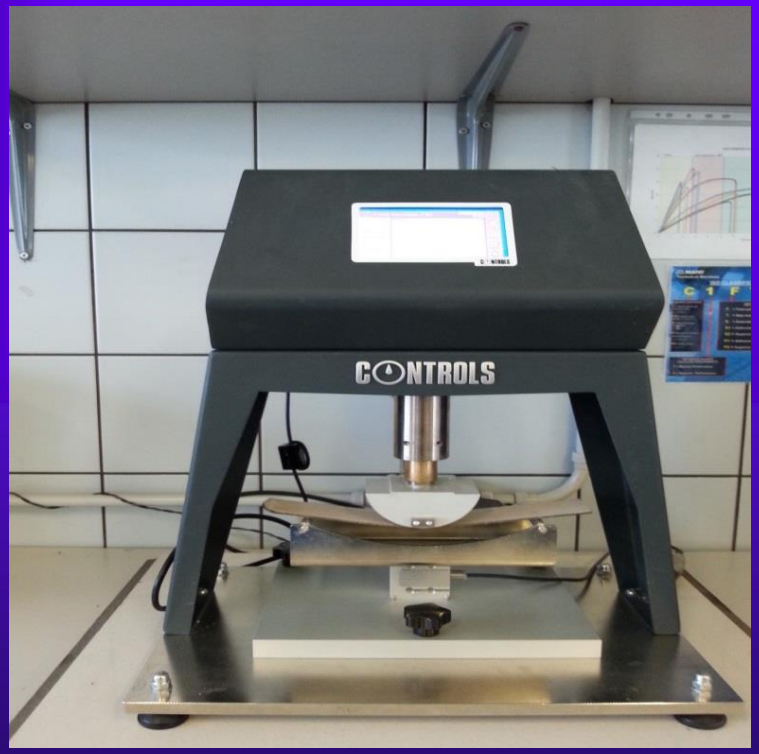


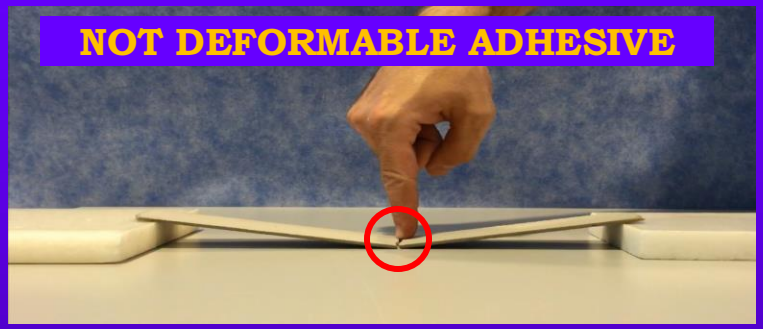




Deformability of a cementitious adhesive is determined in a flexural test by measuring the deflection of the specimen.

Class S1	Deformation between 2.5 and < 5 mm
Class S2	Deformation ≥ 5 mm





Recap:

3 Types of Adhesive Choices for Tile & Stone Installations:

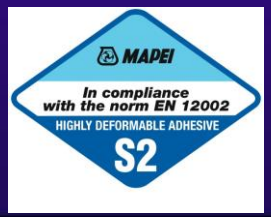
- **Cementitious Type (C1 and C2):**
  - Normal vs Improved Performance
  - Single-component (mix with water)
  - Two-component (powder & latex)
  - Flexible/Deformable (available in single & two component)
  - Fast-setting with rapid hydration property
- **Dispersion Type (D1 and D2)**
- **Reaction-Resin Type (R)**

Bedding Selection

- Same type, but different performance:
  - Technical competence
  - Marketing strategy
- Suitability & compatibility with
  - Finishing: size, quality, back profile …
  - Locality & environment : internal/external, wall/floor, thermal variation …
  - Substrate: concrete, brick, deformable substrate i.e., dry wall, waterproofing coat …

How to Select the Right Adhesive for Tile & Stone Installations

Examples	Required Adhesive Characteristics
Marble on WALL	C2, High Tensile Strength
Natural Marble sensitive to moisture	Fast-set (F) or Type R
Agglomerate Stones class B	Fast-set (F)
Deformable substrate	Deformable class S1, S2
Glazed ceramic tile subject to crazing	Two-component, S1
Large Tiles ≥ 300 x 600mm in size	Extended Open Time (E)
ALC/AAC substrate	Medium flexible
Subject to thermal variation	Deformable class S1 or S2
Subject to differential movement	Deformable class S1 or S2
Quick turn-around schedules	Fast-set (F)



Considerations when Selecting Adhesive for Tile work in PPVC/PBU Construction

- Module construction & substrate type; volumetric concrete, lightweight concrete, metal structure, drywall board
- Movement & vibration from transporting module to site and erection
- Time allowed for installation to cure before transporting module out of yard

Types of Grout

Grouts	EN 13888 & ISO 13007-3	ANSI
1-part cementitious	CG	A118.6
2-part cementitious		A118.7
Reaction resin	RG	A118.8

Required characteristics:

- Abrasion resistance
- Flexural & compressive strengths
- Shrinkage
- Water absorption
- Chemical resistance (RG only)

CLASSIFICATION OF CEMENTITIOUS TILE GROUT

Improved grouts (Class CG2) must have:

- **Abrasion resistance ≤ 1000 mm^3**
- **Reduced Water absorption ≤ 2 g (after 30 min.)**
- **Reduced Water absorption ≤ 5 g (after 240 min.)**

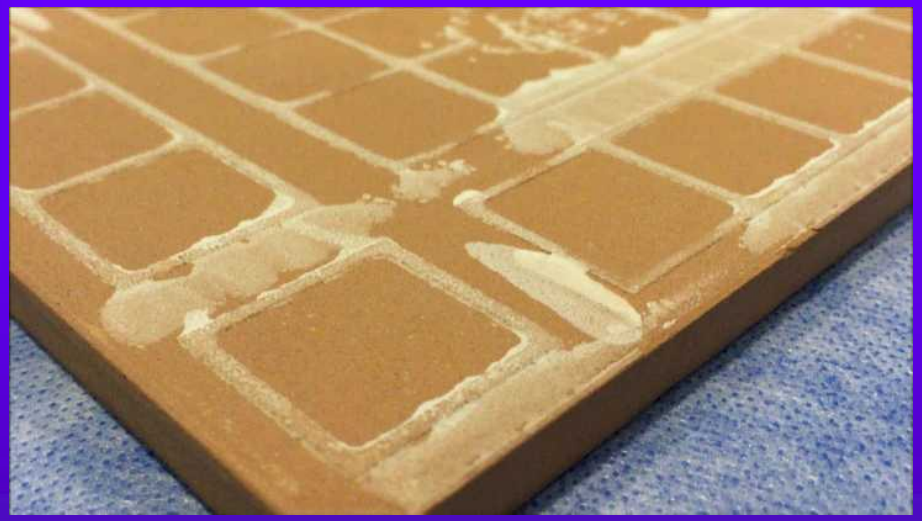
The values required for flexural and compressive strength and for shrinkage are the same of normal grouts.

Grouts – Selection Criteria

- Fineness & consistency
  - "Sanded" is for wider joints with better shrinkage resistance
  - "Un-sanded" is for narrow joints

- On porous and/or rough surfaces, make trial before using pigmented grouts

Grout Application on Absorbent Tile Surfaces



If tile surface is absorbent:

- Dampen tile surface to reduce suction or
- Apply tile and grout sealer on tile surface before grouting

Grouting on rough surfaces ….

- **Dampen surface before grouting**
- **Apply tile and grout sealer on tile surface**
- **Use scrubbing pad to loosen mortar trapped on the rough surfaced tile/stone**

Application Properties – Cleaning Time

EN 13888: time interval between filling joint & starting to clean tiles

- Too early: grout being removed
- Too late: stains on tiles are difficult to remove; acid washing will damage both tile/stone & grout

Final Properties – Abrasion Resistance

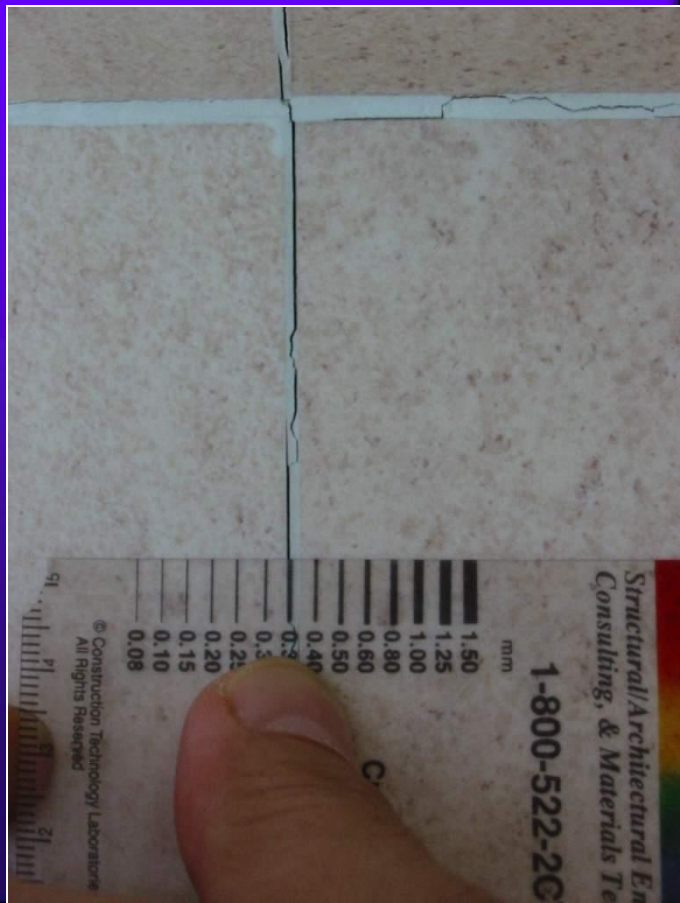
EN 13888: capability of grout surface to resist wear

- CG: Normal ≤ 2000 mm^3
  High ≤ 1000 mm^3
- RG: ≤ 250 mm^3

Final Properties – Shrinkage Resistance

EN 13888: length reduction of grout prism during hardening

- CG: ≤ 2 mm/m = 0.2 %
- RG: ≤ 1.5 mm/m = 0.15 %



Final Properties – Water Absorption

EN 13888: by capillary action when grout is in contact with water without pressure

- After 30 min: CG: Normal ≤ 5 g
  Reduced ≤ 2 g
- After 240 min: CG: Normal ≤ 10 g
  Reduced ≤ 5 g
  RG: Normal ≤ 0.1 g

Final Properties – Flexural & Compressive Strengths

EN 13888:

- Flexural strength:
  CG ≥ 3.5 MPa
  RG ≥ 30 MPa
- Compressive strength:
  CG ≥ 15 MPa
  RG ≥ 45 MPa

Minimum Joint Width

- Design preference (aesthetics)
- Tiles' manufacturing tolerance
- Consistency and alignment btw floor & wall

		Minimum Joint Width
Wall Tiles	Dry pressed	1.5 mm
	Extruded	6 mm
Floor Tiles	Dry pressed	3 mm
	Extruded	6 ~10 mm
Stones	Smooth finish	1.5 mm
	Rough texture	6 mm

Types of Movement Joints in Tile & Stone Work

- Silicone Sealants

- Polyurethane Sealants : one-component, two-component, self-leveling, thixotropic

- Preformed

Takes into consideration:
Sealant's Expansion capability
Thixotropic for Vertical Applications

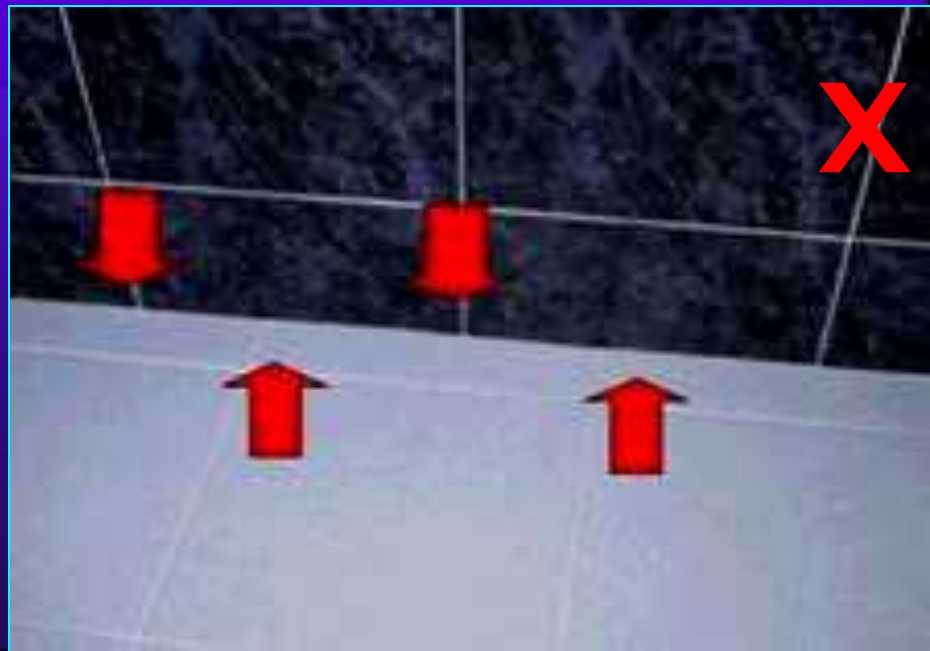
Inspection and Common Complaints in Tile & Stone Works

Quality Inspection

- Jointing
  - Consistent tile size: Tile size should be consistent according to specifications.

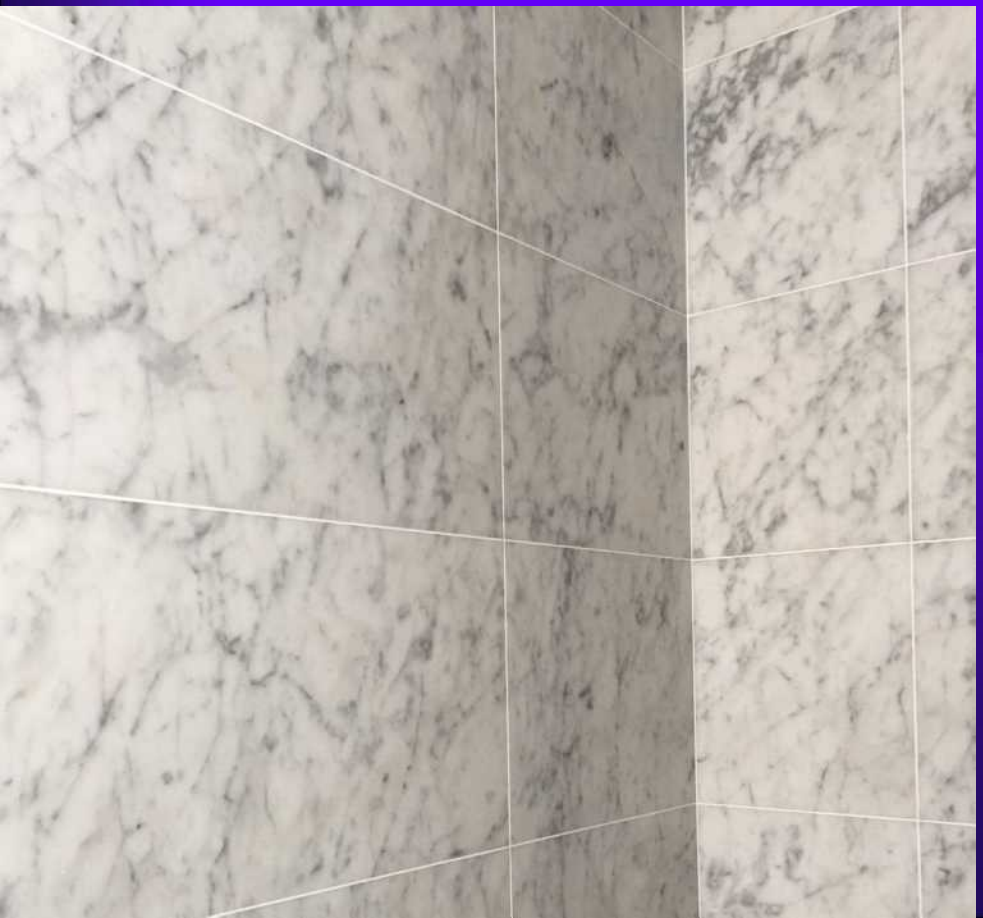
Quality Inspection

- Jointing
  - Floor joints aligned & consistent with skirting & wall tiles



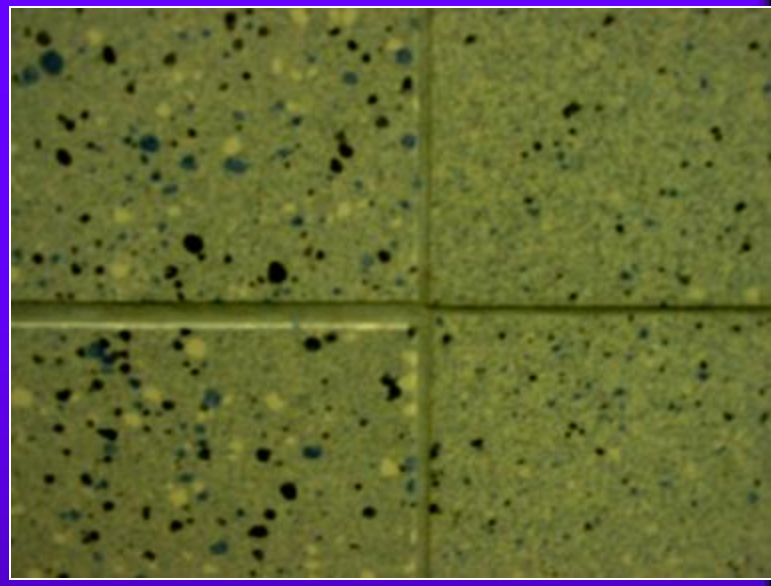
Quality Inspection

- Jointing
  - Consistent joints between wall and floor; aligned



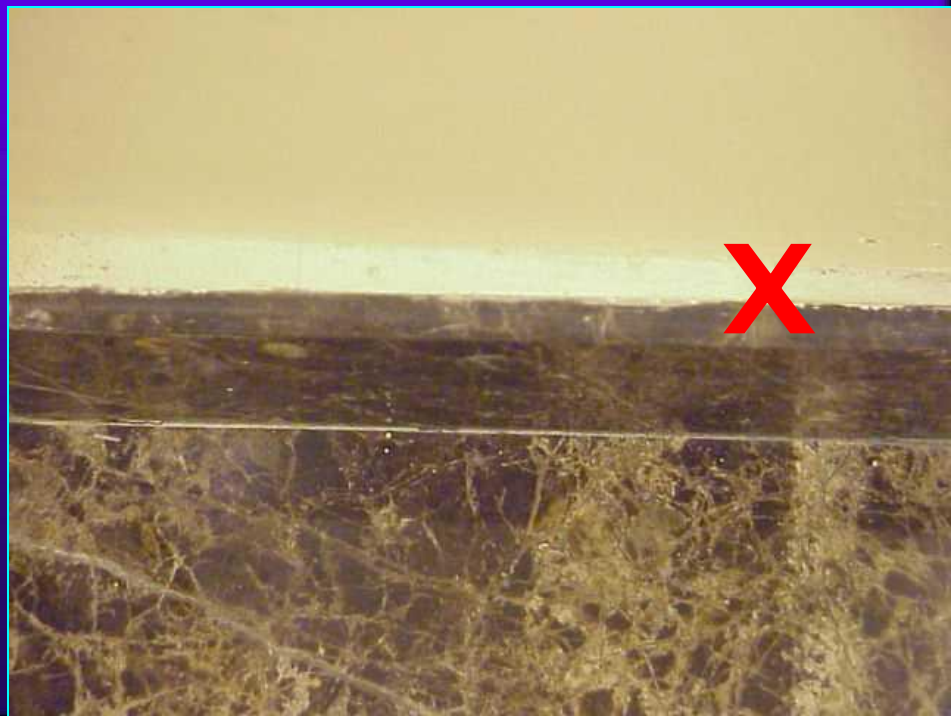
Complaint - Out of Alignment

- Inconsistent dimension of tile/stone
  - Select suitable tile/stone
- Poor workmanship e.g. tiles not properly aligned during installation
  - Use skilled worker



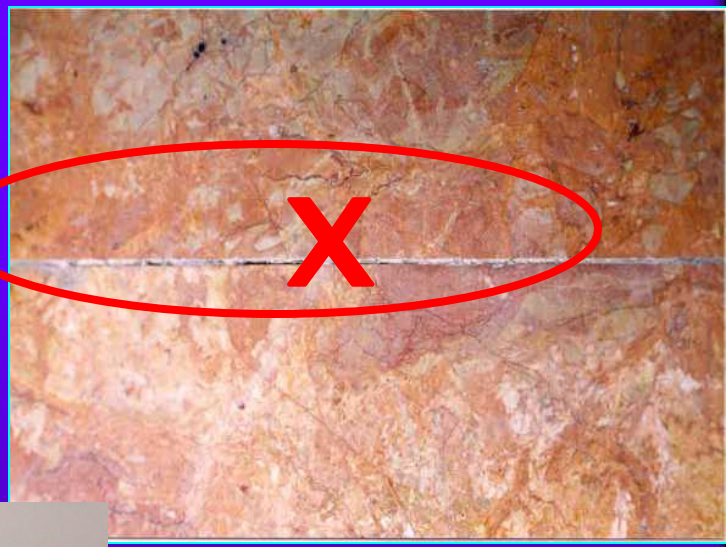
Quality Inspection

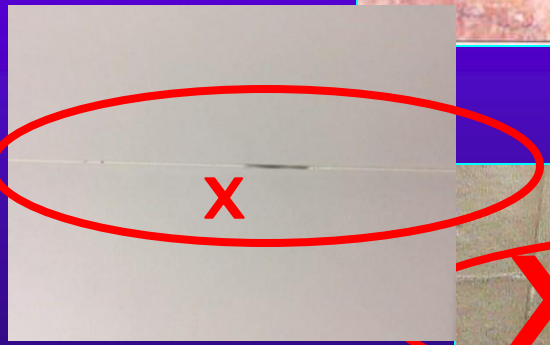
- Jointing
  - Consistent skirting thickness

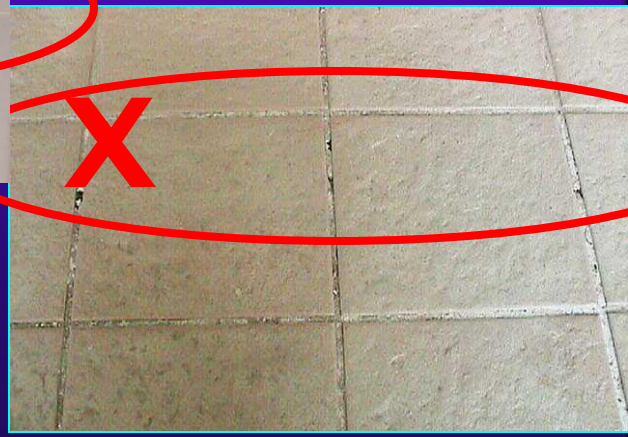


Quality Inspection

- Jointing
  - Consistent & neat jointing

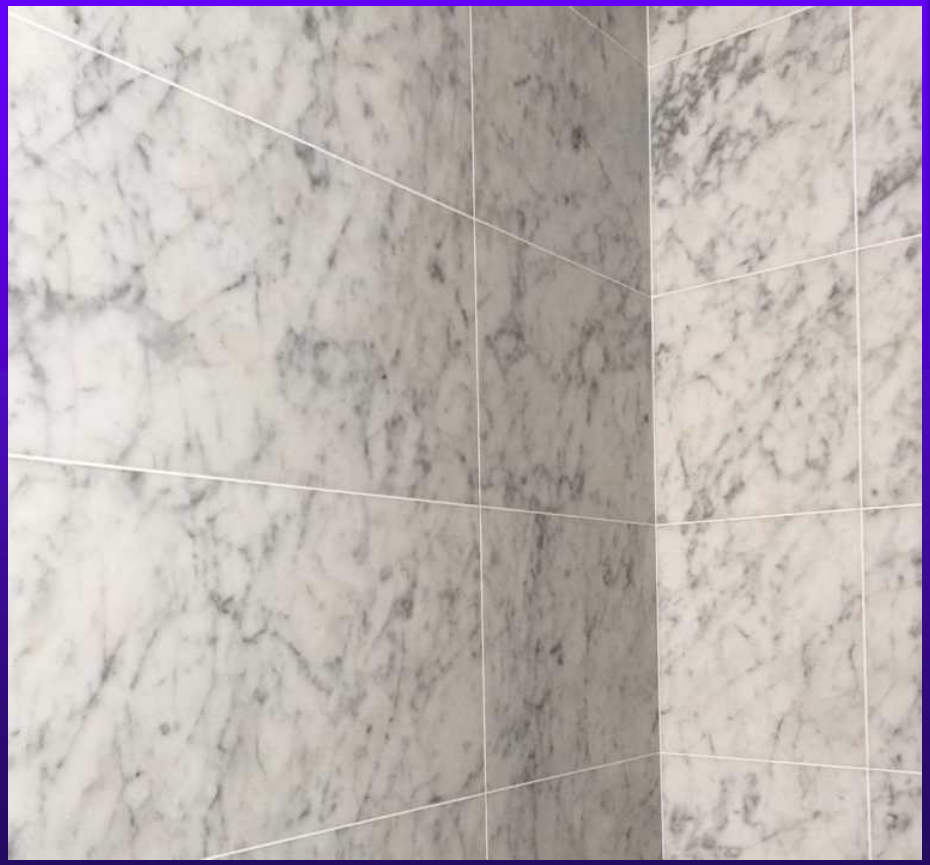






Quality Inspection

- Jointing
  - Consistent & neat jointing



Complaint - Dirty Joints

- Poor quality of grout used
  - Select suitable grout
- Joint not properly filled
  - Fill properly
- Tiled surface not properly cleaned after tiling
  - Clean after setting

Tile Grout Not Properly Filled

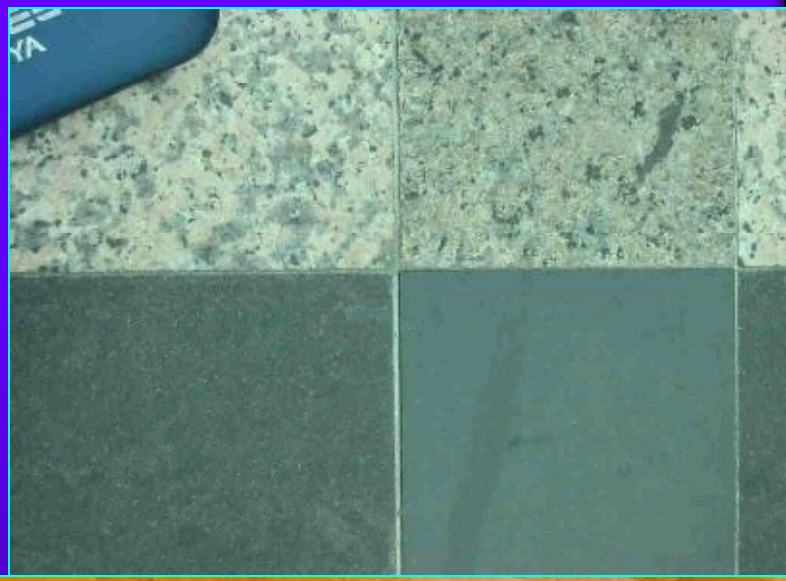
- Insufficient joint depth
- Tile Grout must fill the tile joint completely or at least 2/3 of the tile thickness

Quality Inspection

- Finishing
  - Not to see mortar stains, paint drips, …

Complaint - Inconsistent Tonality

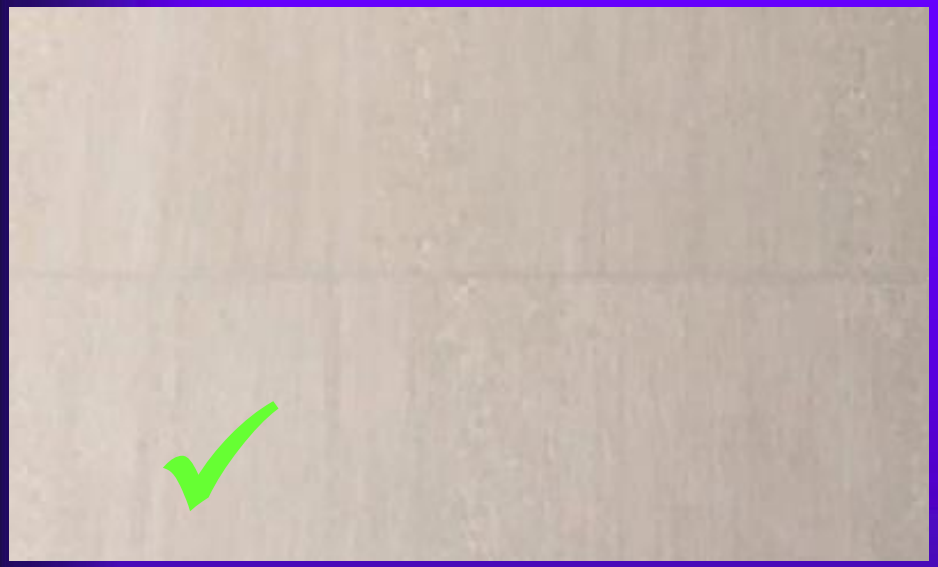
- Choice of material with excessive colour variation
  - Careful selection
- Lack of pre-laying to ensure colour variation is acceptable
  - Carry out pre-lay



Quality Inspection

- Finishing
  - Consistent colour tone, pattern & shade
  - Establish acceptable tonality range

Quality Inspection



Consistent tonality – pattern and shades are well blended

Inconsistent tonality

Quality Inspection

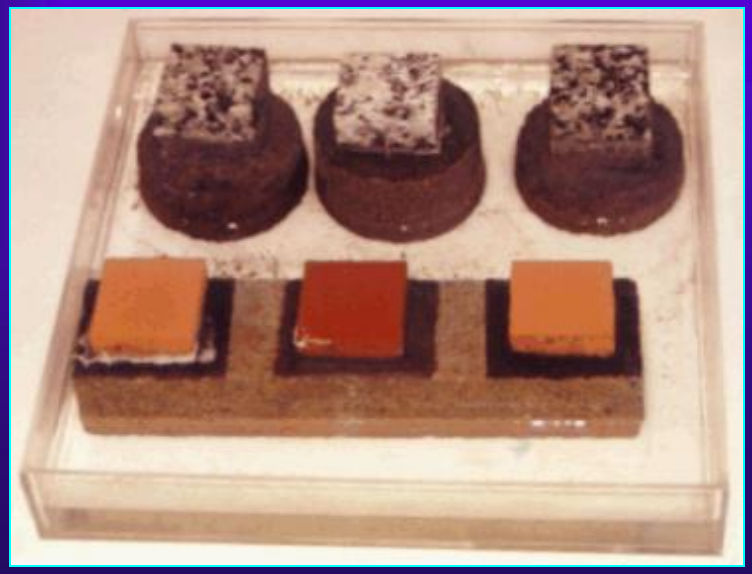
- Inconsistent Tonality

Possible causes:

- Lack of pre-laying to ensure color variation is acceptable
- Uneven drying time of the stone

Complaint - Inconsistent Tonality

- Prolonged dampness due to water ingress
  - Use proper waterproofing



Complaint - Staining

- Stain by other trade after laying
  - Proper protection
- Spillage of chemicals
  - Avoid spillage
- Efflorescence – see next

Complaint - Efflorescence

What causes efflorescence?

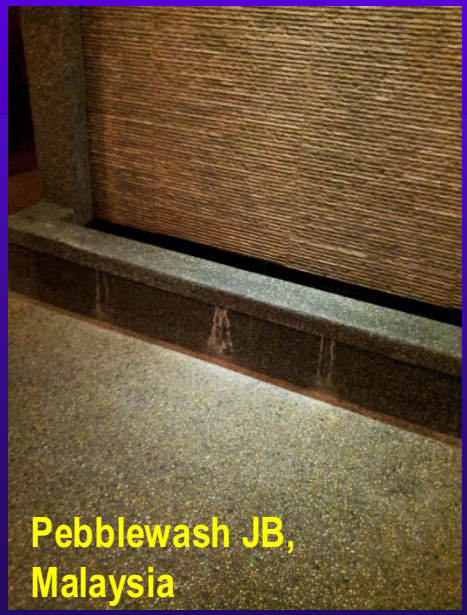
Efflorescence

Singapore


Singapore


South Korea


Japan

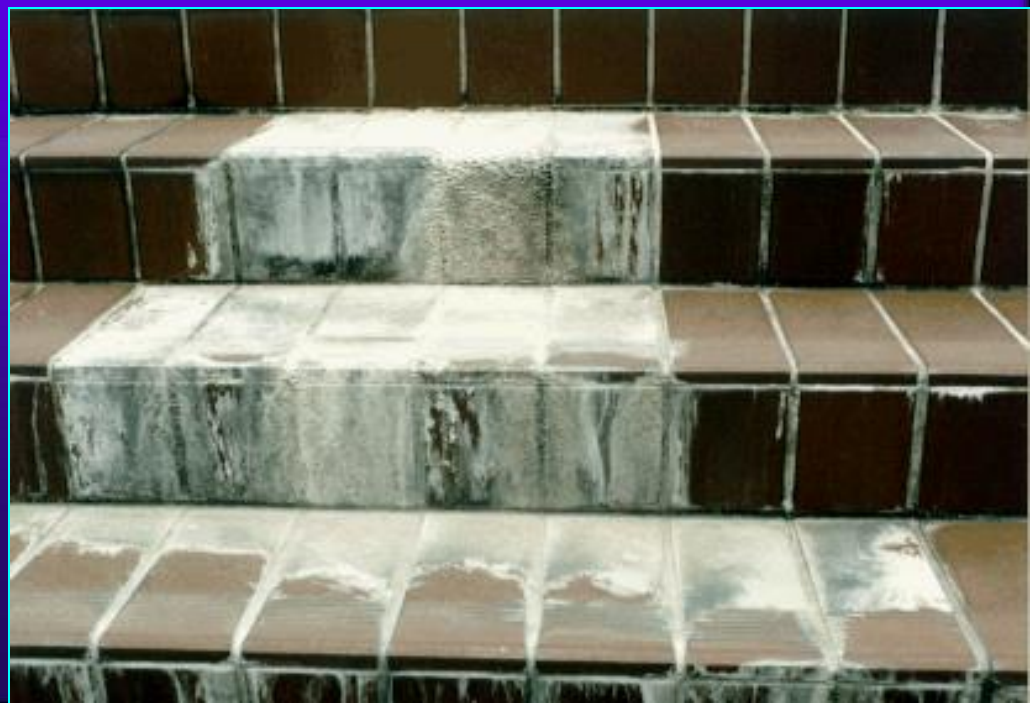

Pebblewash JB, Malaysia

Complaint - Efflorescence

- Salt within tiles or tile bed or cement-based substrate
  - Avoid excessive wetting
- Water getting into adhesive from substrate or through tile joints
  - Use proper waterproofing

Efflorescence Prevention

- Eliminate at least one of the following:
  - soluble salt
  - water
  - water path

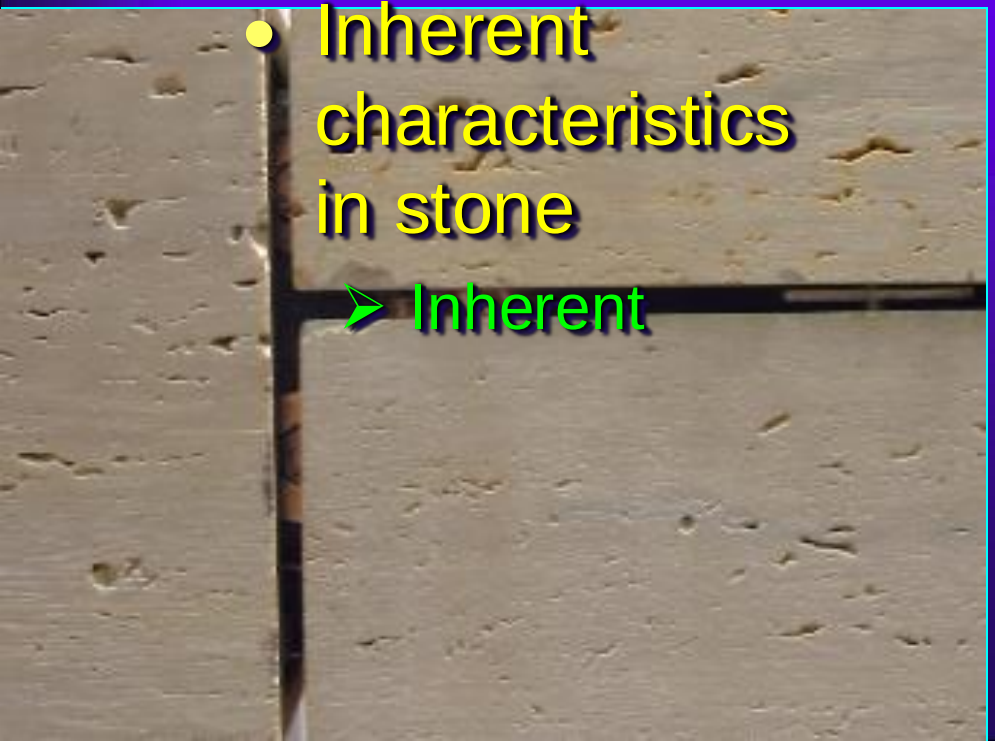


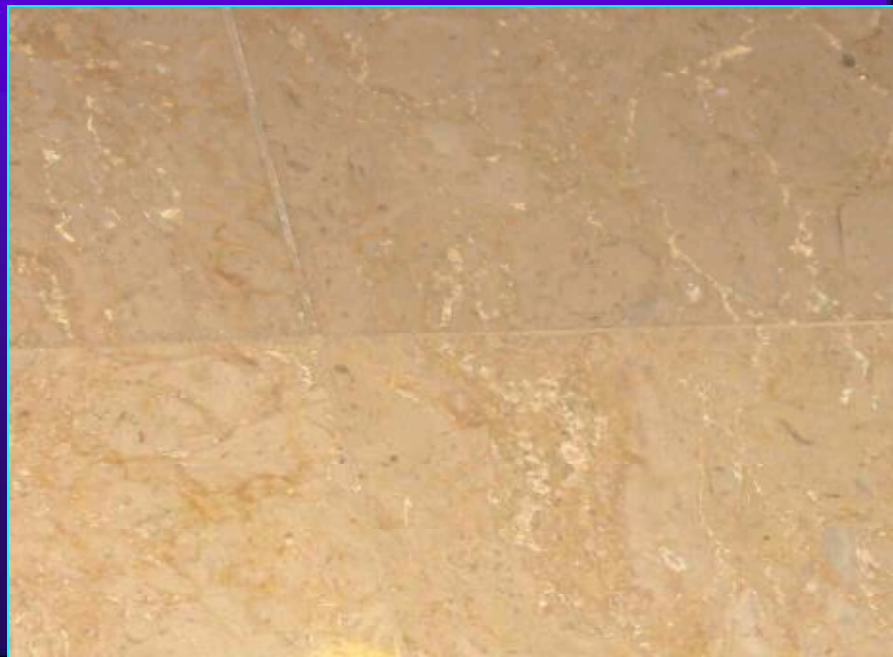
Efflorescence

External floor tiling – Before tile joints are grouted, be careful that water does not get into the installation through the open joints. Provide shelter to protect the “open” joints from rain/water after tiles have been laid.

Complaint - Pinholes

- Use of porous marble without proper care
  - Select suitable stone
- Inherent characteristics in stone
  - Inherent



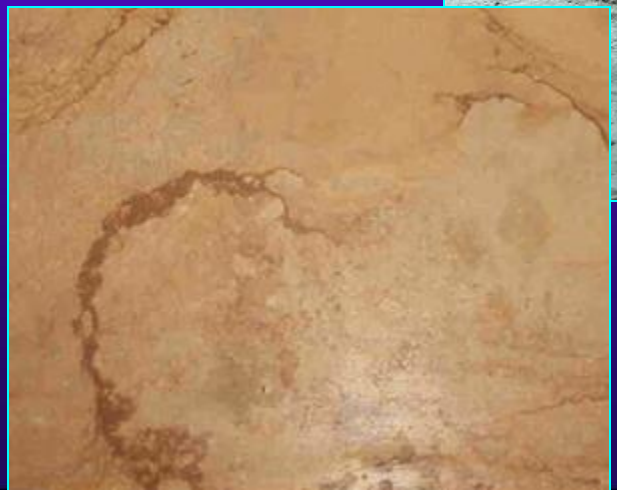


Complaint - Splotches or Dull

- Spillage & left-over of food and cosmetic products
  - Avoid spillage or quick cleaning
- Cleaning solution e.g. acidic & strong alkaline
  - Use suitable cleaning solution
- Alkalinity of cementitious grout
  - Use suitable grout

Complaint - Splotches or Dull

- Efflorescence
  - Avoid excessive wetting
- Excessive direct sunlight
  - Minimise exposure to sunlight
- Inherent characteristics
  - Inherent

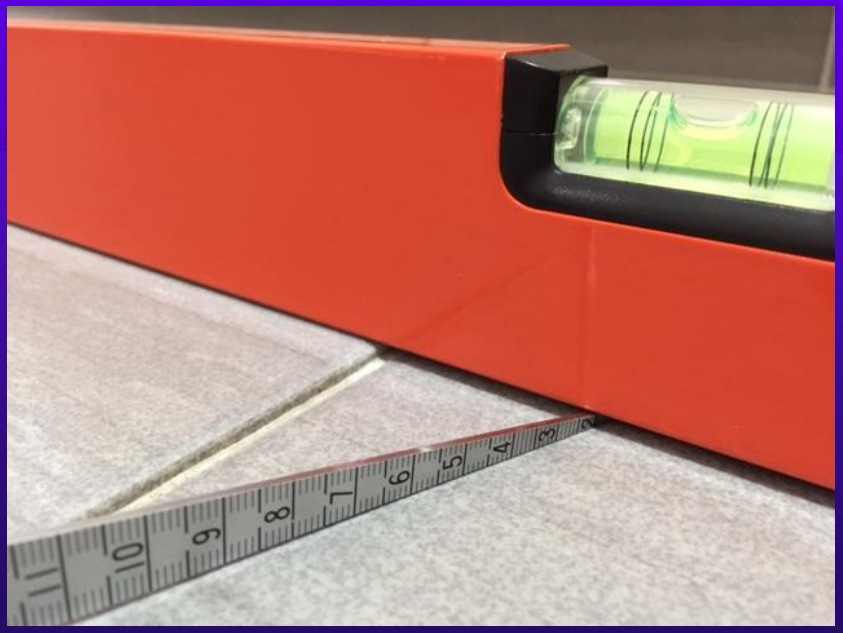


Quality Inspection

- Evenness
  - ≤ 3 mm over 1.2 m
  - Proper fall & direction in wet areas, NO water ponding

Quality Inspection

- Evenness
  - Lippage between 2 tiles should not be more than 0.5 mm



Complaint - Uneven Surface or Lippage

- Dimensional defective tile
  - Select suitable tile
- Warped stone
  - Proper dimensional stability
- Varied tile thickness
  - Correct tile thickness
- Uneven substrate
  - Proper surface preparation

Complaint - Uneven Surface or Lippage

- Incorrect bedding thickness
  - Use proper tool
- Lack of consideration for curing of bedding material
  - Proper curing
- Insufficient levelling of each tile
  - Ensure tiles are even & level using spirit level

Complaint - Uneven Surface or Lippage

- Insufficient tapping of tiles into position
  - Ensure tiles are uniformly tapped into place
- Premature loading onto freshly completed tiling
  - Proper protection

Quality Inspection

- Cracks & Damages
  - View from 1.5 m, NO chip, crack, or other visible damages

Quality Inspection

- Cracks & Damages
  - Vein cannot be felt
  - Cracks can be felt

Complaint – Cracked Tiles

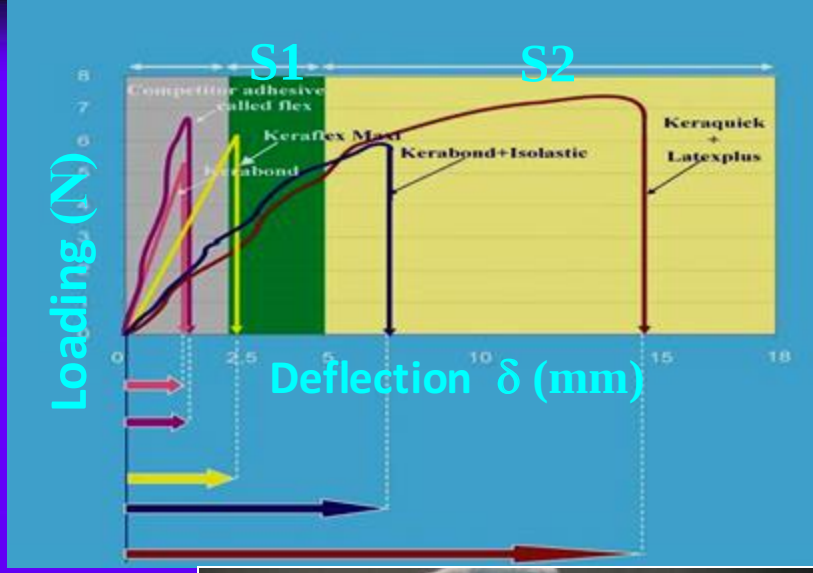
- Inadequate expansion or control joints
  - Allow movement joints
- Tiles laid over cracks
  - Need special treatment

Complaint – Cracked Tiles

- Direct impact
  - Proper protection
- Damage by other trade after laying
  - Proper protection
- Poor cutting & handling
  - Use proper tool

Complaint – Cracked Tiles

- Excessive external vibration
  - No butt joint
  - Allow movement joint
  - Use “forgiving” adhesive
- Crazing of glazed tiles due to moisture movement
  - Confirm soaking not leading to crazing before installation



Complaint - Jagged Edges

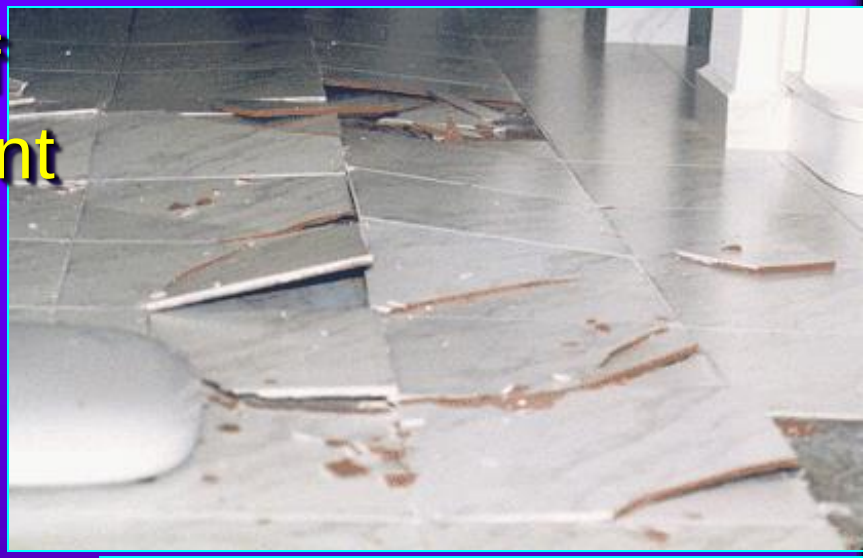
- Not sufficient movement joint
  - Allow movement joint
- Butt joint
  - No butt joint

Adhesion Failure – Possible Cause

Lack of / Insufficient Provision of Movement Joints

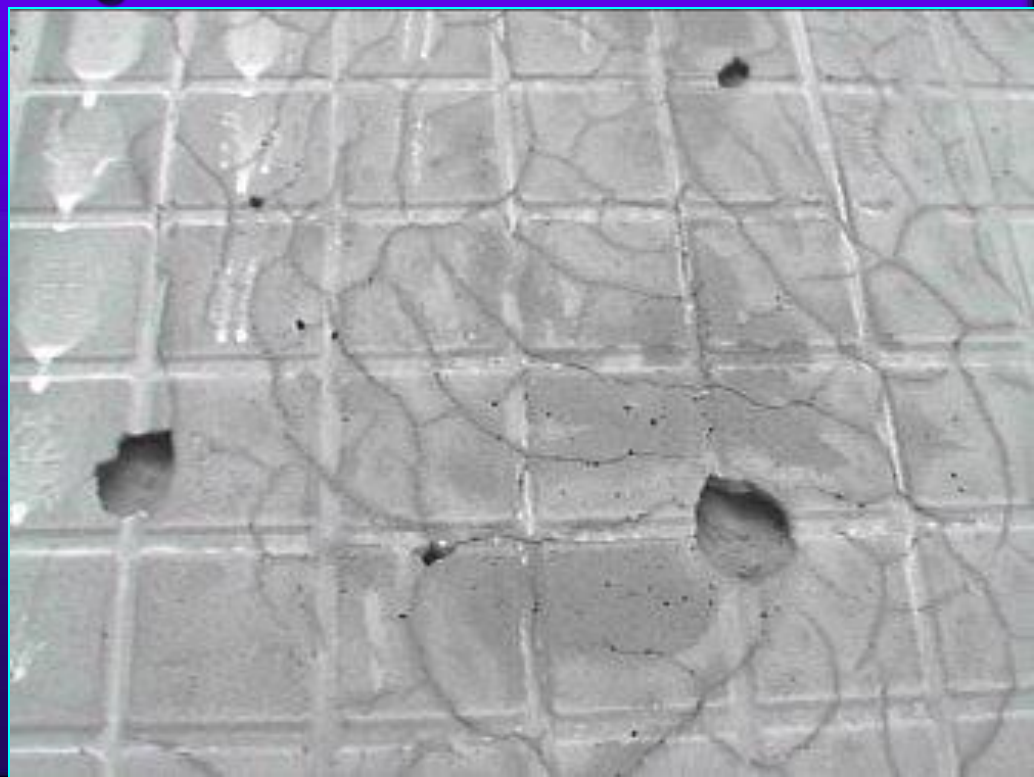
Complaint - Adhesion Failure

- Inadequate provision of expansion or control joint
  - Allow movement joints
- Incompatible tile & bedding material
  - Use proper materials
- Contamination of tile back by dust & dirt deposit
  - Clean tile back before installation



Complaint - Adhesion Failure

- Concrete or mortar not properly cured, and drying shrinkage crack occur after tiling
  - Allow sufficient curing

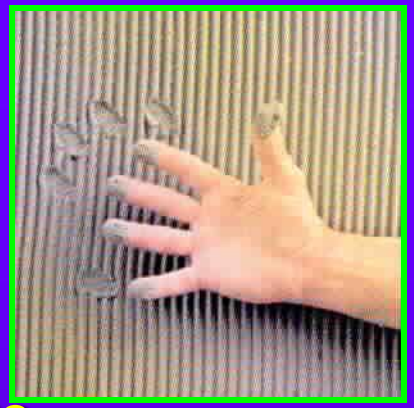


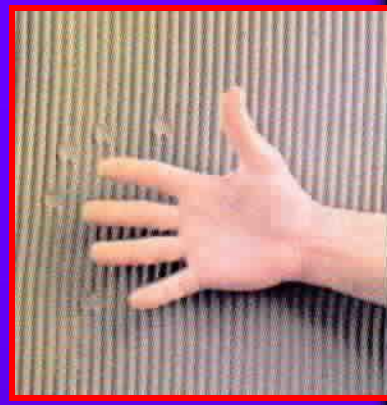
Complaint - Adhesion Failure

- Substrate not properly cured, cleaned & prepared

Complaint - Adhesion Failure

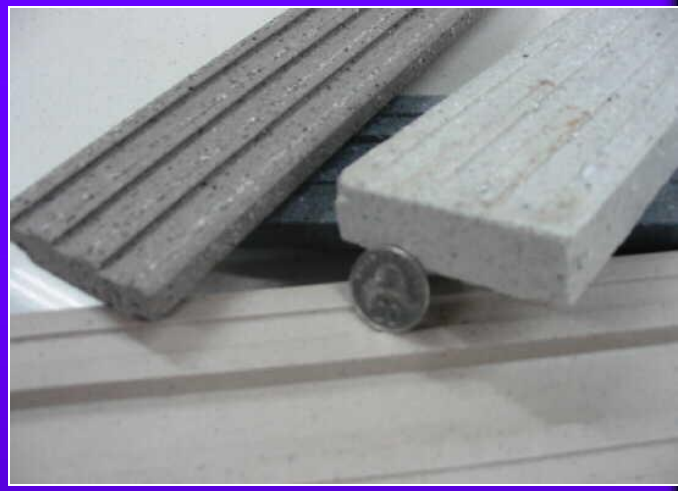
- Incorrect installation of tiles, e.g.
  - ⇨ insufficient tapping
  - ⇨ “open time” of adhesive has lapsed
- ➢ Install tile according to proper procedure





Complaint - Adhesion Failure

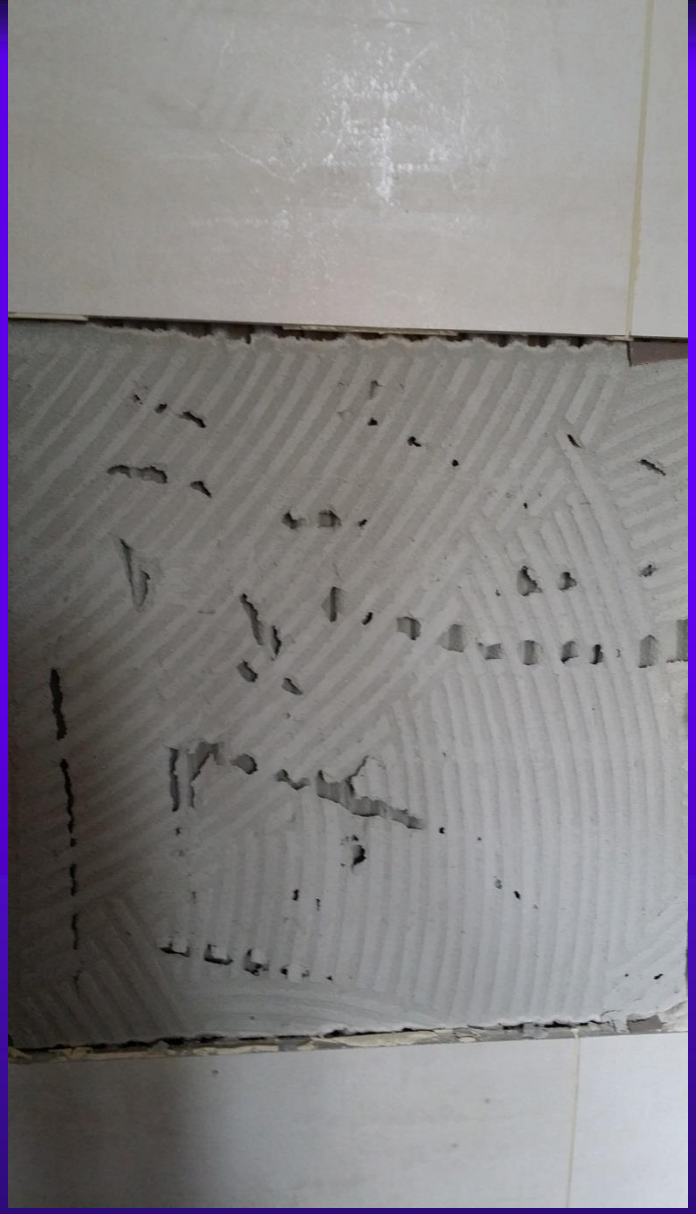
- Inadequate provision of mechanical key in tiles
  - Allow adequate mechanical key or use appropriate adhesive



- Failure to soak porous tiles before tiling on cement-based bedding
  - Soak porous tiles in clean water for at least 30 min

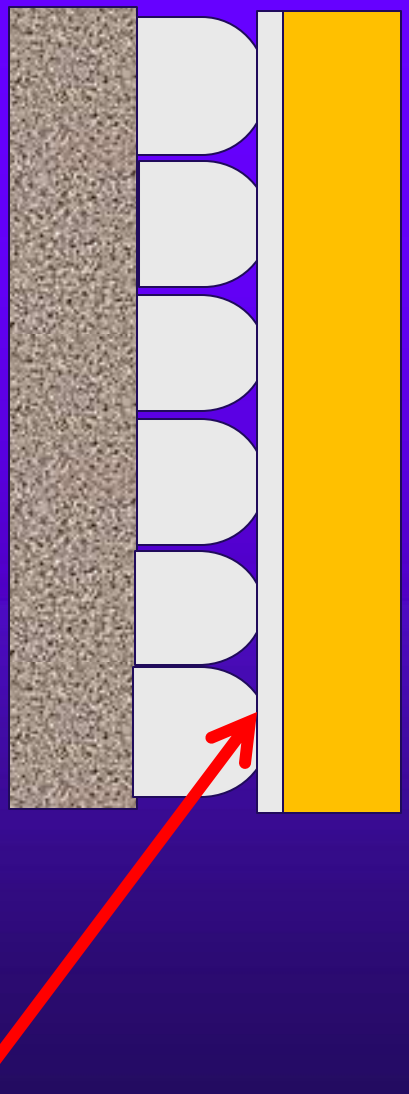
Insufficient adhesive contact which may cause weak Adhesion & Hollowness.

Caused by using the wrong notched size.



Adhesive not firmly pressed in and not fully compacted. Trowelled ridges not collapsed and compressed.

Weak Adhesion

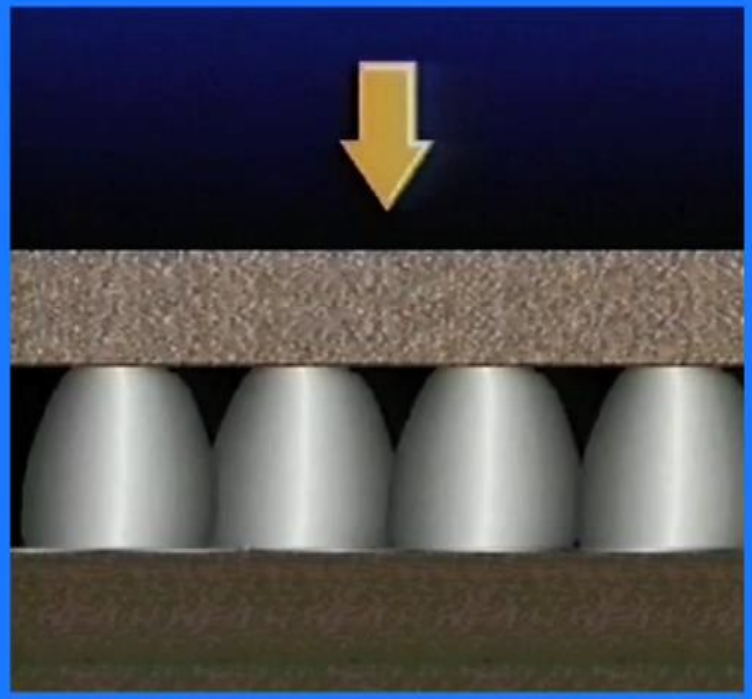


The weak link is between the 2 layers of adhesive where they meet.

For a good grip, the 2 layers must be compressed into one compacted layer of adhesive bedding

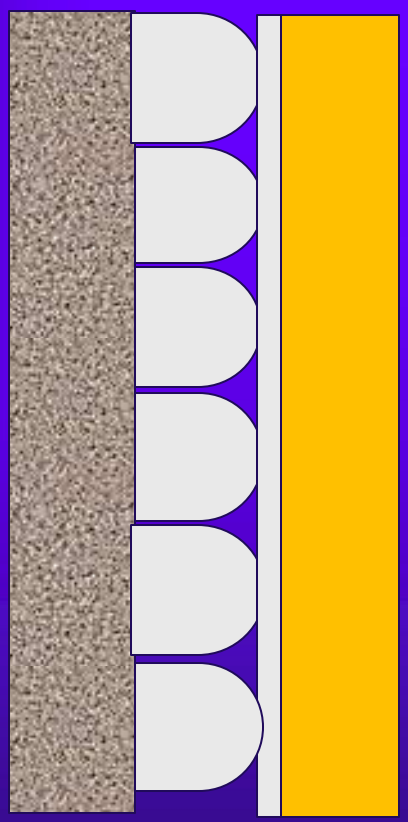
NB: Drawing not to scale

Displace air by pressing on stone or tile from the centre out & collapse adhesive ridges by moving the tile or stone across the adhesive ridges.

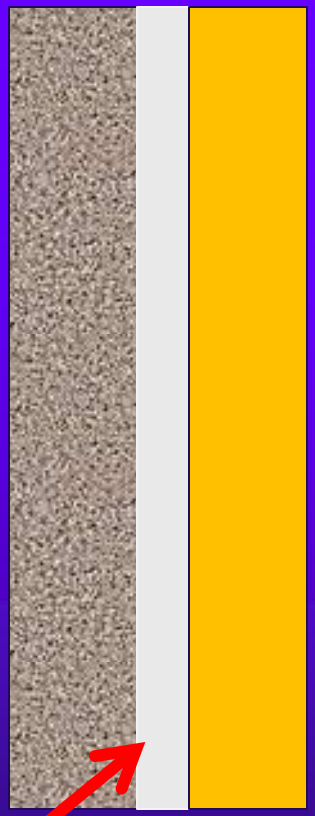


Straight lines are easier to collapse

Application with Notched Trowel



Initial Thickness



FINAL Thickness

After compressing the 2 layers into one compacted layer, the final adhesive thickness will be approximately half of the initial applied thickness.

i) Debonding can occur at this weak Adhesive Layer.

ii) Pull-out readings can be low because of this weak Adhesive Layer.

Complaint - Adhesion Failure

- Incompatible resin used to secure nylon reinforcement
  - Check compatibility or resin used

- Back-sealer on stone
  - Check compatibility of sealer used.
  - Ensure no excess residue on back surface of stone

Complaint - Adhesion Failure

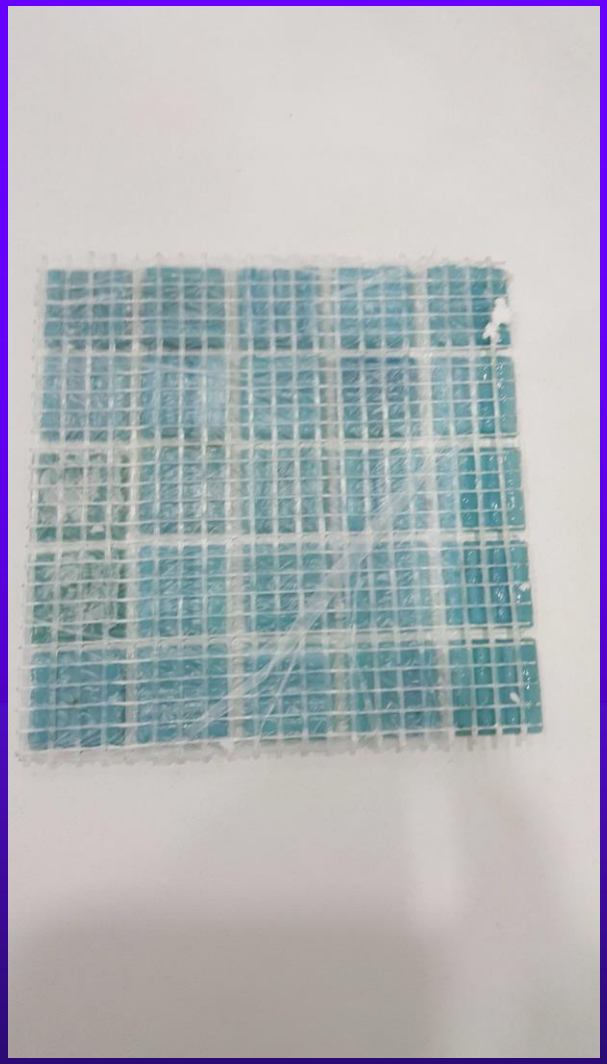
- Nylon reinforcement not securely adhered

Marble with Back-Netting

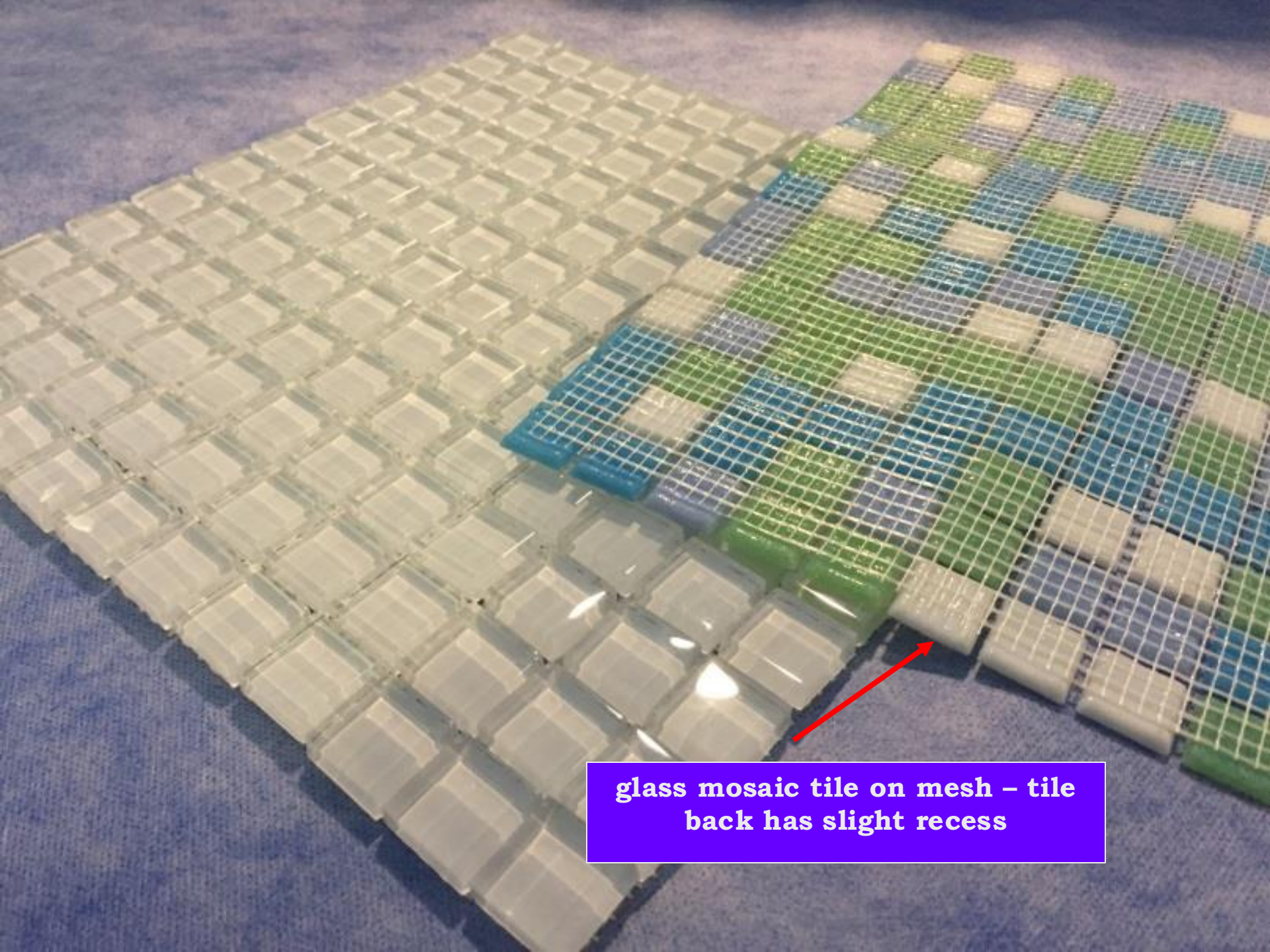
Integrity between back-netting and the marble

Glue Residue from Back-Netting

Tiles - Different Types of Back-netting



The tile adhesive will not be in direct contact with the tile back surface.


glass mosaic tile on mesh – tile back has slight recess

Agglomerates : Warped & Cracked after Floor Already in Service

Possible causes:

i) Expansion in the stone

ii) Shrinkage in the substrate

Agglomerates: Warped & Cracked After Floor Already in Service

Solution: ***Allow a wider joint to accommodate expansion.***

NB: Ensure that screed is cured and with low moisture residual content before stone installation.

Agglomerates: Warped After Floor Already in Service

Solution: ***Allow a wider joint to accommodate expansion.***

NB: Ensure that screed is cured and with low moisture residual content before stone installation.

Warped Stone After Installation

Recommendation for restrained surfaces:

Gap between last marble and aluminum door frame to be sealed with sealant (restrained surfaces).

Complaint - Adhesion Failure

- Potential debonding with Back-sealing application

Caution

- Water-beading"

- Sealer Residue on the back of the marble

Quality Inspection

- Hollowness
  - No hollow sound when tapped

Quality Inspection

- Hollowness
  - No hollow sound when tapped with CONQUAS rod

Complaint - “Hollow” Sound

- Tiles set on concrete slab over large open area
  - Acoustical effect rather than bonding problem
- Air void in either setting bed or slab, causing one part to sound differently from another
  - Tile to be properly laid

Installation Method : Using Steel Notched Trowel

Installation Method : Back-buttering

Complaint - “Hollow” Sound

- Separation or waterproofing membrane installed between slab and bedding material
  - Acoustical effect rather than bonding problem
- Elevation of subsurface is irregular, causing one part to sound differently from another
  - Tile to be properly laid

Conclusion

- Good tiling works should be achieved by Doing It Right the First Time
- Ensure quality during design and installation instead of doing rectification works