



THE TILE
ASSOCIATION

Adhesives and Grouts In Internal Tiling

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1. Foreword

A Technical Working Group of the Tile Association has prepared the paper “Adhesives and Grouts in Internal Tiling”.

The paper has been written with the aim of providing advice for all parties in the process of undertaking tile fixing projects and should be read in conjunction with current and forthcoming British, European and International Standards.

The Tile Association acknowledges the support given by members of the Working Group, Adshead Ratcliffe and Ceram in the drafting of this document.

2. Scope

Every tiling project requires adhesive and grout. This document sets out to provide an explanation of the purpose of adhesive and grout and advice on how to ensure a successful tiling project by using the correct adhesive and grout in the correct situation.

The scope of the document includes ceramic tiles, natural quarried stone and resin agglomerate. The document excludes external tiling.

3. Adhesive

Definition

An adhesive is a compound that adheres or bonds two surfaces together. In the case of ceramic and natural stone tile adhesives, there are three main product types:-

1. Dispersion Adhesives – These are designated Type D adhesives complying with BS EN 12004 and consist of a mixture of organic binding agent(s) in the form of an aqueous polymer dispersion, organic additives and mineral fillers. These pre-mixed products are ready to use for the fixing of wall tiling but since they set, harden and develop adhesion by drying at least one surface being adhered to must be absorbent. The maximum bed thickness is normally 3mm.

2. Cement Based Adhesives – These are designated as Type C adhesives complying with BS EN 12004 and are described as a mixture of hydraulic binding agent, aggregates and organic polymer additives. These adhesives are mixed with water or aqueous admixtures just before use, the cement component reacting with water so that the adhesive sets, hardens and develops adhesion. Generally suitable for both wall or floor tiling and available with normal or rapid setting/hardening properties and the hardened adhesive can be resistant to water, frost, etc. The adhesive bed thickness is normally 3mm but application at a bed thickness greater than 6mm is possible with some products. Cementitious adhesives are available in grey or white and can develop adequate adhesion without having to dry.

3. Reaction Resin Adhesives – These are designated as Type R adhesives complying with BS EN 12004 and consist of a mixture of synthetic resin, mineral fillers and organic additives in which hardening occurs by chemical reaction. Normally supplied as two pre-gauged components which are to be mixed together to produce the adhesive. The adhesive sets by chemical reaction initiated when mixing these

components together. Often one of the components contains a chemical resin e.g. epoxide, the other a hardener (curing agent).

Why use adhesives?

Proprietary manufactured adhesives have several advantages over the use of traditional cement/sand mortar for the fixing of ceramic and natural stone tiles. For example:

- They are easier to apply than cement/sand mortars
- They are easier to mix 'on-site'.
- Fast track fixing of tiles can be achieved with fast setting adhesives.
- The fixing of ceramic tiles and natural stone inherently faster, using proprietary adhesives.
- Consistency of the adhesive mix and its reproducibility is assured.
- The drying shrinkage is 'controlled' by specialist additives incorporated into the adhesive formulation and is therefore significantly lower than normal cement/sand mortar.
- The controlled drying shrinkage of proprietary adhesives reduces the risk of crazing with thinner tiles.
- The use of polymer technology incorporated into the adhesive widens its application parameters e.g. the adhesive can be used on an impervious background as well used for the fixing of porcelain tiles.
- The need for pre-soaking the tiles is eliminated.
- The general physical and mechanical strength of a proprietary adhesive is improved compared with cement; sand mortars.

Adhesive Classification

BS EN 12004:2007 – Adhesives for Tiles – Requirements, evaluation of conformity, classification and designation applies to ceramic tile adhesives for internal and external tile installations both for walls and floors.

This terms and definitions of this standard apply to dispersion (ready mixed), cementitious and reaction resin based adhesives and classify these adhesives as follows, based upon the test criteria outlined in this standard, using relevant adhesive test methods :-

Fundamental Characteristics

These characteristics outline the fundamental requirements within BS EN 12004 which a good quality ceramic tile adhesive must have. The following table illustrates these fundamental characteristics for each of the differing types of ceramic tile adhesive:

Table 1- Fundamental Characteristics for Dispersion (Ready-mixed) & Reaction Resin Tile Adhesives

Fundamental Characteristics	Dispersion (D)	Reaction Resin (R)
Initial shear adhesion strength	√	√
Shear adhesion strength after heat ageing	√	-
Shear adhesion strength after water immersion	-	√
Open time: tensile adhesion strength (20 mins.)	√	√

Table 2 – Fundamental Characteristics for Cementitious Tile Adhesives

In the case of cementitious based adhesive, the adhesive may be classed as Normal Setting or Fast Setting.

Fundamental Characteristics	Cementitious (C)	Cementitious (C)
	Normal Setting	Fast Setting
Initial tensile adhesion strength	√	-
Tensile strength after water immersion	√	√
Tensile strength after heat ageing	√	√
Tensile strength after freeze-thaw cycles	√	√
Early tensile adhesion strength	-	√
Open time: tensile adhesion strength (10 mins)	-	√
Open time: tensile adhesion strength (20 mins.)	√	-

Additional (Optional) Characteristics

Additional characteristics outline those requirements within BS EN 12004 for adhesives have enhanced levels of performance under specific service conditions. The following table illustrates those enhanced performance criteria for the different types of ceramic tile adhesive:

Table 3 – Additional Characteristics for Dispersion (ready-mixed) Cementitious & Reaction Resin Tile Adhesives.

Additional Characteristics	Dispersion (D)	Cementitious (C)	Reaction Resin (R)
Adhesion strength after water immersion	√	-	-
Adhesion at elevated temperatures	√	-	-
High Initial tensile adhesion strength	-	√	-
High tensile strength after water immersion	-	√	-
High tensile strength after heat ageing	-	√	-
High tensile strength after freeze-thaw cycles	-	√	-
Extended open time: tensile adhesion strength	√	√	-
Slip	√	√	√
Shear adhesion strength after thermal shock	-	-	√

The Classification and designation of tile adhesives as outlined in BS EN 12004 is as follows:

C = Cementitious
D = Dispersion (Ready mixed)
R = Reaction Resin

Tile Adhesive Classes

1 = Normal adhesive
2 = Improved adhesive (meets the requirements for additional characteristics)
F = Fast setting adhesive (cementitious only) achieves 0.5 N/mm² in 6 hr.)
T = Non slip (walls)
E = Extended open time i.e. > 30 minutes (for cementitious and dispersion adhesives only)

Examples:

D1T = Normal dispersion adhesive with reduced slip

D2T = Improved dispersion adhesive with additional characteristics and reduced slip.

C1T = Normal cementitious adhesive with reduced slip

C2TE = Improved cementitious adhesive with additional characteristics, reduced slip and extended open time.

In addition to the above criteria, found in BS EN 12004:2007 – Adhesives for Tiles – Requirements, evaluation of conformity, classification and designation may also be classified according to BS EN 12002 The determination of the transverse deformation for cementitious adhesives and grouts. This standard defines two classes

- S1 - Deformable adhesive with a transverse deformation ≥ 2.5 mm < 5 mm
- S2 - Highly deformable adhesive with a transverse deformation ≥ 5 mm

Example: C2FTE, S1 - Improved tensile adhesion, rapid setting, non-slip, extended open time with greater than 2.5mm deformability, but less than 5mm

New adhesive products or adhesives where the formulation has been changed are required by the standard to be independently tested using an accredited European Test House. The standard also sets out a defined frequency of testing for existing adhesive products to be tested 'in-house' i.e. by the manufacturer.

4. Grout

Definition

A grout is either a mortar (basic components cement, sand and water) or a proprietary material that is designed and used for filling the joints and cavities found between pieces of masonry, ceramic or natural stone tiles.

Why use Grout?

There are various forms of movement which, experience has shown may be set up within tiling systems which if not properly controlled can sometimes result in de-bonding, cracking or "tenting" (bulging) of tiles. These forms of movement are referred to in the TTA document "Movement Joint in Internal Tiling" and BS 5385: Part 4, the code of practice for tiling and mosaics in specific conditions.

BS 5385 the codes of practice for wall and floor tiling recommends that tiles are not butt-jointed together. Where tiles are in contact with each other, this will increase further the effects of any stress built up within the tiling layer where movement exists or may be anticipated e.g. Partition walls. The tiled surface thus becomes more rigid as tiles are "forced" together.

Leaving a suitable width of joint between tiles and filling these joints with a suitable grouting material enables localised stress relief to occur and when combined with the use of adequate movement joints, will reduce the risks of any problems occurring.

Grouts effectively fill the voids between ceramic or natural stone tiles, providing resistance to water penetration and preventing debris such as dirt, dust from filling the gap.

As well as the practical functionality, correct use of modern proprietary coloured (pigmented) grouts in conjunction with the vast ranges of tiles available will provide an aesthetically pleasing, durable, hard wearing and practical decorative surface finish.

When installed correctly, good quality tiles, adhesives and grouts should give years of trouble free service and under normal conditions will require minimal maintenance.

Further advice on suitable methods for cleaning tiles may be found in the TTA Document "The Cleaning of Ceramic Tiles".

Types of Grout

There are commonly three main "chemical types" of proprietary wall and floor grouts available

*Dispersion** – A pre-mixed dispersion of water based polymers, typically acrylic, mineral fillers and organic additives designed predominantly for use for the filling of wall tile joints.

Note: * Dispersion based grouts fall outside of the scope of BS EN 13888 Grouts for tiles – Definitions and specifications.

Cementitious (Cement based) – Powdered grout consisting of a cement binder, aggregate and powdered additives (including polymers). These grouts are suitable for use in both wall and floor tiling and are available in a wide range of colours.

Reaction resin based – A specially formulated grout consisting of a resin, typically epoxy resin and a curing agent. These grouts are generally impervious to water, have good resistance to a wide variety of chemicals and are easy to clean and maintain hygienically. Suitable both for walls and floors.

Grout Classification

BS EN 13888: 2002 – Grouts for tiles – Definitions and Specifications applies to ceramic tile grouts for internal and external tile installations both for walls and floors.

This terms and definitions of this standard apply to cementitious and reaction resin based grouts and classifies these grouts as follows, based upon the test criteria outlined in this standard, using relevant grout test methods :-

Cement Based

CG1 – Normal cementitious grout with fundamental characteristics such as abrasion resistance, flexural and compressive strengths when subjected to dry storage/ freeze-thaw cycles as well as water absorption measured over time.

CG2 – Improved cementitious grout, typically highly polymer modified cementitious grouts with additional characteristics such as reduced water absorption and higher abrasion resistance.

Cement based grouts can also be broadly divided into narrow joint (typically for walls) and wide joint for wall/floor application.

Narrow joint grouts are typically used for filling tile joints between 1-3mm in width. Wide Joint grouts are generally suitable for filling tile joints at widths greater than 3mm.

Reaction Resin

RG – Reaction resin grout, with measured characteristics such as abrasion resistance, flexural and compressive strengths after dry storage, shrinkage and reduced water absorption.

5. Design Considerations

5.1 Size of Tile

Ceramic tiles are available in a wide range of sizes ranging from small mosaics e.g. 25 x 25 mm through 100 x 100mm, 150 x 150mm, 152 x 152mm, 200 x 100mm, 250 x 125mm, 200 x 200mm to 300 x 300mm or larger. **A large format tile would arbitrarily be deemed to be of a typical size of 300 x 300mm or greater.** Ceramic tiles must meet the requirements of BS EN 14411.

In the case of natural stone, BS EN 12057: 2004 “Natural Stone Products – Modular Tiles – Requirements” specifies the requirements for flat modular tiles of natural stone. Modular tiles under this standard are defined as “Flat pieces of natural stone squares or rectangular, nominally ± 610 mm obtained by cutting or splitting at a nominal thickness ≤ 12 mm”.

5.2 Choice of Adhesives and Grouts for Service Conditions

The choice and suitability of the correct tile adhesives and grout are dependant upon factors such as size and type of tile (as designated by BS EN 14411), the nature of the substrate to which the tiles are to be fixed and the service conditions i.e. the nature of the prevailing conditions under which the tiling will be exposed throughout the service life of the particular tiling installation.

The following table is designed to offer general guidance for the correct selection of adhesives as defined in BS EN 12004:2007 – Adhesives for Tiles – Requirements, evaluation of conformity, classification and designation and grouts as defined in BS EN 13888: – Grouts for tiles – Definitions and Specifications.

Wall tiling in wet duty or external locations and all floor tiling should be carried out in a 3-6mm solid bed of adhesive ensuring that as far as reasonably practicable voids are eliminated beneath the tiles

Recommended Adhesives *

* Note 1: Dependant upon the substrate to receive tiling and tile type conforming to BS EN 14411

Common Service Conditions	Dispersion Based (Ready mixed)	Cement Based	Reaction Resin	Further Reference
Pool Tank Base	N/A	C2, C2E, C2F, C2T	R2, R2T	BS 5385: Part 4 & TTA Document "Design and Construction Process for Swimming Pools".
Pool Tank Walls	N/A	C2T, C2TE, C2FT.	R2, R2T	BS 5385: Part 4 & TTA Document "Design and Construction Process for Swimming Pools".
Internal Dry Walls	D1, D1T, D2, D2T, D2TE,	C1T, C1FT, C2T, C2TE, C2FT.	R1T, R2T	BS 5385: Part 1
Internal Dry Floors	N/A	C1, C1T, C1F, C1FT, C2, C2E, C2F, C2T, C2FT.	R1, R2	BS 5385: Part 3
Occasional Wetting (Domestic) Showers Walls	DIT **, D2T, D2TE	C1T, C1FT, C2T, C2TE, C2FT.	R1, R2	BS 5385: Part 4
Occasional Wetting (Domestic) Showers Floors	N/A	C1T, C1FT, C2T, C2TE, C2FT.	R1, R2	BS 5385: Part 4
Communal Shower Walls	D2T, D2TE	C1T, C1FT, C2T, C2TE, C2FT.	R1, R2	BS 5385: Part 4
Shower Floors	N/A	C2, C2E, C2F, C2T	R1, R2	BS 5385: Part 4
Heated Screed Floors	N/A	C2, C2E, C2F, C2T	N/A	BS 5385: Part 4 & TTA Document "Tiling to Heated Floors".
Minor Vibration - Walls	D2T, D2TE	C2T, C2TE, C2FT	R1, R2	BS 5385: Part 4
Heavy Trafficking - Floors	N/A	C2, C2E, C2F, C2T	R1, R2	BS 5385: Part 3

** Note 2: Refer to the individual manufacturer's recommendations

Common Service Conditions	Cement Based	Reaction Resin	Further Reference
Pool Tank Base	CG2 For Hard Water only (> 200mg/l expressed as CaCO ₃)	RG For Hard or Soft water (lower Calcium levels).	BS 5385: Part 4 & TTA Document "Design and Construction Process for Swimming Pools".
Pool Tank Walls	CG2 For Hard Water only (> 200mg/l expressed as CaCO ₃)	RG For Hard or Soft water (lower Calcium levels).	BS 5385: Part 4 & TTA Document "Design and Construction Process for Swimming Pools".
Internal Dry Walls	CG1 or CG2	RG	BS 5385: Part 1
Internal Dry Floors	CG1 or CG2	RG	BS 5385: Part 3
Occasional Wetting (Domestic) Shower Walls & Floors	CG1 or CG2	RG	BS 5385: Part 4
Communal Shower Walls	CG1 or CG2	RG	BS 5385: Part 4
Shower Floors	CG1 or CG2	RG	BS 5385: Part 4
Heated Screed Floors	CG2		BS 5385: Part 4 & TTA Document "Tiling to Heated Floors".
Minor Vibration - Walls	CG2	RG	BS 5385: Part 4
Heavy Trafficking - Floors	CG2	RG	BS 5385: Part 3

5.3 Weight Considerations for Wall Tiling

The maximum weight of tiling which can be supported by a dry, well-adhered plaster background is 20kg/m². This is equivalent to ceramic tiles with a maximum thickness of 8mm or natural stone tiles with a maximum thickness of 7mm

The weight of tiling to a plasterboard background direct (without plaster skim) should not exceed 32kg/m². This is equivalent to a ceramic tile adhesive with a maximum thickness of 12.5mm and natural stone with a maximum thickness of 10mm.

The weights quoted includes both the tile and adhesive

Further advice should be sought either from the manufacturer, regarding the suitability of the adhesives and grouts and also guidance must be sought from the board manufacturer regarding additional information on recommended methods for the installation of these boards.

The following table offers general guidance to some common types of building board and the maximum recommended weights for tiling.

Wall Substrates	Maximum Weight of Tiling per m ²
Gypsum Plaster	20Kg/m ²
Gypsum Plasterboard Direct (without a plaster skim)	32Kg/m ²
Plywood (WBP)	Up to 30Kg/m ²
Lightweight Tilebacking Boards*	Up to 40Kg/m ² . Dependant upon the type and thickness of the board.
Glass reinforced Cement Sheets*	Up to 50kg/m ² , Dependant upon the type and thickness of the board.
Gypsum Fibre boards*	Approximately 35- 40Kg/m ²

5.4 Selection of Adhesive for the Fixing of Large Format Tiles

A suitable adhesive should be selected which conforms to BS EN 12004:2007 – Adhesives for Tiles – Requirements, evaluation of conformity, classification and designation. The selection of the adhesive will also be dependant on factors such as:

- The type of tile selected
- The nature and type of substrate to which the tiles are to be fixed
- The service conditions to which the tiling will be exposed.

For larger format tiles, (typically 300mm x 300mm or greater) use of a pourable i.e. lower viscosity adhesive will be advantageous in achieving a solid bed. Further advice however should be sought from the manufacturer to confirm their suitability.

5.5 Fix and Grouting Products

Proprietary dispersion (ready mixed) for combined fixing and grouting are available in the UK and are aimed primarily at the D.I.Y market for domestic use only. It should be noted that the properties of both adhesives and grouts differ, therefore combined “fix and grout” products offer a compromise not fulfilling all the specific requirements of the adhesive or grout. Further advice on their use should be sought from the manufacturer.

5.6 Physical Properties of Grouts

BS EN 13888 Grouts for tiles – Definitions and specifications was introduced for the purpose of characterising and defining cement based or reaction resin grouts and their ability to accommodate stresses that they can be subjected to within a tiling installation. The additional or special characteristics, which are highlighted in this standard, are intended to take into account certain climatic and environmental factors which may be detrimental to the grout's performance.

5.6.1 Compressive Strength

In building structures, construction backgrounds will contract upon drying out and setting. Therefore in wall and floor tiling installations, where tiles are fixed using adhesives this will result in the generation of stresses e.g. compression (or squeezing) which will affect the tile finish and cause a weakening of the adhesion bond. Where the grout is rigid i.e. it has no polymer additive, any stress will affect the weakest point which is the bond between grout and the tile edge resulting in the grout debonding from the tile edge. The physical properties of the grout therefore should be increased to cope with this movement through the introduction of powdered polymers to improve adhesion and deformability. The compressive strength of the grout may also be modified by varying the cement content and the blend of fillers or aggregates used.

Compressive strength of both cement based and reaction resin grouts are defined as a fundamental grout characteristic in this standard, and tested in accordance with the method outlined in EN 12808-3: 2002 Grout for tiles – Determination of flexural and compressive strength, under the following conditions :

- After dry storage - conditioning at 27 days at $(23 \pm 2) ^\circ\text{C}$ and $(50 \pm 5) \%$ Relative Humidity
- After freeze thaw cycles – 6 days conditioning as above, followed by 21 days immersed in water, before subjecting to 25 freeze thaw cycles i.e. wet/freezing/wet etc.:

In both cases compressive strength, is a fundamental characteristic (requirement) for the grout and must be

$\geq 15 \text{ N/mm}^2$ * ($\geq 2176 \text{ psi}$) – For cement based.

$\geq 45 \text{ N/mm}^2$ * ($\geq 6534 \text{ psi}$) – For reaction resin.

*** Note: Average values for compression strengths for cementitious grouts are expected to fall typically between 20 – 40 N/mm².**

5.6.2 Flexural Strength

The flexural strength of a grout is a measure of the ability of a grout to withstand bending and is measured in terms of stress i.e. the maximum force at the point of failure upon application of a 3 point load.

Under BS EN 13888, flexural strength, is also a fundamental characteristic (requirement) and for grouts must be

$\geq 3.5 \text{ N/mm}^2$ ($\geq 508 \text{ psi}$) – For cementitious after both dry storage and freeze-thaw cycling.

$\geq 30 \text{ N/mm}^2$ ($\geq 4356 \text{ psi}$) – For reaction resin after dry storage only.

5.6.3 Transverse Deformation for Cement Based Adhesives and Grouts

The determination of the transverse deformation for cementitious adhesives and grouts may be found in BS EN 12002. In simple terms this is a measurement of by how much the adhesive or grout under test is able to deform when subjected to a 3-point bending load. Deformation occurs from the horizontal plane and is measured in mm.

Both cement based adhesives and grouts are defined according to the measured value for the transverse deformation as:

S1 $\geq$ 2.5 mm and $<$ 5 mm. (deformable)

S2 $\geq$ 5 mm (Highly deformable).

6. Applying adhesive

6.1 Adhesive Application Tools

6.1.1 Gauging Trowel

Ideally square or rounded profile, gauging trowels are designed for the mixing of cementitious or reaction resin adhesives. In addition to its use as a tool for mixing, the trowel is used to transfer the adhesive from its container onto the spreading trowel or to transfer the adhesive directly onto the floor to be tiled.

6.1.2 Drill with Mixing Paddles

This method is recommended for use with cementitious based adhesives. Particularly suitable for larger adhesive mixes i.e. where large areas of tile fixing is required. Blending the adhesive powder with water and /or a proprietary polymer admixture with the drill speed set to the slow setting is recommended e.g. $<$ 300 r.p.m. This is especially important with rapid setting adhesives as the generation of additional heat via friction during mixing on higher speeds will 'speed up' the chemical reaction within the cement, potentially resulting in a significant reduction in the working time i.e. a reduction in pot life and application time.

6.1.3 Adhesive Spreading Trowels

Spreading tools (known as 'trowels') are usually supplied for application of tiles adhesives for both Floor and Wall applications. The main purpose of the trowel is to transfer the adhesive from the mixing vessel or container onto the substrate to be tiled, and spreading the adhesive to achieve the required coverage.

Selecting the right trowel for each installation is vital to ensure that the required coverage of adhesive is achieved, as recommended in BS 5385 Parts 1-5, the code of practice for the fixing of floor and wall tiles.

6.1.3.1 Proprietary Trowel Types

6.1.3.2 Floor Trowels

Solid-Bed Trowel

This trowel is recommended for solid bed fixing of floor tiles, but may also be used for larger wall tiles, typically greater than 300mm x 300mm. Used correctly, the adhesive transferred and the pattern created should ensure 100% coverage at a depth of 3-4mm when the tile is compressed into the adhesive. The trowel is ideal for irregular backgrounds or tiles with recessed or keyed back patterns.

Large Format Trowel

These trowels are longer than the Solid-Bed trowel and usually have deeper notches. This makes the adhesive profile produced particularly suitable for the installation of large format tiles, typically greater than 300mm x 300mm. It also enables relatively quick application of the adhesive over large areas.

Specialist Solid-Bed Trowels

There are other proprietary trowel types available for use with tile adhesives. For example trowels which provides a uniform bed of adhesive, topped with ribs into which the tiles can be fixed, i.e. giving a solid bed, solid surface of adhesive.

6.1.3.3 Wall Trowels

6mm Notched Trowel

Suitable for the application of adhesive for wall tiles in dry interior locations for most ceramic, marble and natural stone wall tiles. The expected adhesive coverage provided by these trowels will be approximately 70%. The final achievable bed depth of adhesive is generally 2-3mm.

N. B The minimum recommended adhesive coverage for internal dry walls, using the notched trowelling method, once the tile is placed into the adhesive ribs is stated in BS 5385: Part 1 and is 'an area of contact of at least 50%, spread evenly over the back of the tiles.'

Solid-Bed Trowel

Designed for use on wall surfaces to enable the solid-bed fixing of most ceramic, marble and natural stone tiles. Typically used with tiles, sizes less than 300mm x 300mm. This trowel is ideal for use in internal wet areas as well as other areas where specific service conditions will prevail and full contact between the adhesive and tile is required, such as in hygiene areas e.g. food preparation areas, where tiles are to be subjected to a limited amount of movement or vibration e.g. industrial plant applications etc. Used correctly, these trowels are designed to achieve full coverage as far as reasonably practical at a depth of 2-3mm.

Mosaic Trowel

Proprietary Mosaic trowels, with 3-4mm notches are designed for use on wall and floor surfaces to enable the thin-bed solid-bed fixing of mosaics of a smaller size, typically 10mm x 10mm. Used correctly, it will achieve 100% coverage at a depth of approximately 2mm

6.2 Mixing of Adhesives

6.2.1 Dispersion Adhesives

The adhesive is manufactured and supplied in a ready to use form and requires no additional mixing on site. The adhesive should be of a smooth lump-free, creamy paste.

6.2.2 Cementitious Based Adhesives

Add the required amount of clean cold water to a clean mixing bucket. The correct ratio of powder adhesive is now added, as recommended by the adhesive manufacturer on their packaging instructions.. With the use of the chosen mixing tool, mix until the adhesive no longer slides from the surface of the tool used. Mix until a lump free paste is formed.

Reaction Resin adhesives

Add the components in the order as recommended by the manufacturer. Mix until a smooth lump-free mix of uniform colour is achieved. Further reference to the manufacturer's mixing instructions should be made for the recommended resin/hardener/filler ratios. Avoid air entrainment by over-mixing.

6.3 Application of the Adhesive

- Before applying the mix or pre-mixed tile adhesive, ensure that the wall and floor substrates to be tiled is free from dust, oil grease, laitance and all other forms of contamination which are incompatible with the adhesive.
- The substrate should be sufficiently flat enough to receive a tiled finish as recommended in BS 5385: Part 1 and Part 3. For thin bed adhesive application, when checked with a 2m straightedge, the gap underneath the straightedge should not exceed 3mm. (SR1).
- Tile adhesives should not be applied in temperatures less than 5°C or in damp conditions.
- Commence by using the gauging trowel to 'load' the required spreading trowel with adhesive.
- Holding the spreading trowel at an angle of greater than 45° to the wall or floor substrate. Spread the adhesive out over the area to be tile. It is good practice to spread no more adhesive than can be tiled within 20 minutes at any one time.
- For improved adhesion to porous substrates, a skim coat of the adhesive may be applied, using the flat edge of the trowel, before combing fresh adhesives onto the wet skim coat. Alternatively apply a suitable proprietary priming agent as recommended by the adhesive manufacturer.

- It is important to maintain the ribs in one direction, which helps to prevent air becoming trapping between the tiles, thereby creating a void behind/beneath the tiles.
- Press/push tiles firmly into position with a slight twisting/sliding action ensuring that the correct contact area is achieved between the adhesive and each tile, dependant upon the type of spreading trowel used.
- Periodically check to ensure the correct coverage of adhesive has been achieved by lifting a tile. Remove the initial bedding material, butter the back of the removed tiles with fresh material and re-fix.
- Allow the adhesive bed to dry as per the manufacturer's recommendations before the commencement of grouting.

6.3.1 Use of Admixtures with Cementitious Based Adhesives

The use of powder polymer technology in proprietary cementitious based adhesives, enhance the physical and mechanical properties of the adhesive as well as widen their application. C2 adhesives in general have higher polymer levels and can be found in the following forms;

1. A single component powder – Requiring mixing with water only in the quantity recommended by the manufacturer. These adhesive types are available for both wall and floor tiling. Pourable grades are also available for floors
2. Liquid polymer admixture/ cementitious adhesive powder – Enhanced physical and mechanical properties can be gained by the addition of a proprietary synthetic polymer emulsion additive to the adhesive powder. The admixture may be supplied 'ready for use' or may require dilution with water, in accordance with the manufacturer's recommendations. They are commonly used to improve the performance of C1 adhesives.
3. Two component adhesives combining cementitious powder and a synthetic polymer liquid admixture. The admixture in this case is essential in order to ensure the adhesive meets the requirements of BS EN 12004: 2007 and is fit for purpose.

7. Grouting process

7.1 Grouting Tools

7.1.1 Gauging Trowel

Ideally square or rounded profiled gauging trowels are preferred as these are designed for the mixing of cementitious or reaction resin grouting material within a suitable clean mixing vessel e.g. a bucket or the original grout container.

7.1.2 Grout Floats/Squeegees

The basic commercially available rectangular shaped grout float comprises a relatively soft rubber based pad bonded to a base with a handle attachment. The soft rubber is particularly suitable for cementitious based grouts for spreading the grouting material into the tile joints. The shorter edges are used mainly where grouting in confined spaces.

Hard rubber grout floats are also available and are particularly suitable for use with epoxide based and dispersion grouts.

Grout squeegees are a more cost effective version of a grout float and are mainly used for walls and also for confined areas.

7.1.3 Sponges

Hand sponges are generally used for cleaning and removal of grout from the surface of the tiles without removing excess grout from between the tile joints. Sponge boards, comprising a sponge bonded to a handle attachment. Sponge boards are recommended for cementitious based grouts as they will have a more limited life span when used for removing epoxy based grouts.

7.1.4 Proprietary Wash Buckets

Proprietary buckets with rollers are available. These are designed to facilitate easier cleaning of grout from the tile surface by removing excess water from the sponge board.

7.1.5 Drill with Mixing Paddle

This method is recommended for use with cementitious based grouts only. Particularly suitable where large areas of grouting are required where a grouting "team" is employed. Blending grouts with the drill speed set to the slow setting is recommended e.g. < 300 r.p.m.

7.1.6 Emulsifying Pad

A pad manufactured from abrasive plastic used to facilitate ease of cleaning off of resin based grouts e.g. epoxy as well as dispersion grouts. Certain manufacturers "colour code" the pads, dependant upon how abrasive they are. Generally it is recommended that a mildly abrasive pad is used. These pads may not be compatible with some types of tiles e.g. soft decorative glazes or those with a metal décor or lustre.

7.2 Tile Considerations Prior To Grouting

7.2.1 Protection of Tiles from Staining

Ceramic tiles vary due to composition, type nature of the surface texture and finish, tile size and use. Surface porosity (e.g. micro-porosity) of certain ceramic and natural stone tiles can result in the potential for these tiles to stain, particularly when a pigment grout is to be applied.

When deciding whether or not to apply coloured grouts to tiles that may be susceptible to retaining particles of pigment, it is recommended to check for the potential risk of staining by applying the grout to a few unused tiles before grouting commences.. If discolouration occurs seal the tile surface with a suitable proprietary temporary tile sealer or impregnating tile sealer (permanent) and repeat the trial.

The number of coats of sealer required will depend upon the nature and degree of porosity and further advice must be sought from the manufacturer of the tile sealer. Recommendations for appropriate type of sealer required may be obtained from the tile manufacturer.

7.2.2 “Picture Frame” Staining of Tiles

Water staining of tiles can occur due to the drawing in of liquids e.g. water and/or in fines materials through the grout joints causing a picture framing effect around the tile, particularly with very porous tiles.

This will normally affect very porous tiles or tiles that have a translucent, glaze finish.

To prevent the water penetration the use of a waterproof (impervious) grout is recommended e.g. reaction resin to BS EN 13888 class RG. Therefore, the most effective remedial measure with the least amount of disruption would be to rake the joints out to the full depth of tile and adhesive, ensuring that the edges of the tiles are thoroughly cleaned and the existing grout is totally removed. This is done in order to prevent tracking of water down the side of the tile.

Once raking out has been completed the tiles should be thoroughly cleaned prior to the joints being re-grouted using an impervious grout e.g. Reaction Resin grout such as an epoxide, to BS EN 13888, classification RG .

The grout must be fully compacted into the joints and the grout joint kept as high as is practicable, in order to allow the grout to totally cover the glazed edge of the tile. If this process is carried out correctly, then this should prevent water ingress into the body of the tile.

On completion of the re-grouting for wet duty installations such as a shower, suitable period of drying out should be allowed, e.g. typically a minimum 7 days following a “re-grout” to ensure that the grout has fully cured prior to putting the shower back into service. Further advice on a suitable drying period for the grout should be obtained from the manufacturer.

Where the shower is newly tiled, allow a minimum of 14 days before putting the shower into use, as recommended in BS 5385: Part 4 the code of practice for tiling and mosaics in specific conditions, in clauses 6.3 paragraph (f) and 6.4 Paragraph (h).

7.2.3 Scratching of Tiles

Care should always be taken during installation, particularly when grouting, to avoid scratching the glazed surface. Soft decorative hand made tiles and tiles with a metal décor or lustre in particular are at greater risk.

Narrow joint grouts, primarily designed for the filling of joints between wall tiles contain finer particle size fillers, making them as a general rule less abrasive. Wide joint grouts have coarser particle size “quartz” type fillers and are therefore not recommended for use with the tile types mentioned above. If practicable it may be possible to carry out an on-site test on a few unused tiles, to assess the compatibility of the grout and tile surface. However if any doubts exist, further advice should be sought from the tile manufacturer.

To reduce the abrasiveness of the grouting process further, consideration would need to be given to carefully “pointing” the grout into the tile joints, thus avoiding excessive contact with the tile face.

BS 5385: Part 1, the code of practice for the design and installation of internal ceramic and natural stone wall tiling and mosaics in normal conditions, recommends the use of masking tape adjacent to the tile joints or if the tile has a protective face, leave in place until grouting has been completed in order to protect soft glazes. It is important to first ensure that the grout float is clean, i.e. free from any hard grout residues.

7.3 Mixing of Grouts

7.3.1 Dispersion Grouts

These grouts are supplied ready to use from the container. The material inside should be a smooth lump-free creamy paste.

7.3.2. Cement Based Grouts

Add the powder to clean, potable, cold water until a lump free smooth paste of uniform colour is achieved. Further reference to the manufacturer's mixing instruction should be made for the recommended powder to water ratio. Avoid air entrainment by over-mixing or drill mixing at too high a speed.

7.3.3 Reaction Resin Grouts

Add the components in the order as recommended by the manufacturer. Typically reaction resin grouts comprise:

- Resin
- Curing Agent (hardener)
- A pre-blended proprietary filler

Mix until a smooth lump-free mix of uniform colour is achieved. Further reference to the manufacturer's mixing instructions should be made for the recommended resin/hardener/filler ratios. Avoid air entrainment by over-mixing.

7.4 Application of Grout

7.4.1 Cementitious Based Grouts

- Ensure that the joints between the tiles are at least 6mm deep (or the depth of the tile if less), and are free from all loose dust and debris.
- Following mixing of the grout, carefully transfer a portion of the grout, using a gauging trowel onto a suitable soft rubber grout float or rubber squeegee.
- At a convenient point, apply the grout across the surface of the tile with the grout float, ensuring that the grouting material fills the joint fully and is compacted well.
- Work in small approximately equal areas, corresponding to approximately 15 minutes of application time. Ensure that excess grout is removed from the tile face using the grout float as work proceeds. At this stage direct the float diagonally across the tiled surface to avoid removing grout from the joints.
- Using a suitable *damp* sponge or sponge board, remove the remaining residues of grout from the tiles, directing the sponge diagonally across the face of the tiles.

- Rinse out the sponge thoroughly in clean, cold water. Ensure that as much water as possible is squeezed out of the sponge. Use of proprietary wash buckets in conjunction with a sponge board will facilitate this.
- Lightly direct the sponge or sponge board in line with the grout joints.
- Finally, once the grout has sufficiently set in the joints, use a clean lint free cloth to polish the tile surface.

7.4.2 Use of Admixtures with Cementitious Based Grouts

Increasing the levels of polymer within proprietary cementitious grouts will enhance the physical and mechanical properties as well as increasing the range of application. In the case of CG2 classified grouts to BS EN 13888, these contain pre-blended polymer enhance performance. Alternatively CG1 classified grouts to BS EN 13888 may be modified by addition of a liquid polymer dispersion, as recommended by the grout manufacturer. Further advice on recommended dilution rates and mixing instructions should be sought from the manufacturer.

Where elevated temperatures exist on-site i.e. above 20°C, highly polymer modified cementitious based (CG2) or dispersion grouts will be prone to an increased drying rate during grout application. Therefore in these situations, care should be taken to ensure the grout is removed as soon as is practicable from the tile face. Where circumstances allow, the use of an emulsifying pad may facilitate easier removal of the grout.

Please note that application of and varying the concentration of a liquid polymer dispersion admixture to cementitious grouts will in general impact visually upon the grout by darkening the final colour.

7.4.3 Dispersion and Reaction Resin Grouts

- Ensure that the joints between the tiles are at least 6mm deep (or the depth of the tile if less), and are free from all loose dust and debris.
 - Following mixing of the grout, carefully transfer a portion of the grout, using a gauging trowel onto a suitable hard rubber grout float/squeegee.
 - At a convenient point, apply the grout across the surface of the tile and/or pointing into joints with the hard rubber grout float, ensuring that the grouting material fills the joint fully and is compacted well.
 - Work in small approximately equal areas, corresponding to approximately 15 minutes of application time. Remove as much of the excess off the face of the tiles as possible, by striking the excess off diagonally to the grout lines ensuring the grout is as high as possible in the joints.
 - Within approximately 30 minutes of application, clean off any surplus grout using a proprietary emulsifying pad. This should be dampened with clean cold water to break down (emulsify) the grout residue. Using a circular motion, keep the pad relatively flat to the tile surface to ensure a flush joint. NB do not allow water to flow/run into un-grouted joints.
 - Clean off the emulsified grout residue with a fine sponge, taking care not to drag grout from the joints, always cleaning diagonally to the grout lines.
 - Any remaining haze** on the tile surface must be cleaned off by the next day using an emulsifying pad with a water based alkaline detergent, ensuring all cleaning residues are thoroughly rinsed away using clean water.
- **NB any haze left on the tile surface must be removed within 24 hours

7.5 Application of Grout to Mosaics

7.5.1 Paper-faced Mosaics

Ideally, for paper faced mosaic, the mosaic sheets should be pre-grouted using a suitable polymer modified proprietary grouting material, ensuring that any surplus is removed before fixing commences.

The grout should only be applied on the back of the sheet, removing as much as possible. The sheet should be applied to the adhesive bed and should be tapped into place using a laying on trowel or wooden beater. Offset each sheet ensuring that the horizontal and vertical alignments are checked periodically. Do not grout too many sheets first as the mosaics may de-laminate from the paper.

After fixing firmly into place, remove the paper-face carefully, by soaking and sponging ideally with warm water in order to remove the paper glue, this should be done before the adhesive hardens completely and allowing for any final adjustment to the tesserae. Grouting may then be completed, followed by preliminary cleaning.

Allow the grout to harden sufficiently before washing off the face of the mosaics with clean water and a sponge.

7.5.2 Other Mosaics

The established joint width between the mosaics, as determined by the tesserae must be maintained in order to provide an aesthetically pleasing overall finish.

Grout should be applied as outlined in the recommendations given in 7.4.1 for cementitious based or 7.4.2 for reaction resin based grouts.

7.6 Location of Movement Joints

The following locations for movement joints for wall and floor tiling should be allowed for:

Wall Joints

Movement joints in internal wall tiling should be incorporated as outlined in British Standard BS 5385: Part 1:1995, clause 3.5.2. Briefly, this document requires that joints be located:

- a. Over existing and/or structural movement joints.
- b. Where tiling abuts other materials e.. baths, sinks, shower trays etc, where tiling is continuous across junctions of different background materials.
- c. In large tiled areas, at internal vertical corners and at 3m-4.5m centres horizontally and vertically.
- d. Where stresses are likely to be concentrated, for example at changes of alignment.

Floor Joints

Movement joints in the floor tiling should be incorporated as outlined in British Standard BS 5385: Part 3:1989: Clauses 19 and 23.6. Briefly, this document requires that joints be located

- a. Over existing and/or structural movement joints.
- b. Around the perimeter of the floor and where tiling abuts columns, curbs, steps and plant fixed to the base.
- c. In large floor areas tiles should be divided into bays at 8-10m intervals

On suspended floors the bay size should be reduced and additional joints provided over supporting walls or beams.

Perimeter movement joints for floor tiling and movement joints for wall tiling in general may be filled with a suitable sealant. Dependent on trafficking, any intermediate movement joints may need to be filled with a harder wearing, more durable sealant e.g. epoxy polysulphide or a suitable proprietary pre-formed movement joint strips. Further advice on the application and location of movement joints may be found in the TTA document "Movement Joints in Internal Tiling" and BS 5385 Parts 1 -5 the codes of practice for wall and floor tiling.

7.7 Watchpoints When Installing Grout

There are several factors which can occur both during the application of the grout and resulting from on-site environmental conditions which can influence the consistency of the final achieved colour of cementitious based grout.

7.7.1 Application

- Increasing the water content above the manufacturer's recommendations can lighten the grout.
- Over wetting the joints during the cleaning off process may wash out pigments from the surface and will ultimately lighten the grout.
- Too dry a mix will darken the grout colour.
- Ensure consistent mixes are maintained throughout the duration of the job i.e. grout powder to water or grout powder to water/admixture ratios

7.7.2 Environment Factors

- A lighter grout colour will result in high humidity areas
- Conversely in drier environments, a lighter colour shade will prevail.
On-site conditions may prevail which will encourage the generation of "efflorescence" (see section 7.8)

7.7.3 Tile Types

The colour of the tile and the physical properties of the tile (i.e. porous or non porous can have an effect on the grout material). This is mainly due to the variation in the hydration of the cement in the grout, which ultimately affects the final colour.

- For porous bodied tiles or tiles with a porous edge, full hydration is not achieved, hence the grout can achieve a darker colour

- For vitrified/porcelain tiles, the tile and tile edges are lower porosity, therefore the hydration is more complete, hence the colour will be lighter in comparison.

7.8 Efflorescence

Efflorescence describes a variety of chemical salts i.e. carbonates which can precipitate out into the surface of bricks, tiles, mortars and grouts, triggered by water migrating through a substrate or other structures bringing these salts to the surface. The resulting white deposits is commonly referred to as "efflorescence"

In tiled installations efflorescence usually appears on the surface of the grout and is particularly common in floor tiling applications. Visually this impacts in the form of a whitish stain appearing particularly on highly pigmented floor grouts during the setting or drying out period.

Efflorescence is not damaging to the grout and the effect is purely aesthetic. Factors which can affect the amount of efflorescence produced relates to:

- The amount of water present, the amount of available soluble salts (normally calcium)
- Drying times (which are extended in cooler temperatures). The longer the moisture is present, the greater the chance of salts dissolving in it and permeating to the surface as the mortar and grout dries out.

This phenomena is prevalent in any systems which contains grey Portland Cement.

Efflorescence is usually encountered in new or recent constructions and is often more likely to appear during cooler temperatures, although rising damp through ground floor installations, where provision for a damp-resisting construction is inadequate can also result in this occurring.

BS 5385 Part 3:2007, the Code of Practice for Design and Installation of Ceramic Floor Tiles and Mosaics recognises this phenomena and outlines recommendations for the removal of efflorescence in Section 11 clause 11.3 Cleaning and maintenance.

Efflorescence can be removed by washing with clean water, however these may reappear when drying out. Progressive washings should diminish the effects, but the frequency of washing may need to be further increased until the deposits cease.

Alternatively, where persistent deposits exist, the most effective treatment is to use an appropriate proprietary acidic based cleaner, applied as per the manufacturer's recommendations. Please note that acidic based cleaners are not suitable for certain types of natural stone e.g. Marble, Travertine or Limestone and an alternative cleaner must be sought in this situation.

6. Sources of Reference/Bibliography

British Standards:

BS5385-3:2007 Wall and floor tiling. Code of practice for the design and installation of ceramic floor tiles and mosaics

BS5385-4: 1992 Wall and floor tiling. Code of practice for tiling and mosaics in specific conditions
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BS EN 12004:2007 – Adhesives for Tiles – Requirements, evaluation of conformity, classification and designation
BS EN 13888 Grouts for tiles
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Design & Construction Process for Swimming Pools

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