ReBuild

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Dr. Fixit Institute

of Structural Protection & Rehabilitation

A Not-for-Profit Knowledge Centre

Tiles, Tile Adhesives and Tiling

Tiled surfaces are enjoying a renaissance in building and home renovations. The reasons are not surprising – tiles are not only functional but are also aesthetic. In fact they have several advantages over other decorative finishes for walls and floors. Most types are easy to put up or to lay, especially when it comes to fitting around obstructions by cutting. Because of the wide variety of colours, textures, patterns and styles even within one material, one can create one's individual designs by "mixing and matching". If a localized area is damaged or discolored, it is much easier to replace one or more tiles than to patch a continuous material.

Modern tiles are available in two broad categories : rigid and flexible. Ceramic, terracotta, paving blocks, natural stones including marble are the known varieties of rigid types while vinyl, cork, carpet and lino tiles are the common examples of flexible tiles.

The majority of ceramic wall tiles are 15 or 20 cm square in shape, although other shapes and sizes are also available. Floor tiles are generally larger – typically 30-45 cm square. Ceramic tiles expand slightly for the first few years and are therefore laid with a grout joint of 2-6 mm. Terracotta tiles are suited for both interior or exterior use and are laid in the same way as the ceramic tiles. Terracotta tiles are somewhat softer and more porous than ceramic tiles and, consequently, they are sealed when used inside the house.

Paving tiles can be dimensionally not very accurate and thick as well. They are always laid in a thick bed of adhesive with a wide grout joint of 12mm or more to allow for the dimensional variations.

In the recent times, natural stone tiles such as slate, granite and marble are being widely used. They take a high polish, are durable and easy to care for. These tiles can be laid with minimal grouting joints.

Unlike ceramic tiles, resilient floor coverings such as vinyl and cork are softer underfoot, making them a popular choice particularly in the foreign countries. These tiles are installed on a suitable underlay. Timber floors or concrete floors for these tiles should be dry. Concrete floors must be at least three months old prior to tiling with vinyl. Vinyl is impervious to moisture and can trap water, causing moisture bubbles to form. Similarly, other flexible tiles also have their own pre-requisites for laying.

On the whole the wide variety of tiles is worth noting and the correct choice demands proper understanding of tile properties and application requirements.

Coming to the tile setting adhesives, three broad classes of materials are recognized : a thick Portland Cement mortar bed (18 to 37 mm); a Portland Cement mortar reinforced with a latex emulsion in a thin bed (12 to 18mm); a thin set organic adhesive (0.8 to 3 mm). Functionally satisfactory tile adhesives for so-called thin bed setting of ceramic tiles can be made from a variety of rubbers, resins, fillers, and solvents. The quality of the tile adhesives in the market place is often inconsistent and unacceptable. Hence, due care has to be taken to procure quality product. The Tile Council research Laboratory and the Tile Contractors Association of America came out with a commercial standard CS 181 – 52 for a water-resistant organic adhesive for setting clay tiles. There is perhaps a need in our country to standardize the tile adhesives of different formulations and application areas.

Although the grout or joint filling material is not an adhesive, it is an important factor in the final success of thin-set tile work. Apart from the wet cement based grouts containing waterproofing compounds, the alkali and acid resistant grouts include epoxy systems, silicate compounds, furfuryl resin compounds and hot Sulphur compounds. These grouts require special installation techniques and are mainly used on floors and counter tops. All grouting materials have one problem in common. If joints are not completely filled and properly cured, contaminating materials may enter the joints and affect the adhesive bond and the back-up material.

New adhesives, with higher bond strengths and more resilience, are being developed so that flexibility of bond continues after long time exposure and use and the adhesive absorb relative movements. Another trend of development is to adopt green adhesive products with low content of solvent and low VOC emission, without sacrificing the functional requirements.

It should be borne in mind that problems with wall tiling are generally concerned with poor bonding to a substrate. Tiling also sometimes suffer from movement problems. The most serious problems arise when tiles are applied over an intermediate undercoat of sand and cement or gypsum plaster, to solid cast concrete walls. Concrete shrinkage can cause compression of the tiles. The tiles eventually detach with almost explosive force. Good practice therefore requires movement joints be provided through tiling at all internal corners as well as at intervals in long runs of tiling; generally the top edge of the tiling on a wall remains unrestrained, perhaps concealed behind a suspended ceiling, to allow similarly for vertical movement, although horizontal movement joints will be necessary with substantial unobstructed heights of tiling.

The above is a snapshot on tiles, adhesives, grouts and the straight tiling process. The design tiling is even more complex and demands a more careful planning and excavation. While tiling appears as a relatively simple act of construction, there is substantial science, arts, skills and engineering behind it. We, therefore, decided to devote the present issue of Rebuild to this interesting topic.

We hope you will appreciate the issue.

Tile and Tile Adhesives

(Partly extracted from "Tile Mantras" a publication of ROFF Tiling Academy, Pidilite Industries Ltd., Mumbai)

Many years ago, tiles were used as a necessity. The type, shape and sizes were all standard. Tiles were meant to perform the basic functions - offer hygiene and waterproof (when the correct adhesive and grout was used), which is essential in bathrooms and kitchens.

Today, with the improvement in technology worldwide, the importance of design and decor has grown manifold. Bathrooms and kitchens have become one of the most popular rooms that people now choose to decorate and have become style statements in themselves. Most people now turn to tiles to create an effect that other accessories find hard to produce.

Tiles are now available in different sizes, colours, textures, materials and designs, giving one the chance to create a unique environment, tailored to one's specific tastes.

Despite these advancements, one of the most crucial aspects i.e. the method for fixing these tiles continues to be old fashioned and usually ineffective, time and labour consuming. As a result the full impact of the beauty of these tiles and the longevity of the flooring is affected.

Types of Tiles

Ceramic Tiles

Most popular for bathrooms and laundries and also suitable for floors in kitchens, entrances, dining rooms, lounges and bedrooms. Ceramic tiles are also durable and can be easily maintained. They are less expensive than porcelain tiles. They are resistant to fire, chemicals and stains, but show less resistance to scratches and cracks as compared to porcelain tiles.

Porcelain Tiles

Better quality ceramic tiles, as they are made from finer materials and fired at very high temperatures. As a result they are much more durable, are more commonly used for floors and are more expensive than regular ceramic tiles. Porcelain tiles are also less porous with a water absorption rate of less than 0.5 % and thus can be termed as almost impervious. Their resistance to moisture makes them suitable for both indoor and outdoor applications. This quality of porcelain tiles also makes them more suitable for harsh conditions than ceramic tiles.

Both ceramic and porcelain tiles come in two forms, glazed and unglazed. The glazed ceramic tiles are a bit slippery than the unglazed ones and they are more suitable for wall applications than for flooring. On the other hand, glazed porcelain tiles are less porous and require low maintenance than the unglazed ones.

Terracotta Tiles

Made up of fired clay and can be used for indoors or outdoors. They are relatively soft and porous and they need sealing if used indoors.

On the outdoor, they absorb moisture and are best if left uncoated; if coated; white salts become trapped under the sealer.

Vitrified Tiles

Made from white clay, heated over high temperatures, which makes them strong and non-porous. These tiles are polished to make them mirror finish; due to which these are used for floors in homes and offices. Vitrified tiles posses much better mechanical strength (MOR), scratch resistance, resistance to acids, alkalies and chemicals, resistance to staining etc compared to marble or natural granite.

Marble

The natural stone available in various sizes & colours. However they are unsuitable for kitchens as they stain easily on contact with acids like wine, vinegar etc. Marble is calcium carbonate which is strongly attacked by Hydrochloric acid which is commonly used in toilet & floor cleaning. Marble yellows over extended time duration whereas vitrified tiles retains their colour for decades. Marble laying is very cumbersome and time consuming whereas vitrified tiles may be laid in a matter of hours and put to use after 48 hours.

Marble is comparatively soft material and hence its abrasion resistance is approximately 3 MOH whereas vitrified tiles have an abrasive resistance of 6-7 on MOH scale.

Granite

Very hard, resists scratching and needs minimal grouting joints. Used for cladding and flooring. Polished natural granite shows several surface textures. It is suitable for flooring and cladding.

It is necessary to take into consideration both technical and aesthetic aspects of tiles.

Technical Features of Tiles

The technical features are those necessary for the material's suitable and reliable performance such as uniformity features, structural features, massive mechanical features, surface mechanical features, thermo-hygrometric features, chemical features, and safety features.

Uniformity features determine the suitability of a batch of tiles to perform a "regular" tiled surface, or free of "irregularities" like bumps or dimples, steps between adjacent tiles, irregular joints course.

Structural features refer to the real structure of the material the tile is made of in particular to its porous structure. The tile porosity provides an immediate indication of the water absorption, which at lowest levels with porcelain stoneware. The products with higher levels of water absorption are porous such as terracotta.

Water absorption

One of the most important of these factors is water absorption. For example, a tile that absorbs significant amounts of water is not suitable for outdoor use. Tiles can be divided into 4 major groups based on their tendency to absorb water such as (i) impervious < 0.5% of water by weight (ii) vitreous > 0.5% but < 3.0% (iii) semi-vitreous > 3.0% but < 7.0% (iv) non-vitreous > 7.0% of water by weight.

These water-absorption characteristics have a major effect on the suitability of tile for different applications.

Mechanical features

It concerns the load bearing strength (for example the weight of people and furniture on a floor) to which the tiled surface may be exposed. The mechanical features are the bending strength and the breaking stress. The first one concerns the material the tile is made of, and it is directly proportional to the water absorption. The breaking stress is a property peculiar to a finished tile, with its own structure and size. Therefore, it is directly proportional to its thickness. Among these features the impact strength is also important.

Surface mechanical features

These features refer to the working surface of the tile and they can be associated with the resistance to scratches, wear and deterioration, due to the handling/moving of hard bodies on the surface and in contact with it.

These features are very significant in case of floors. The most important one is the abrasion resistance that provides a measurement of the propensity of a tile to wear down (if unglazed) or to alter its appearance (if glazed) as a result of the above mentioned conditions. As for unglazed tiles, this value tends to increase as water absorption decreases; therefore, porcelain stoneware will have the highest level and the best performance.

Abrasive Wear (ASTM D 2486-00) : 37 cycles per minute over a 10" travel

Resistance to wear of unglazed ceramic tile(ASTM C501-84): ≥ 500 by Taber Abrasion

Thermo-hygrometric features

These features describe the resistance to specific temperatures ("thermo") and dampness ("hygrometric") conditions, such as thermal shock and frost resistance and for glazed tiles only, crazing resistance. The frost resistance highly depends on the porosity and on the water absorption: the lower the values are, the less the chances of damage by frost will be.

Crazing, in the form of thin cracks of the glaze, can be formed by some building or environmental conditions. The crazing resistance depends on the glaze composition. Some types of glaze run higher crazing risks compared to others. Further thermo-hygrometric features are represented by thermal expansion and dampness expansion, that is to say the measurement of the tile dimensions increase, when submitted to higher temperature and dampness levels.

As regards to thermal expansion, no major differences exist between the various types of tiles, though a slight increase has been noticed in the presence of a great vitreous phase, which means in products with a more compact, vitrified body.

Fire Resistance (ASTM E 84-05) : Flame spread < 15

Accelerated Weathering (ASTM G 155-05a): After 3000 hours: $\Delta E < 4.5$, no deteriotion, fading or chalking of surface of tile colour

Accelerated Aging (ASTM D 1037-99) : No evidence of cracking, delamination, warpage, checking, blistering, color change, loosening of tiles or other detrimental defects.

Chemical features

The chemical features are the stain resistance, resistance to household products, acid and alkali resistance.

Chemical Stain Resistance to withstand without discoloration or staining (ASTM D 543-95), 10% hydrochloric acid, urine, saturated calcium chloride, black stamp pad ink, chewing gum, red aerosol paint, 10% ammonium hydroxide, 1% soap solution, turpentine, Urea, 5%, diesel fuel and motor oil.

Safety features

These features particularly preside over the safety of tiled areas regarding accidental or sanitary risks.

The main safety feature, also very important for outdoor, public and industrial areas, is the slip resistance, which is inversely proportional to the surface friction coefficient.

Slip Resistance (ASTM C 1028-96) for wet/dry Static Co-efficient of Friction > 0.80

Aesthetic features of Tiles

The aesthetic features of tiles are considered based on size, colour and decoration.

Tile Adhesives

An adhesive is a material used for holding two surfaces together. An adhesive must wet the surfaces, adhere to the surfaces, develop strength after it has been applied, and remain stable.

Classification as per IS 15477:2004

Type 1 Adhesive : Mainly for tiles of standard body composition with apparent porosity greater than 3 percent. These are suitable for most ceramic (that is non-vitrified) tiles and the majority of porous stones and background.

Type 2 Adhesive : Mainly for tiles of standard body composition with an apparent porosity less than or equal to 3 percent. Type 2 adhesive will be suitable for vitrified/fully vitrified tiles, dense and large dimension tiles (slabs), and where background and location is especially demanding.

Classification based on generic types

Cement based : A mixture of a hydraulic binder and mineral aggregate (fine sand) with or without, a small amount of organic additives. Produced as a dry blend that is mixed with water immediately before use.

Polymer based : A ready-for-use compound of polymeric binding agents (aqueous emulsion or latex) and mineral fillers.

- Polymer Modified Adhesive : Enhanced by liquid admixture normally Type 1 adhesive having enhanced adhesion/bonding and flexibility. By addition of liquid admixture resultant adhesive meet the performance criteria of Type 2 adhesive.
- Highly Polymer Modified Adhesive : Usually Type 2 adhesives having higher bond strength and flexible characteristics.

Reactive resin : The adhesive comprises two or more separate organic components, which polymerise and set when they come into contact. The parts may contain mineral fillers and they are only mixed immediately before use.

Classification based on useage

1. **General purpose :** For installation of ceramic tile and mosaics in interior area of buildings, where the face of the tiled surface is subjected only to intermitted exposure of water.
2. **Extreme condition :** For installation of ceramic tiles and mosaics in applications where high diffrential movement occur or where high adhesive strength is required (e.g. cold room, walls, floor subjected to heavy traffic, tiling of flexible substrates).
3. **Water resistance :** For installation of ceramic tiles and mosaics in application where face of the tiled surface is subjected to prolonged exposure of water.

Selection of Tile Adhesive

Product Description	Single Component Cement based adhesive	Single Component Heavy duty cement based adhesive	Two Component cement adhesive+ binder	Epoxy Ahesives
Flooring (Internal/External)				
Ceramic/Vitrified/ Natural stone on cementitious substrate	Y	Y	Y	N
Ceramic/Vitrified on wooden flooring	N	N	Y	N
New tiles on existing Mosaic/ Ceramic	Y	Y	Y	Y
New tiles on existing Vitrified/ Granite/Marble	N	Y	Y	N
Wall Tiling(Internal/External)				
Ceramic/Vitrified on cementitious substrate up to 10' height	Y	Y	Y	N
Ceramic/vitrified on cementitious substrate more than 10' height	N	Y	Y	N
Natural stone on cementitious substrate up to 10' height	N	Y	Y	N
Natural stone on cementitious substrate more than 10' height	N	N	Y	N
Glass mosaics on cementitious substrate(wet area)	N	N	Y	N
Glass mosaics on cementitious substrate(dry area)	N	Y	Y	N
Ceramic/Vitrified on wooden substrate	N	N	Y	Y
Ceramic/Vitrified tile/Natural stone on Ceramic/ Vitrified tile/ Natural stone	N	N	Y	Y

Ceramic/Vitrified tile/Natural stone on Metal	N	N	N	Y
Inlay of Marble	N	N	N	Y
Metal/Leather/ Wood/Glass on tile/ Stone	N	N	N	Y
Swimming Pool Tiling				
Ceramic/Vitrified	Y	Y	Y	N
Fully Vitrified(Glass mosaics)	N	Y	Y	N

Y- Yes, N- No

Properties and Test Methods

Shear and Tensile Adhesion (IS 15477:2004)

Requirements	Type 1	Type 2
Tensile adhesion, Min		
a) Dry conditions	750 N	-
b) Wet conditions	450 N	-
Shear adhesion, Min		
a) Dry conditions 24 h	2.50 KN	4.00 KN
b) Dry conditions 14 days	8.00 KN	10.00 KN
c) Heat aging condition	4.00 KN	5.00 KN
d) Wet condition	4.00 KN	5.00 KN

Compressive Strength (ASTM D1621) : Min.68.9 kPa
Tensile Strength (ASTM D 1623) : 117.2 kPa @ 82°C, 65% RH
Water Absorption (ASTM D 2842) : Max 3.96% by Volume
Water Vapour Permeance (ASTM E 96) : Max. 152.7 perm pa.s.m^2
Density (ASTM D 1622) : 30.6 Kg/ m3
Dimensional Stability (ASTM D 2126) : 1.01 @-40°C, 2 weeks
10.44@70°C,97% humidity, 2 weeks

Mixing of Adhesive and Grouts

The amount of water and/or liquid admix required for preparing the adhesive should be as stated by the adhesive manufacturer in parts by weight, i.e. liquid to dry powder (if a range of values is given, the average shall be used).

Prepare a minimum quantity of 2 kg of the adhesive in a mixer of the speed settings (140 ± 5) rotations per minute and (62 ± 5) rotations per minute planetary movement.

Carry out the following procedure:

- Pour the liquid into the pan and
- Scatter the dry powder over the liquid
- Mix for 30 s and take out the mixing paddle;
- Scrape down the paddle and pan within 1 min.
- Replace the paddle and mix for 1 min.

Let the adhesive mature in accordance with the adhesive manufacturer's further 15s.

In the case of ready-to-use dispersion adhesives or reaction resin adhesives, the manufacturer's instructions shall be followed.

Surface Preparation

For effective bonding, the adhesive must intimately wet the surface of each substrate being joined together. In addition, a chemical bond must form between the surface of the adhesive and the substrate. To satisfy these conditions, the surface of the substrate must be clean, reasonably smooth, and chemically receptive to the chosen adhesive.

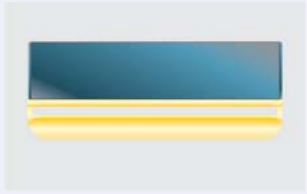
Surface preparation promotes adhesion by making it possible for the adhesive to wet the actual surface of the substrate, rather than its apparent surface. In many cases, what appears to be the surface is, in reality, a layer of grease, dirt, oil, or some other contaminant.

To a large extent, surface preparation determines how well and for how long a bond will hold. In fact, if the chosen adhesive can withstand the service conditions to which the bond will be subjected, life and service expectancy of that bond will be directly proportional to the degree of surface preparation.

Tiling Tools

Spatula for applying adhesive.

Notched applicator to spread and rib the adhesive bed.



Rubber squeegee to spread the grout.

Tile cutting machine for cutting hard tiles.

Tile pincers to nibble small pieces of tiles.

Tile scorer to scribe a line on the tile surface where a break is needed.

Step by step application

Cementitious Polymer Modified Tile Adhesive

Clean the tiling substrate thoroughly

Mix powder to water in proportion 2.5 part to 1 part by volume

Mix it thoroughly until a lump free paste is achieved

Apply the adhesive paste on a tiling substrate with 2 mm notch trowel

Touch the paste intermittently and if sticks to finger then continue tiling

Start placing glass mosaic sheets with slight twisting action

Continue the tiling

Remove the backing paper after 24 hrs & clean the tiles

Cementitious Polymer Modified Tile Adhesive on existing Tiles(Non Skid)

Clean existing tiles thoroughly. Mild acid etching followed by water washing is preferred

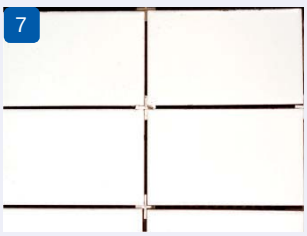
Mix powder to water/liquid in proportion 2.5 to 1 part by volume

Mix until a lump free paste is obtained

Apply the paste on existing tiles with 3 or 6 mm notch trowel

Touch the paste intermittently and if sticks to finger then continue tiling

Start placing the tiles with slight twisting action



Continue tiling by keeping at least 2mm joints between tiles

Start filling joints by pressing paste firmly

Heavy Duty Tile Fixing Adhesive

For Vertical Cladding & Tile-on-Tile Applications

Clean the tiling substrate thoroughly

Mix powder to water in proportion 3 part to 1 part by volume

Mix until a lump free paste is formed

Apply the adhesive paste on a tiling substrate with 2 mm notch trowel

Touch the paste intermittently and if it sticks to finger then continue tiling

Start placing stone tiles

Precautions

- The tiling substrate should be sound and thoroughly cleaned
- The substrate to be tiled should be dry or at “SSD” (Surface Saturated Dry) condition
- Check the trowelled adhesive paste intermittently
- Always add powder to water/liquid
- Check the uniform bedding behind tiles intermittently
- Allow tiling to cure for 24hrs & do not allow the tiled area subject to traffic for 24 hrs
- Tiling substrate should be wet while working in hot sunny days externally
- Do not put the tiles on skinned (dried) adhesive paste
- Do not wet the tiles for fixing
- Do not spread the adhesive paste more than 1 sq mt at once
- Do not add any cementitious material to tile adhesives

Tile grouting

Tile grouts are generally of polymer modified cementitious or epoxy resin based. It should be flexible in nature; should accommodate movements and also should not shrink like white cement. It should have a good bond with all types of tiles, thus making joints impermeable to water. In situations where non-toxic, chemical resistant properties for tile joint filler are required especially in food and pharma industry, epoxy resin based is the ideal solution.

1. Grouting should not begin until the tile setting material is properly cured (a minimum of 24 hours).
2. Wipe the tile surface with a damp cloth before grouting.
3. Using a Float, trowel the mixed grout over the surface and into the grout joint, careful to assure all joints are filled fully. Hold the float at a 45^{o} angle to the surface of the tile.
4. As soon as possible, remove excess grout from the tile surface with float held at a 90^{o} angle and moving diagonally across the joints. Strike the joint with the blunt end of a tool-compacting the surface but not digging out the grout.
5. Clean remaining grout from the tile surface as soon as grout firms up enough to be worked without being pulled from the joint by using a Scotch Bright Pad, or a pad of dampened cheese cloth or tile cleaner.

Under extreme heat or low humidity conditions, the floor should be covered with brown Kraft paper to retain moisture. Do not use polyethylene as it may result in uneven drying and discolored joints. The grouted floor must be protected from traffic for 72 hours after installation.

Clean the tiling substrate thoroughly

Mix it thoroughly until a homogeneous paste is obtained

Start filling joints by pressing paste firmly

Clean the grouted joints with damp sponge diagonally

Green Building Tile Adhesives- A primer

(Extracted from ASI Journal (Adhesive & Sealants Industry),A bnp Publication Volume 14,Number 8,Aug,2007 pp 24-28 and Volume 15,Number 6,June 2009 pp 28-33)

Green product

A product can be termed as green if it meets low VOC and no hazardous air pollutant qualifications, reduces safety concern for end users, is functional and easy to use, and if the materials are reusable and/or recyclable in the industrial processes. A green product can have impact from point of manufacture all the way down the line to the end of the product's life. In case of adhesives it should contain no PBB (polybrominated biphenyl) or PBDE (polybrominated diphenyl ether) flame retardants, VOC-free materials and materials that meet the upcoming halogen-free (safer for disposal) specifications.

Green adhesive

Key criteria for defining an adhesive as green include formulas that are green because of what is not in them(e.g., hazardous air pollutants and ozone depletors);products that are green because they reduce the environmental impact of building operation(e.g., the energy efficiency gained from the effective use of caulks and sealants);and products that contribute to a safe and healthy environment(e.g. low VOCs or formaldehyde free adhesives).The Table 1 given below can be taken as a benchmark for green adhesive for consumer products.

Table 1 : Green adhesives for Consumer products(less than 16 oz)

Product category	VOC% by weight	VOC g/l
Construction, panel & floor covering	15	200
Caulks and sealants	4	60
General purpose adhesives	10	120
Contact cements(general purpose)	55	600
Contact cements(special purpose)	80	735

Recommendations of TERI-GRIHA, New Delhi

VOCs, especially formaldehyde, urea formaldehyde, urethanes, and other chemical substances contained within the building materials can be injurious to health and can also be odorous. The aim is to select materials with low to zero quantities of such chemicals so as to minimize the source of emission. In selecting low VOC materials, a practical thumb rule is to choose water-based products with low odour.

Most construction adhesives offer adequate bond strengths in water-based varieties. As adhesives usually have a high-VOC emission potential hence use adhesives with low-VOC or no-VOC emissions such as acrylics or phenolic resins for indoors.

Advantages of Green products

The VOC emissions level is greatly reduced from the levels that existed a decade ago.

These are non-flammable and safer in particular environment where other volatile products are being used.

These are less hazardous to human health and the environment than other traditional adhesives.

Latest Green adhesive Technology

The three basic green technologies have come up in the last decade. The first was the family of low-solvent containing, low-VOC floor covering adhesives. Taylor developed a patented adhesive technology called Meta-tec technology in 2001.This technology was built on the inclusion of more bio-renewable resources, and also improved the performances of the product class by increasing strength and water resistance through its patented cross-linking system. Further Meta-tec technology has developed by offering alternative moisture cure technology with telechelic-modified silane polymer chemistry. This will open up many new avenues for product development for the next decade.

Current options for end users

There are currently three options that can be used to address these environmental issues; incineration to maintain solvent chemistry; process conversation to aqueous chemistry; and substitution with low HAPs (High Air Pollutants) solvent chemistry.

Incineration is the leading option for customers who place a high priority on maintaining their current process and warranty risk, as well as have the scale to invest in incineration. While the price of solvent and its performance provides the most attractive option for end-users who have the scale to invest in incineration.

The second option for using aqueous adhesives dos not have a clear cost-benefit profile in light of other options. The cost-in-use economics and performance of current aqueous adhesive offerings do not provide the incentive needed of environmental regulatory drivers. How ever, at this time aqueous products are the only commercially viable solution to address and/or eliminate VOC, HAP and CO_2 emissions resulting from adhesive application.

The third option for using low-HAP products.

Soya is being used as adhesives for wood and researches are being made to use it as tile adhesive in future.

Failure of Tiling System

(Extracted from "Guide to the deterioration and failure of building materials" By R. O. Heckroodt pp.76-84, published by Thomas Telford)

One of the major causes of the failure of tiling system is poor workmanship particularly incomplete bedding the tiles in the adhesive, which allows puncturing and other kinds of impact damage to occurs, laying tiles on area of adhesive where the open time has been exceeded, resulting in poor adhesive of the tiles, is another common.

Causes of failure

For an adhesive to perform successfully it must: achieve good contact with both adherends; set to a solid material; distribute and dissipate stresses; and continue to function for a given life time i.e. has good ageing properties in its working environment (e. g in different weathering conditions).

There are several agents which can cause or contribute to failure, the chief ones being :

(i) Environment stress(fatigue) caused by different thermal or moisture movement by mechanical shock;

(ii) Weathering of the bond line in exposed situations, e.g. embrittlement by oxidation of rubbery components;

(iii) Hydrolysis-water might enter the joint by diffusion, by wicking at interfaces and/or by penetration through cracks and holes;

(iv) Solvents-leaching of plasticizers or other components;

(v) Biological attack by agents such as fungi and bacteria.

There are three basic ways in which an adhesive joint can fail :

(a) Fissure in one of the substrates (adherend)-Cohesive failure in adherend;

(b) Fissure in the body of the adhesive-Cohesive failure in the adhesive;

(c) Separation at the interface between the adhesive and one of the adherends-adhesive failure

Some tiling failures manifest themselves quite soon after the tiles have been fixed, while other failures may take many months or even years to become apparent. Two types of failure of tiled areas that were initially sound can be distinguished like material failure and system failure.

Material failure

Tile adhesive failure

The first aspects to establish when tiles de-bond from the substrate are whether or not-there were opposing dimensional changes in the different elements of the tiling system. This kind of system failure is characterized by droning, bulging or ridging of the tile layer. The different types of adhesive failures during testing between adhesive and substrate (Fig: B.1), between adhesive and tile (Fig: B.2) and between tile and pull head plate (Fig: B.3) are shown by sketches below.

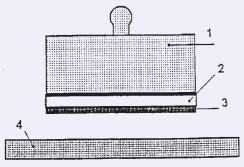


Figure B.1

Adhesive failure between adhesive and substrate (AF-S)

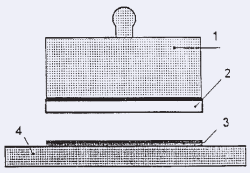


Figure B.2

Adhesive failure between tile and adhesive (AF-T)

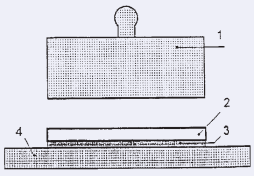


Figure B.3

Adhesive failure between tile & pull head plate (BT)

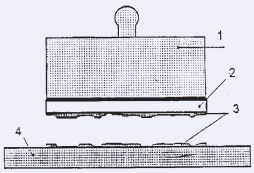


Figure B.4

Cohesive failure within the adhesive (CF-A)

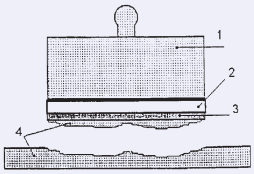


Figure B.5

Cohesive failure within the substrate (CF-S)

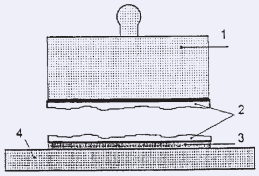


Figure B.6

Cohesive failure within the tile (CF-T)

1. Pullhead plate 2. Tile 3. Adhesive 4. Substrate

The adhesive can fail because an inappropriate type was used for the specific application or as a result of the ingress of aggressive chemical.

Inappropriate adhesive

Adhesive of specific type and class are required for adverse conditions, such as room walls, floors subjected to heavy traffic, external facades and flexible substrates. The development of modern adhesive has resulted in a degree of overlapping of the types, depending on the performance characteristics required. The adhesive

could thus also be classed according to the application conditions, and specifications. Adhesive and cohesive failure may attribute to errors in specification.The failure due to inappropriate adhesive is shown in fig. 1

Fig 1 : Adhesion failure due to use of cement as adhesive

Cohesive failure

Cohesive failure tends to be associated with faults in specification such as the choice of an adhesive not flexible enough to withstand movement stress or the failure to provide movement joints.

The other type of failure of the material may be due to cohesive within the adhesive (Fig: B.4), within the substrate (fig: B: 5) and within the tile (Fig: B.6) may take place as per the given sketches.

Attack by Aggressive Chemical

Cement based adhesive are attacked by sulphate (leached from the substrate or adjoining soil) as well as fertilizers, sewage effluent, industrial chemical etc. Note that a sulphate resisting Portland cement will only be effective against sulphate but not against acids that may be part of industrial and sewage effluent.

Poor Workmanship

Factors involving poor site workmanship, such as inadequate surface preparation, uneven or frugal application of adhesive and insufficient pressure applied when making the bond, tend to give rise to adhesive failure. This does necessarily mean that an observed adhesive failure can automatically be attributed to errors in workmanship.

Tiles may de-bond at the adhesive interface because one or more of the application characteristics of the adhesive have been exceed, usually by exceeding the pot life or open time. This type of failure is the result of ignorance, poor workmanship or inadequate supervision.

Preventive and remedial action

Crazing of the glaze surface, lime blowing or disintegration caused by frost action and salt. Crystallizations are processes that cannot be stopped by any subsequent treatment or action; they are inherent defect of the tiles. The remedy if the defect becomes unacceptable is to re-tile the area with sound tiles and by using appropriate adhesive.

- Careful attention should be given to the choice of materials, correct work procedures and good workmanship.
- Be aware that the application of surface sealant or impregnates to porous, unglazed tiles could exacerbate to their spalling due to salt action.
- It is of utmost important that the correct type of tile adhesive be selected and that all materials and installation procedures should be adhered.

System failure of tiled floor and wall

A tiled floor or wall is a complex multi component layered system. It consists of various elements.

- The visible parts, namely the tiles, grouting and movement joints.
- The invisible parts, which could include some or all the following adhesive, screed or plaster, membrane and slab or wall.

Each element makes a specific functional contribution to the unit as a whole. All the elements have different properties and frequently slow incompatible behaviour. As far as the failure of a tiling system is concerned, the dimensional stability of the entire component is the determining factor. If all the component of an integrated floor checking dimensionally by exactly the same amount in the same direction than the floor as an unit will expand without any internal stresses being developed.

Different movement

The reason for dimensional change of the tiling elements are temperature change, irreversible moisture expansion of the ceramic tiles, as well as drying shrinkage and creep of the floor or wall.

Thermal movement

The variation in thermal expansion of clay bricks and tiles is small and changes in ambient temperature do not cause signification stresses in a tiled bricks wall system.

The different in thermal expansion of cement products and clay tiles can be significant and, coupled with the decimal temperature gradient could be enough to cause stress damage to such tiled systems. Special precautions are required in particular with the tiling of cold storage spaces.

The failure due to thermal movemnet is shown in Fig 2

Fig 2 : Failure due to thermal movement

Irreversible moisture expansion of tiles

The moisture expansion of some ceramic tile can be considerable physically restraining the tile will not prevent from expanding. If the floor system is unable to accommodate the stresses caused by the strain, the tiles will either crushed or the adhesive will fail and the tiles will lift from the floor or detach the wall.

Some tiles have an expansion as high as 0.1% (1.0 mm / m) after 5 years of exposure, which is of the same magnitude as their crushing or critical strain. Table 1 lists the categories in which tiles are placed according to their total expected moisture expansion (as measured after 96 hours of steaming.)

Table 1 : Thermal expansion of materials in tiling systems

Materials	Thermal expansion (mm/m per 20°C)
Dense concrete	0.22 – 0.26
Calcium Silicate bricks	0.16 – 0.28
Fixed Clay bricks and tiles	0.14 – 0.18

Movement Joint

It is a fallacy to think that movement joint will prevent failure between tiles and the base. These joint are there to accommodate shrinkage, settling, and dynamic movement between different parts of the structure. They cannot be used as a cure for poor design, or to avoid the effect of unbridled fast tracking.

Failure of adhesive bonds in flooring

Due to specification:

- Wet screed (construction water or faulty damp proofing material)
- Wrong adhesive used
- Insufficient movement accommodation
- Plasticizer migration of leaching by washing

Workmanship:

- Inadequate adhesive cover and/or insufficient pressure applied
- Incorrect use of open time (i.e. flooring laid too soon or too late
- Inadequate surface preparation

Failure of adhesive bonds in internal walls

Due to specification:

- No allowance for initial movement (shrinkage of background/expansion of tiles)
- Wrong adhesive chosen (wet conditions, service movement or incompatible with background)

Workmanship:

- Inadequate adhesive cover and/or insufficient pressure applied

Failure of adhesive bonds in internal walls

- Non-allowance for thermal movement between facing and background,
- Frugal application of adhesive and insufficient pressure used in installing the facing.

Failure of adhesive bonds in Swimming pools

- Incorrect choice of materials
- Inadequate application of adhesive

By taking care of the above facts the failure of the tiling system can be effectively minimized.

The various other International standards may be referred for tile adhesives and grouts as given below.

ISO 13007 : Ceramic tiles-Grouts and adhesives Part 1: Terms, definitions and specifications for adhesives, Part 2: Test methods for adhesives, Part 3:Terms, definitions and specifications for grouts, Part 4: Test methods for grouts

BS 5980(1991) : Specification for Adhesives for use with ceramic tiles and mosaics

EN 12004 (2007) : Adhesives for tiles-Requirements, evaluation of conformity, classification and designation

EN 1308 : Adhesives for tiles-Determination of slip

EN1324(2007) : Adhesives for tiles-Determination of shear adhesion strength of dispersion adhesives

EN1346 : Adhesives for tiles-Determination of open time

EN1347 : Adhesives for tiles-Determination of wetting capacity

EN 1348(2007) : Adhesives for tiles-Determination of tensile adhesion strength for cementitious adhesives

EN12002 : Adhesives for tiles-Determination of transverse deformation for cementitious adhesives and grouts

EN 12003(1997) : Adhesives for tiles-Determination of shear adhesion strength of reaction resin adhesives

EN 12808-1 : Adhsives and grouts for tiles-Part 1: Determination of chemical resistance of reaction resin mortars

ANSI A118.7(99) : American National Standard Specifications for Polymer Modified Cement Grouts for Tile Installation (N-3.3, N-3.4, N-3.5, N-3.6 and N-3.7)

Training Programmes by DFI-SPR

- Organised One day Training Programme on 12th June 2009 on "Cracks in Structures & Remedial Measures" at DFI-SPR, Mumbai. It was attended by Engineers from LIC, CIDCO, Mehata Asoociates, Grasim Industries Ltd, TCE Consulting Engineers, ITD Cementation India Ltd & Private Contractors.

Oganised One day training programme on 17th July 2009 on " Waterproofing Of Basements & Internal Wet Areas" at DFI-SPR, Mumbai. It was attended by Engineers from Lokseva Decor, Grasim Industries Ltd, Build Concrete Solution, Gemini Construction, Mehta Associates, Madhav & Co., Manish Agencies & Hindustan Petroleum Corporation Ltd.

DFI-SPR and MSME (Ministry of MSME, Government of India) jointly conducted a five day certificate training programme from 29th June - 3rd July 2009 titled "Professional Course in Construction Chemicals for Waterproofing – Application & Repairs" for construction supervisors, contractors, engineers, civil engineering students, real estate agents and entrepreneurs at MSME–DI, Sakinaka, Mumbai. The participants and also the chief guests from State Bank of India greatly appreciated and lauded this unique training designed and imparted by Dr.Fixit Institute to develop the entrepreneurship skills in construction professionals of the country.

DFI-SPR Promotes global construction practices through its Healthy Construction Lecture Series

DFI-SPR organized technical seminars "Healthy Construction Lecture Series" on 25th and 26th of June 2009 in Kolkata and New Delhi respectively. Dr. Caspar J.W.P.Groot, an eminent faculty from Civil Engineering and Geoscience department of Delft University of Technology, Netherlands was invited as the Guest Speaker to deliver a special lecture on "Masonary Repair: Restoration of Heritage structures". The programmes were praised by the prominent personalities from the engineering fraternity of both these cities.

Training Programmes and Courses

DFI– SPR has scheduled a list of training programmes for the year 2009 - 10. These programmes have been designed for upgradation of knowledge base for practicing site engineers at the site.

Open programme calendar for 2009-10

Sr. No.	Month	Date	Topic	Fees	Details of the topic
1	August-09	27th and 28th August	Construction Chemicals - An Emerging Trend	Rs. 3000/-	• Construction chemicals – an overview • Concrete admixtures • Waterproofing chemicals and systems • Grouts and repair materials • Protective coatings • Industrial floorings • Tile adhesives and joint fillers • Joint sealants
2	November-09	19th and 20th November	Structural Diagnosis and Condition Analysis of RC Structures	Rs. 3000/-	• Distresses in concrete structures • Condition survey • Diagnostic techniques • Methods of non destructive tests • Damage rating • Repair techniques
3	January-10	14th and 15th January	Building Maintenance - Waterproofing and General Repair	Rs. 3000/-	• Distresses in concrete structures • Condition survey • Diagnostic techniques • Methods of non destructive tests • Damage rating • Repair techniques

Commencing Part Time (Evening), 3 months duration course

Dr. Fixit Institute of Structural Protection & Rehabilitation (DFI-SPR) along with Sardar Patel College of Engineering, Mumbai, is jointly conducting a three months part time certificate course on “Repairs and Waterproofing of RC Structures” for the final year graduate level students and the practicing engineers / professional in the relevant field in Aug 2009.

Commencing Aug 09 - Distance Education Correspondences Courses jointly with NICMAR

Six Months Graduate Certificate courses are organised in three diciplines:

- Waterproofing and Maintenance of Concrete Structures
- Advanced Technology for Concrete Repair
- Application of Polymeric Materials in Construction

Duration : 6 months

Eligibility : Diploma in any branch of engineering OR Graduation in any non-engineering field & having 2-3 years experience in relevant fields.

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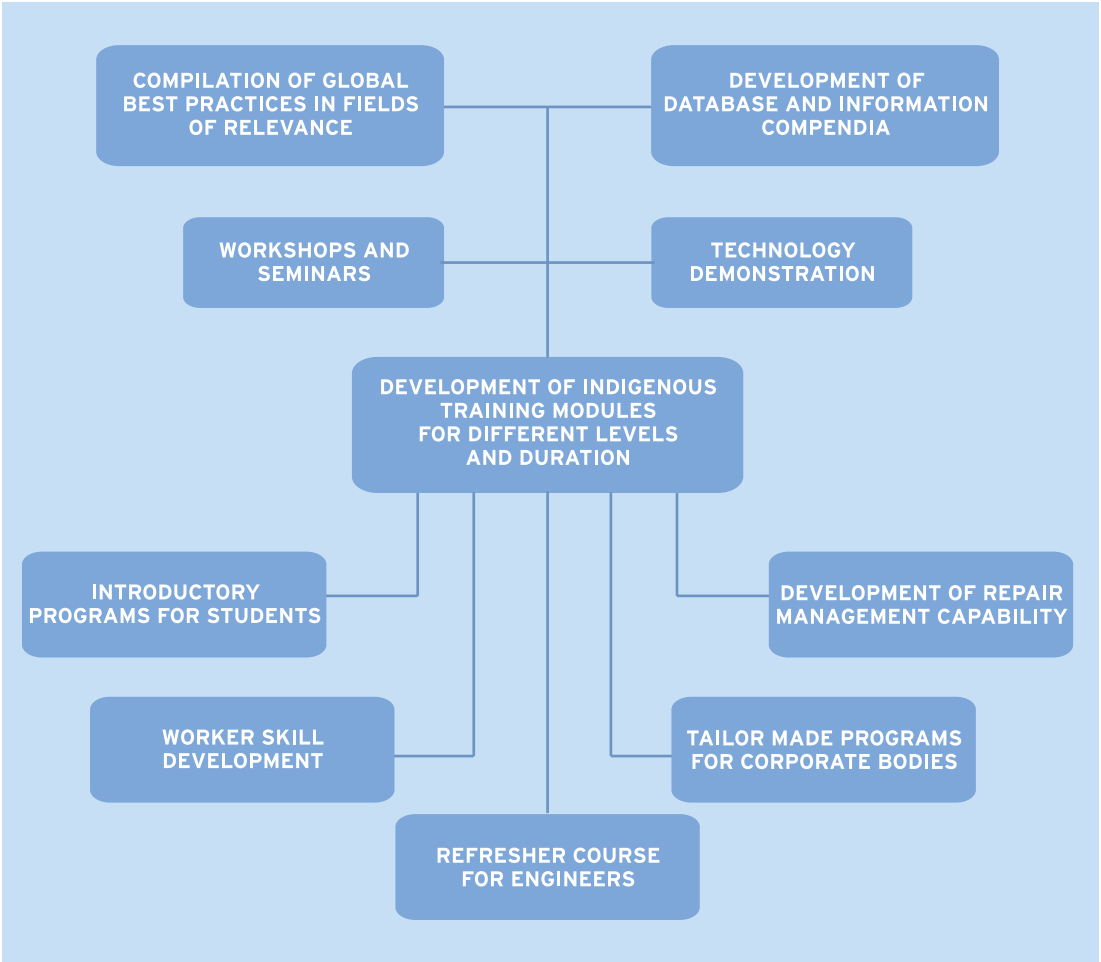
To act as a platform for enhancing the service life of built environment through global sharing of knowledge and practices in the field of waterproofing, structural protection, repairs and rehabilitation.

DFI - SPR : ACTIVITY CHART



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