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ADHESIVE SELECTION FOR CLADDING

How To Choose Adhesive For Fixing Various Substrates On Cladding

Design Issues, Factors to be considered while applying Tiles, Stones etc. on Vertical Surfaces

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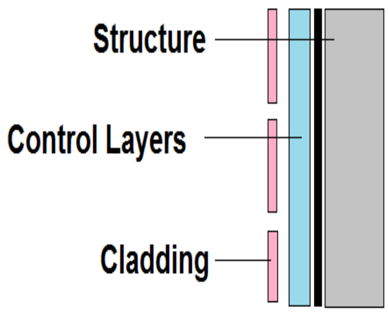
Exterior Cladding

External cladding is the application of one material over another to provide a skin or layer intended to control the infiltration of weather elements, or for aesthetic purposes. Cladding does not necessarily have to provide a waterproof condition but is instead a control element.

This control element may only serve to safely direct water or wind in order to control run-off and prevent infiltration into the building structure.



Concrete block (plastered or natural), brick (also potentially plastered or 'bagged'), plywood panelling, glass, rammed earth, and even fibreglass have all been used as 'envelopes' for homes. Waterproofing is critical, but problems of the recent past have largely been addressed and new homes today use specific techniques to avoid these issues.

Substrates

It is the surface to which the cladding material is attached using adhesive and is the part of the principal load-bearing component of the exterior wall cladding assembly.

Common types of Substrates for Direct Adhered External Cladding

1. **Concrete**
   Cast-in-place concrete
   Pre-cast concrete panels
   Glass Fibre Reinforced Pre-Cast Concrete (GFRC) panels
2. **Concrete Masonry Units (CMU)**
   Standard weight aggregate
   Lightweight aggregate
   Cellular concrete (Aerated Autoclaved Concrete, Gas Beton, Ytong®)
3. **Clay masonry units**
   Brick masonry
   Hollow clay masonry
4. **Cement plasters/render (Bonded or Unbonded over Metal Lath)**
   Water/sand/cement/lime
   Latex/sand/cement
5. **Cement Board Units (CBU)**
   Cement board (e.g. PermaBase®, Util-A-Crete®, Durock®, etc…)
   Fiber cement underlayment (e.g. HardieBacker® Board)
   Calcium silicate board and Corrugated sheet steel
6. **Corrugated sheet steel**
7. **Stones and Tiles**

Structural Movements in Exterior

- Live loads (wind, seismic) and dead loads (gravity)
- Thermal movement in Drying shrinkage*
- Moisture expansion*
- Elastic deformation under initial loads
- Creep of concrete under sustained load*
- Differential settlement

*Denotes types of movement in concrete or wood structural frames only

Loads

Forces caused by gravity, wind or seismic loads must be analysed to determine the required tensile and shear bond strength of adhesive mortars to resist these forces

Thermal Movement

All building materials expand and contract when exposed to changes in temperature. There are two factors to consider in analysing thermal movement:

- The rates of expansion of different materials (also known as the linear coefficient of thermal expansion)
- The anticipated temperature range exposure

For example, a porcelain tile has an average coefficient of linear expansion of between 4 – 8 x 10-6 mm/°C/mm of length. Concrete has an expansion rate of 5 x 10-6 in/in/°F (9 – 10 x 10-6 mm/°C/mm). The surface temperature of a tile or stone may reach as high as 160°F (71°C) in hot sun, and the lowest ambient temperature in a moderately cold climate may be 14°F (-10°C), resulting in a temperature range of 146°F (81°C) for the tile.

Thermal induced structural deflection

This is bending of the building's structural frame and can occur when there is a significant temperature differential between the exterior and interior of the structural frame, causing the frame to bend and exert force on the exterior wall assembly. For example, a 100°F (38°C) temperature differential between the interior and exterior structural steel or concrete members in an extremely hot climate with an air-conditioned interior can result in a change of length of 7/8" (22 mm) over a 100' (30.5 m) distance.

Moisture Shrinkage/Expansion

Underlying structures or infill walls constructed of concrete or concrete masonry will undergo permanent shrinkage from cement hydration and loss of water after initial installation.

As an example, reinforced concrete walls will ultimately shrink between 0.00025 – 0.001 times the length (0.025 – 0.10%), depending on a number of variables such as water/ cement ratio or the amount of steel reinforcing. A concrete framed building which is 120' (40 m) high can shrink up to 3/4" (19 mm) vertically. Cladding will not shrink, and in some cases, will undergo moisture expansion

Structural Deformation

As a building is constructed, the weight of materials increase, and permanent movement, known as elastic deformation, occurs in heavily stressed components of the structure.

For example, the spandrel beam or lintel over the windows is allowed to move or deflect up to 1/500 of the span. Therefore, a beam spanning 15' (4.6 m) between columns is allowed to move approximately 3/8" (10 mm) vertically from initial position under full load. The spandrel beam is typically the optimum location for a horizontal movement joint at each floor level of a building. The joint should continue from the surface of the cladding and through the adhesive and leveling mortars.

Deformation movement in concrete structures, also known as creep, occurs more slowly and can increase initial deflections by 2 – 3 times. Example: A typical 10 story building is 130' (40 m) tall. Creep, or long term deformation, may be as high as 0.065% of the height. Creep would be calculated as follows: 40 m x 1000 mm x 0.00065 = 1" (25 mm) potential reduction in the height of the concrete structure.

Required Properties in Cladding Material

- Low water absorption rate
- Thermal movement compatibility with adhesive and substrate
- High breaking strength
- Chemical resistance
- Thermal movement and shock resistance
- Adhesive compatibility
- Dimensional stability (heat and moisture insensitivity, moisture expansion)
- Frost resistance (cold climates)
- Dimension and surface quality/tolerance
- Crazing resistance of glazing

Required Properties in Cladding Adhesives

- High adhesive strength (tensile and shear bond strength)
- Water resistant
- Flexible (differential movement)
- Permanent
- Fire and temperature resistant
- Safe
- Good working properties (open time, pot life, sag resistance)

High Adhesive Strength (Shear and Tensile)

The shearing force exerted by seismic activity is by far the most extreme force that an adhesive must be able to withstand. The shear stress exerted by an earthquake of a magnitude of 7, on the Richter Scale, is approximately 215 psi (15 kg/cm2) so this value is considered the minimum safe shear bond strength of an adhesive to both the surface of the cladding and the substrate

Water Resistance

For proper exterior performance, an adhesive must not be soluble in water after it is cured. The adhesive should also develop water insensitivity within 24 hours so as not to require an unreasonable degree of protection against deterioration in the event of a rainstorm.

Flexible (Differential Movement)

Adhesives must have a low modulus of elasticity, or flexibility, to withstand differential movement between the cladding material and the underlying substrate/structure. Differential movement can be caused by uneven or sudden temperature changes, moisture expansion or shrinkage of the cladding, substrate or the structure, or live loads such as wind or seismic activity

Permanence

The criteria of permanence may seem obvious, but even if all other performance criteria are met, beware that some "old" technology urethane or epoxy adhesives can deteriorate over time, depending on how they are chemically modified, even if installed properly. Some epoxies can become brittle with age, and some urethanes can undergo a phenomenon known as "reversion," where the adhesive may soften and revert back to its original viscous state. Certain polymeric modification of cement mortars work only to enhance the workability and curing process, so as to improve the physical characteristics of cement, but do not contribute any significant lasting improvement to physical characteristics of the cement adhesive mortar.

Fire and Temperature Resistance

When cured, adhesives must meet building codes and standard engineering practice by not contributing any fuel or smoke in the event of a fire. In addition, the adhesive must maintain strength and physical properties during and after exposure to the high temperatures of a fire, or from absorption of heat from solar radiation under normal service. Some types of direct adhered systems, such as those employing silicone or epoxy adhesives, may be limited in their fire resistance by the loss of adhesive strength when exposed to very high temperatures.

Safe

The adhesive should not be hazardous during storage, installation, and disposal. This includes other materials which may be necessary for preparation or final cleaning. The adhesive should be non-toxic, non-flammable, low odor, and environmentally (VOC) compliant.

Good Working Properties

The adhesive should have good working properties to ensure cost-effective and problem-free installation of tile, stone, masonry veneer, or thin brick. This means that the adhesive must be easy to handle, mix, and apply without having to take extraordinary precautionary measures or unusual installation steps. Good initial adhesive grab to substrate and cladding, long pot life, long open time (tacky, wet surface after spreading), vertical sag resistance (both the adhesive alone and with tile), and temperature insensitivity are all recommended working properties.

The performance and use of ceramic tile adhesives are regulated by country or region according to a partial listing of prominent standards shown in Figure

Standards For Ceramic Tile Adhesives	
Country or Region	**Standard Name / Number**
Australia	Standards Australia (AS) – AS 4992 – Ceramic Tiles – Grouts and Adhesives Part 1 AS 2358 – Adhesives for Fixing Ceramic Tiles
Brazil	Associação Brasileira de NormasTécnicas (ABNT) NBR 14081
China	Standardization Administration of China (SAC) JC/T 547
Europe	European Standards (EN) – EN 12004 – Adhesives for Tiles – Requirements, Evaluation of Conformity, Classification and Designation
France	Association Française de Normalisation (AFNOR) NF EN 12004
Germany	Deutsches Insitutfür Normung (DIN) EN 12004
India	**IS 15477; IS -4101-3; IS 1414**
Italy	Ente Nazionale Italiano di Unificazione (UNI) EN 12004
Singapore	Standards, Productivity and Innovation Board (SPRING SG) SS EN 12004
United Kingdom	British Standards Institution (BSI) EN 12004
United States	American National Standards Institute (ANSI) A118

Types of Adhesives for Direct Adhered Facades

- Cement paste or Cement/Sand Mortar (mixed with water)
- Dispersive Powder Polymer-Modified Cement Mortar (mixed with water)
- Latex (liquid polymer) Modified Cement Mortar (Latex in lieu of water)
- Modified Emulsion Epoxy Adhesives (cement, water, epoxy resins)
- Epoxy Resin Adhesives (100% epoxy)
- Urethane Adhesives
- Silicone (Structural) Adhesives

Traditional Cement Mortar Mixed with Water

Until the development and improvement of synthetic latex, polymeric and resin additives in adhesives, Portland cement mixed with or without sand and gauged with water, has traditionally been used as an adhesive for exterior ceramic tile, stone, masonry veneer, and thin brick cladding.

Dispersive Powder Polymer Modified Cement Mortar

This type of cement based adhesive mortar is available only as a manufactured proprietary product. There is a wide variety of this type of adhesive mortar products on the market. These materials typically are mixed with potable water; however, many dispersive powder polymer mortars can be mixed with liquid latex additive to improve performance (see latex modified cement mortar). These adhesive mortars differ mainly by the type and quantity of polymeric content. Performance characteristics may comply with either ANSI A118.1 or A118.4 standards or, with ISO 13007 and EN 12004 requirements.

Types of Dispersive (Polymeric) Powders

- Modified cellulose
- Polyvinyl acetate powder (PVA)
- Ethylene vinyl acetate copolymer powder (EVA)
- Polyacrylate powder

Latex (Liquid Polymer) Modified Cement Mortar

There are a wide variety of proprietary liquid additives that can be used with both generic cement and sand, or with proprietary cement mortar powders, including some products from the previous category of dispersive powder polymer mortars, to prepare an adhesive for external cladding materials. As with dispersive powder polymer products, the liquid additives differ mainly by the type and quantity of polymeric content.

Types of Liquid Additives

- Vinyl acetate dispersions
- Acrylic dispersions
- Styrene-butadiene latex

Epoxy Resin Adhesives

Epoxy resin adhesives are typically three component systems, consisting of an epoxy resin and hardener liquids, and some type filler material, such as silica sand. Epoxy adhesives which conform to ANSI A118.3 are essentially 100% epoxy solids. More economical versions of epoxy adhesives, known as modified epoxy emulsions, are also available in the market. Modified epoxy emulsions, which conform to ANSI A118.8, consist of special epoxy resins and hardeners which are emulsified in water, and then mixed with a cementitious mortar. This type of epoxy adhesive combines the economy of cement based mortars and the increased strength of epoxy adhesives.

Silicone (Structural) Adhesives

Structural silicone attachment of glazing materials has been in use since the early 1970's and has been used extensively around the world to create adhesive attached glass facades. The ability of structural silicone to withstand ultraviolet radiation, while maintaining a consistent modulus of elasticity over a wide range of temperatures, and maintaining adhesion to glass and aluminum, ultimately led to use for direct adhesion of tile, stone and thin brick in the 1980's.

Adhesive Application Methods for External Cladding

1. **Thin bed (adhesive or positive method)**
2. **Thick bed (one-step, float and butter, buttering)**
3. **Spot mounting (dab, butterball method).**
4. **Negative cast (precast concrete panels)**

The cardinal rule for the installation of any material with an adhesive is:
Adhesion will only be as good as the materials and surface which is being adhered. The highest strength adhesives and most careful application to the best quality cladding will not overcome an improperly prepared substrate.

Selecting a Structural Adhesive

Structural adhesives should be chosen with the end user requirements firmly in mind.
In particular end use conditions to consider include:

1. **Expected conditions during end use**
   - Temperature – how hot? How cold?
   - Humidity – will the material be exposed to rain? To salt water?
   - UV exposure – will the joint be exposed to the sun and can the UV penetrate the substrates to reach the adhesive?

2. **Chemical resistance required**
   - Fluids (motor oil, gasoline, diesel fluid, jet fuel) – will these come in contact with the joint?
   - Cleaning solutions (weak acids and bases) – will the joint be cleaned frequently?
   - Are there specialized chemicals which may contact the bonded part?
   - Will contact be continual (e.g. in a filtering assembly) or only occasional?

3. **Cleanliness / Environmental issues during production and end use**
   - Outgassing, ionics, corrosion potential—is the part being bonded sensitive to these issues (for example, electronics or optics)
   - Toxicity, disposal – are there regulations that come into play? Will the adhesive be used in food packaging or a medical device?
4. **Mechanical Challenges**
   - Impact, vibration, fatigue– will the bonded part be subject to high impact or vibration forces in use? What about thermal cycling and dis-similar coefficient of thermal expansion substrates?
   - Stress type and magnitude – how high are the stresses on the bond line? What types of stresses will the bond line experience (NB: this is a very involved question that will be further addressed in another paper in this series.)
   - Height & Size of the Cladding – Though this is covered in Stress type however one general method of selection of Adhesive to be used is based on the Size of Cladding Material to be used and Height at which Cladding is being done.

Types of Structural Adhesives and Their Performance Criteria

Although hybrid products can be formed, in general the categories of structural adhesives are:

- Epoxies (one and two part formulations)
- Acrylics (two-part and two-step formulations)
- Urethanes (two part formulations)
- Cyanoacrylates (“instant adhesives”)
- Cementitious Adhesives

Structural Adhesive family properties comparison

Property	Epoxies	Acrylics	Urethanes	Cyanoacrylates
Overlap Shear – Metals	Best	low to high	moderate	low for long term bonding
Overlap Shear – Plastics	Moderate	Best	moderate	High
Overlap Shear Thermoset Composites	Best	high	High	moderate
Peel Strength	low to best	low to (occasionally) high	Good	low
Impact Resistance and Toughness	poor to best	poor to good	Good	low
Flexibility	As desired.	poor to good	excellent	low
Temperature Resistance Range	Best	moderate	moderate	low
Solvent Resistance	Best	moderate	High	low

Structural adhesive family handling and processing comparison

Property	One-Part Epoxies	Two-Part Epoxies	Acrylics	Urethanes	Cyanoacrylates
Storage Requirements	Difficult	Easy	moderate	moderate	moderate
Shelf Life	short at room temp	Long	moderate to long	moderate	moderate
Measure/Mix required?	No	Yes	Yes	Yes	No
Room Temp Cure?	No	Yes	Yes	Yes	Yes
Pot Life	Very long	long	moderate	moderate	long
Initial cure time	not possible without heat	moderate to long without heat	fast	moderate	Very fast
Full Cure Time	fast	slow unless heat curing	fast	slow unless heat curing	Very fast
Odor	little	some	usually strong	Little	moderate