AQUA CHAT Newsletter

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What forces create an adhesive bond with thin-set mortars? – (Part 1)

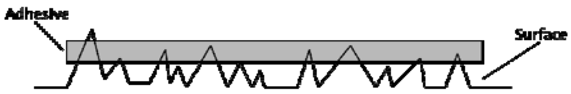
This months Aqua Chat is courtesy of Scott Worthington from Custom Building Products..

Last month I delivered a presentation at the tile and stone exhibition in Sydney Australia on the use of sealers on the bonded side of natural stone. One of the issues I covered was how some sealers are not bond breakers, but that they do change the way an adhesive, like cement thin-set, will interact with the sealed surface. To fully understand this position you need firstly to understand the major forces at work when you bond something with adhesive. So this month's article (part 1) will deal with the two major forces at work during adhesion and next month (part 2) I will cover how these are relevant to using sealers on the back or bonded side of stone and tile.

There are actually a number of theories regarding the forces at work when two things are bonded together with something like cement thin-set. However the two theories regarded as the most influential forces in this relationship are the mechanical and chemical interactions.

Mechanical: This force is the most common and well known. When you go to any seminar or read any literature on how cement based thin-sets work for example the term mechanical bond will be used to describe the major force at work. When you study the back of a stone or tile it is not really smooth at all. Even the very dense smooth surfaces like granite and porcelain tile are actually a maze of microscopic peaks and troughs akin to the surface of sandpaper. It is when the adhesive penetrates the open spaces of the surface as well as those on the surface of the substrate and displaces the air that is present that a mechanical bond is formed. The strength of the mechanical bond is determined, not only by the type of adhesive being applied and its hydration or cure, but also by how well the adhesive "wets out" the surfaces. The more complete the adhesive wets out the surface, the stronger the mechanical force and bond will be. The diagrams Fig 1a and Fig 1b show clearly how this works.

Chemical: The second important but less well know force in forming an adhesive bond is the chemical interaction between the adhesive and adherend. These chemical interactions are based mainly upon the adsorption theory. The general definition of adsorption is the "accumulation of gases, liquids or solutes on the surface of a solid or liquid". This should not be confused with the more common term of absorption that is a different process where substances diffuse into a liquid or solid. A common example of adsorption at work is a charcoal gas mask – see Fig 2 below. The theory of adsorption states that you gain adhesion from molecular contact between two materials and the surface forces that develop from this contact. These molecular bonds can be attributed to Van der Waals bonds. These are secondary bonds, (as opposed to stronger primary bonds like ionic and covalent bonds), that cause otherwise neutral molecules to be attracted to one another. For this chemical attraction and molecular bonding to occur the adhesive and substrate or surfaces must be in very close proximity to one another. Therefore just like a mechanical force proper wetting out of the surfaces with adhesive is essential in creating strong chemical bonds.



Incomplete wetting out of surface with adhesive results in inferior mechanical and chemical forces and overall adhesion.

Fig 1a

Complete wetting out of surface with adhesive results in superior mechanical and chemical forces and overall adhesion.

Fig 1b

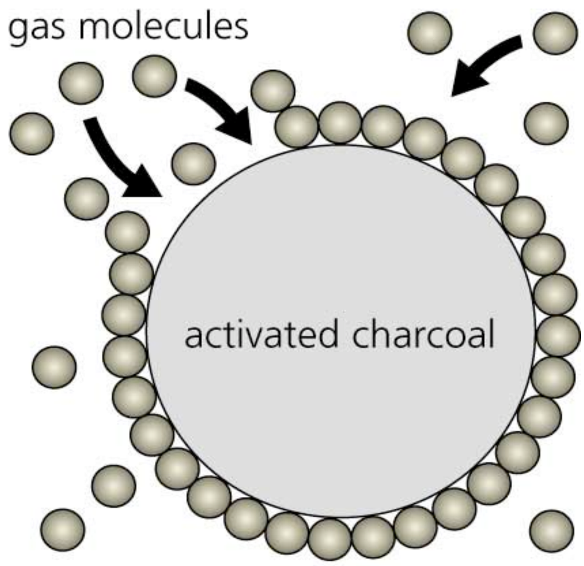


Fig 2 - **Adsorption** example, where activated charcoal in a gas mask attracts toxic gas molecules allowing the person wearing the mask to breath fresh air.

When we look at the different types of stone and tile we install with adhesive there is a wide variation in both surface texture and water absorption. The different surfaces will rely on both forces for good adhesion but in many cases to a lesser or greater degree. For example limestone or pressed ceramic wall tile generally have relatively rough porous surfaces making it reasonably easy to gain a good mechanical bond to them. In this case there is less reliance on forming a chemical bond to enhance overall adhesion. Also if a surface is too rough then it becomes more difficult to form a good chemical bond. This is because the adhesive and surface need to be in much closer contact to forge the molecular bonds than for a reasonably sound mechanical one.

However when the material is dense like granite (an extreme case would be Absolute Black Granite) or porcelain tile then the surface is much smoother making the formation of a good mechanical bond much more difficult. For these types of materials it is the forces formed by chemical interaction and bonding that are the most important in creating an effective adhesive bond. This helps to explain why we need different types of adhesive chemistry to bond different materials and surfaces. For example polyesters create good mechanical bond but promote relatively poor chemical interaction. Acrylics on the other hand are used commonly to modify more high performance thin-sets that are recommended for installing smoother materials such as granite and porcelain tile. This is because acrylics cure though a polymerization reaction rather than just the cross linking one of polyesters. This results in each unit of acrylic resin being bonded to the next in long chains. And as each unit contains an ester group (esters usually have high Van der Waals bonding characteristics) acrylics are commonly believed to show much higher chemical interaction making them ideal for bonding dense materials like granite and porcelain tile. At the top of the tree are epoxy adhesives. They work completely differently from the other adhesives. They provide the highest chemical interaction mainly due to their high concentration of hydroxyl groups (hydroxyls having even higher Van der Waals bonding characteristics than esters). Due to their low rate of shrinkage during curing they also maintain a good mechanical bond enhancing overall adhesion to even the most dense and smooth surfaces.

The simple equation one can draw from these two main forces of adhesion is that although both are at work to some degree in most situations different surfaces can rely on one force more than the other. The more textured and porous surfaces like limestone, sandstone and pressed earthenware ceramic tile rely more heavily on the formation of a mechanical bond. Where in contrast dense smooth materials such as granite, porcelain tile, glass mosaics and the more contemporary resin bonded engineered stone, rely more on chemical interaction to form sufficient adhesion.

Wetting Out: One common element in establishing both strong mechanical and chemical forces of adhesion is the process of wetting out. This is best achieved by initially working adhesive intimately into both the substrate and stone or tile surface, prior to applying the main body of adhesive (normally) to the substrate. A typical notch trowel is well designed for this purpose as it almost always has one flat side without notches that is ideally suited for working the adhesive into the surface.

This process of wetting out is something that is acknowledged in most international tile and stone installation standards. For example the American ANSI standard for the installation of ceramic tile with dry-set or latex Portland cement mortars (ANSI 108.5 – section 3.0 installation of tile for floors – sub sections 3.2.2 and 3.3.3) clearly incorporates this procedure. To further enhance contact (hence overall coverage and ultimately adhesion) most standards (see ANSI 108.5 section 3.3.3) also advocate “beating ” the stone or tile into the adhesive bed. This is normally done using a non-marking rubber mallet and a beating block to evenly distribute the load.

Conclusion: In summary establishing good adhesion is about maximizing both the mechanical and chemical forces at work. Selecting the right adhesive for the specific material is critical so that the appropriate forces of adhesion required by that material are delivered. Other factors are of course important in gaining good adhesion such as proper mixing, curing and overall coverage of adhesive. (Note that ANSI 108.5 calls for a minimum adhesive coverage of 80% and 95% for wet areas and all exterior installations). However it is the relatively simple process of wetting out that is perhaps the single most important factor in creating strong adhesion, because neither of the two forces of adhesion are maximized without it. In my experience it is this simple process that is most often overlooked and forgotten. The bottom line is that if you do not properly wet out the surfaces to be bonded you will not maximize adhesion or the performance of the adhesive you have paid good money for.

(Note – in part 2 of this article I will cover how these forces of adhesion relate to using sealers correctly on the bonded side of stone and tile).