Some aspects of engineered stone that are not usually advertised

Introduction

Engineered stone products have made a substantial impact on the natural stone industries in most countries. Clearly, they have taken a significant market share of all products used in domestic and commercial applications, be it stone, laminex, wood, or stainless steel. In Australia, marble and granite fabricators who were using about 5% of engineered product to 95% natural stone at the beginning of 2002 were abundantly aware that the drive of the market was causing a rapid shift in this ratio so that by the end of 2002 the ratio for some of these fabricators was in favour of the synthetic material. Stone fabricators who resisted the use of synthetic material were forced by competitive factors to adopt new strategies which incorporated the manufacture of this synthetic material. There are a number of reasons for this sudden surge of popularity including advertising and promotions, especially directed towards interior designers and developers. Much of this advertising compares the virtues of the synthetic product against natural stone. However, not all of the advertising is honest and it is the misrepresentations that are made verbally and in written form that has the natural stone industry objecting.

What is it?

Engineered stone, also known as quartz agglomerate, stone composite, rock solid granite, and synthetic stone is purportedly composed of about 93% natural and man-made products held together by about 7% of resin. At last count there were about 8 such products, some produced in the same factory but marketed under different names.

Reasons for popularity

There are many genuine reasons for the increased popularity of these products over other traditionally used materials. If a developer constructs a set of 48 identical units his interior design team can see huge advantages in having exactly the same colour on the kitchen bench in Unit 1 as in Unit 48. Being man-made the colour homogeneity is produced to a formula mainly through the addition of oxides and pigments. Slight variations in the texture and colour of natural stone are typically cited as negatives for designers. Moreover, being man-made the colour range is greater than for natural stone. There are bright yellows, lime greens, incredible blues, and other unnatural colours that are not represented in the stone spectrum. With such colour possibilities the interior designers can have a field day.

Because of their construction there is no question that the majority of engineered stone is tough, has high strengths, has a high abrasion resistance and is resistant to staining from most everyday household substances. However, there is also marble-based engineered stone which is significantly weaker than the quartz-based product, scratches fairly easily, and is certainly not resistant to reaction with any common food substances such as champagne, white wine, red wine, salad dressing, tomato sauce, and natural citric fruit juices.

Although launched in 1986 engineered stone is still considered a new product to the construction industry and for this reason considerable money is spent annually on advertising in a variety of magazines aimed at the home owner and the natural stone industry. Quite often the advertising is done by high profile personalities (e.g. Ita Buttrose).

It has been interesting to observe the trends for the popularity of engineered stone in different countries. For example, there was a short sharp period of interest in the product in Italy some years ago but the popularity has since waned. In Australia there has been a sudden surge of interest (particularly at a certain aesthetic or financial level) and, although opinions are divided we appear to be at, or just over, the crest of the wave. Its distribution and uptake appears to have been slower in the United States largely because it has coincided with a boom in the availability and popularity of natural stone, particularly limestone and granite. Most analysts believe that the trend for the engineered product in the Unites States is still on the up. Based on the conservative character of the average American consumer (and taste) it is generally expected to become quite popular in that country.

Composition

As noted above, most varieties of engineered stone are reported to contain mostly quartz with small amounts of broken mirrors, coloured glass, metal shavings and pearly oyster shells, This solid component usually accounts for 93% of the material but sales talk and some manuals occasionally push this value up to 97%. That leaves little room for the resin. When viewed in thin-section (petrography) it is very difficult to reconcile these high proportions of filler with what is observed because there appears to be much more than 3-7% of resin (see photographs).

In many of the textured varieties the colour and texture is derived from the rock fragments. Petrographically, these rock fragments can consist of plagioclase feldspar, alkali feldspar and quartz, with lesser amounts of muscovite and biotite mica, carbonate, epidote, chlorite and other secondary minerals. Some of the brownish aggregates contain weathering and alteration products such as hydrated iron oxide and in another there was a large crystal of metamict allanite (a mildly radioactive rare-earth-bearing epidote) that had decayed because of α-particle bombardment. A common sales pitch is that because the engineered product is man-made it, unlike natural stone, does not contain any radioactivity. This has been shown to be a deliberately misleading representation on both counts; indeed, one of the manufacturers presents radiation data (albeit with incorrect units).

In terms of hardness, there is a considerable difference between the hardness of these minerals (3-6) compared to that of quartz (7). As the grainsize increases and the proportion of minerals and rock fragments other than quartz becomes significant there has to be a decrease in the geotechnical characteristics and the ultimate performance of the product. In some engineered stone the proportion of crystalline quartz is as low as 20%. Another variety that has become quite popular in Australia contains mother-of-pearl shell fragments. These fragments are highly calcareous and as such are highly susceptible to the same reactions which affect marble and limestone (etching, staining, dissolution and scratching).

The resin used in the manufacture of engineered stone varies between manufacturers but most use polyester varieties. Some epoxies are also used but these tend to be for more specialized purposes. Small amounts of additives to these base resins allow the manufacturers to describe them as proprietary thereby concealing the base variety. Other compounds added to the resins to enhance performance include stabilizers, catalysts, colouring, oxide, UV absorbers, and cross-linking agents.

Industry concerns

Arguably, the principal concern to the natural stone industry is the degree of misrepresentation that occurs in the spoken and written sales talk. Many outlets for this man-made product are seriously stretching the truth about their product and about natural stone. A recent example had a representative provide a quotation to a long-term colleague who is well-informed in the geoscientific field. Among the misrepresentations were: (a) granite bench tops easily dissolve if hydrochloric acid comes into contact with it, (b) there is nothing in it apart from quartz and resin, (c) it has a much higher strength than granite, (d) it can be used in more applications than natural stone, (e) it lasts much longer than natural stone, (f) granite is dangerous because it harbours deadly bacteria, and (g) granite bench tops emit radon gas which is harmful to your health. It could be argued that the salesman promoting their synthetic product was poorly informed or new to the job and desperate to get sales; however, other anecdotal evidence has confirmed similar sales talk elsewhere. Among the written misrepresentations are references to their products as rock solid granite and granite bench tops. Some advertise their products as a unique form of granite - implying that it is a natural product. Others believe that theirs is the best European natural quartz agglomerate - again implying a natural product. Another describes their product as having a brilliant stone surface presumably because they have been manufactured "for nearly 30 years using some of the finest European granites". What is a "fine" granite? More ambiguity follows with a deliberate intermingling of descriptions of their product and natural stone. They continue by stating that the composition allows the **granite** to be made into sheets only 6.5mm thick. Why do the manufacturers and distributors of these synthetic products attempt to gain cudos for their materials by portraying it to be something that it is clearly not? It is not natural and will never be! It is not granite and will never be! Why not describe it and advertise it for what it is - a synthetic alternative to a natural product?

Another clear misrepresentation comes by way of the MSDS (material safety data sheet) which for one commonly used engineered product contains the following descriptions:

1.	Melting point	1610ºC	
2.	Specific gravity	2.66	
3.	Appearance	Odourless (???)	
4.	Ingredients	Crystalline silica	60-100%
		Natural metallic oxides	Balance
5.	Fire hazard	non-combustible (but note: fire-fighters should wear full protective clothing and self-contained breathing apparatus operated in positive pressure mode)	

Clearly the data provided do not pertain to the purported engineered product. Try heating one of these products to just 1000ºC (a very hot fire or oxy-acetylene torch) and see whether it is combustible or not and experience the medically undesirable vapours that are emitted!

Geotechnical comments

When it comes to the technical data that are published for engineered stone it is also abundantly clear that there is a chronic lack of knowledge and understanding of the numbers and what they mean. Unfortunately, this is not just applicable to the synthetic products but also to natural stone, The laboratory people doing the testing don't know much about the products they are testing and the manufacturers don't know much about the methods of testing and the significance of the numbers. Give the numbers to an accountant or a journalist for publication and what have you got?

It is always interesting to observe the numbers that are published, the techniques that are used, the standards that are employed, and the units that are used. Quite often the units are omitted for various reasons, the main one of which appears to be ignorance. Also of great interest are the testing programme and the test results with respect to their comparisons with natural stone. Some of the manufacturers have dug deep to find obscure standards by which to test their products and developed a new vocabulary to describe some of their products. Some have used standards that appear to be more applicable to other products. If they see that need to challenge natural stone why not use the standards that typically apply to stone.

Undoubtedly one of the principal reasons for the advertisers to list as many tests and results are to bamboozle the uninitiated and, for that matter, the vast majority of people involved in construction (architects, engineers, builders, and designers). To properly understand the geotechnical tests and the meaning of the number is a specialized area and requires an intimate knowledge of the product as well as the testing procedures. The interpretation of results should not be left up to those construction people nor to a laboratory technician.

When it comes to testing the engineered stone or natural stone it must be multiply emphasized that there are many ways of manipulating results so as to provide the most outstanding result (to be entered in a table). This is very obvious when inspecting test results done in overseas laboratories. For example, when testing the compressive strength of a product (to ASTM C-170) the manufacturer is almost certainly likely to choose one from their range of products that is known to have superior strength. When subjecting 5 samples to compression in the dry state there will be a range of values. Similarly, when subjecting another 5 samples (of a specific size) to compression in a saturated state there will be another range of values. Which value is the manufacturer going to use - the single highest one of course, irrespective of any other circumstances.

Because of the diversity of testing methods employed on different continents it provides some licence to manipulate numbers so that they appear smaller or larger than the results for natural stone or for a competitor. Americans prefer to quote the relevant results in PSI (rather than MPa) because the numbers are so much bigger. Doesn't 10,430 PSI sound so much bigger than 71 MPa? Incidentally, 71 MPa for compressive strength quoted by one manufacturer is only about 60% of the l**owest** value recommended for granite (if used in construction) and only a little higher than for some marbles and high-density limestones. And doesn't the coefficient of thermal expansion of 1,36 x 10^{-5} inch per ^{o}F look so much less than that for average stone. And wow, how accurate are their results for density when they quote their numbers to the fourth decimal place. Does that show technical excellence or an ignorance of the significance of numbers in relation to what is being tested? But I am confused about the value of 2082kg/cm^2 given for the results of a freeze/thaw test and a maximum hardness for the scratch test of 7.5 when the hardest component is only 7, and the resin much less than that.

Another company has a novel way of presenting the technical data on a strongly speckled background which is distracting to the reader. An inspection of the results shows that there is limited useful information for the interested consumer. For example, they advise that the product is "anabsorbent" (presumably meaning non-absorbent) yet tests were carried out for frost resistance and, surprise, surprise, found to be resistant. Their product was also resistant to cigarette embers, chemical agents, and sudden changes of temperature, to add to scratch, stain, and heat resistant. The coefficient of linear thermal coefficient was listed as 27.6 (27.6 what?) and the impact resistance as 5.9 joules. How is a consumer to be adequately informed by these "results", especially when there are no comparisons available for either a similar product or natural stone?

It seems that another manufacturer is equally confused by expansion coefficients of their product (or the adhesive that is required) stating that one or the other has a value of 25x10 m/m/ºC. That is one hell of a value (in the English version). Similarly, another manufacturer gives a range for their coefficient of thermal expansion of 239 to 341. Is it so difficult for suppliers to get test data correct?

An examination of the geotechnical tests that have been carried out for one variety of engineered stone shows that there appears to be a substantial difference between the results for water absorption presented by the supplier (0.04 wt.%) and an independent laboratory (0.14 wt.%). That is a difference of 350%! Of additional interest is the 4-5 hardness (scuff-tough) given for a common variety of engineered stone. If it contains the purported 93% of quartz and glass (with hardness's ranging from 6 for glass to 7 for quartz) how is it possible mathematically to get a hardness of 4-5 on Mohs scale? And if the result given has been determined as such then it is certainly not very resistant to scratching and abrasion.

In relation to the content of natural radionuclides a manufacturer has supplied results which show that for a new element in the periodic table (RA) the content is less than 120 Bg/kg. Presumably they are talking about the element Radium (Ra) that is measured in microcuries in the US and bequerel (Bq) in Europe. In isolation, a value such as this has little relevance because radon emanates from all the materials used for the floors, ceilings, walls, etc. It depends on the radium concentration in the building materials but also on the material's porosity, humidity, permeability, and thickness. Furthermore, radon emission depends substantially on the natural material on which the dwelling is built. Putting it into context, most Scandinavian natural building stones have Ra-226 contents between 0.5 and 400 Bq/kg. Bricks made of clay have Ra-226 contents of 25 to 160 Bq/kg and concrete 5 to 160 Bq/kg. In contrast, most wood materials tested have Ra-226 contents ranging between 0.3 and 0.5 Bq/kg. Just to add to the complexity, because radon is emitted it is also measured (Rn-222) as an exhalation rate expressed as Bq m^{-2} h^{-1}. Because it is a gas, radon mixes with all other gases in dwellings and for the concentrations of Rn-222 to be meaningful it must be measured as part of the surrounding air. To do this requires a monitoring of annual mean radon gas concentration in the living area. Recommended levels for Rn-222 in existing dwellings should be below 200 Bq/m^3. Where the activity concentration of Ra-226 in any building material (including engineered stone) is more than 100 Bq/kg (see above given value), radon gas concentrations of up to 200 Bq/m^3 could be expected and should be monitored.

If not already sufficiently confused, the amount of radioactivity received by humans is typically measured as a dosage. For dosages to be recorded and monitored the radioactivity in natural building materials is measured as μSv/h (microsieverts) which is related to the gamma radiation levels in the surrounding natural foundation material as well as all building products made from natural materials (concrete, bricks, plaster walls, fill, etc). The recommended upper level for exposure to external radiation in both existing buildings and commonly frequented places outdoors, such as playgrounds, is 1 μSv/h, expressed as ambient dose equivalent rate.

Problems encountered

Since the dramatic increase in its use during the last two years the stone industry has had to come to terms with these synthetic products and, although not entirely happy, it has generated a considerable amount of revenue for those fabricators who have been prepared to change and incorporate it in their portfolio. For many it has been a rapid learning curve not only from the viewpoint of the product itself but in the many applications for which it has been used.

Chemical stability

At any visit to an active bench top processing facility (fabricator) around this country there is a high probability of being greeted by a pungent chemical odour. This unpleasant and incongruous smell (in a traditionally stone-based workshop) emanates from the cutting, grinding and polishing of engineered stone and is due primarily to the release of VOC's (volatile organic compounds). These compounds are common components of many chemical industries and many health issues related to these industries have been documented and addressed. However, their presence in the stone industry is relatively new and it is possible that our regulatory vigilance has been tardy. The curing of epoxy in engineered stone is important and manufacturers extol the virtues of their procedure. Although there should be no uncured epoxy in slabs of engineered stone by the time it is being processed there have been observations that some end-users and workers have a hyper-sensitivity to epoxy (presumably the VOC's). For example, workers in the ship-building industry who have become sensitive to the touch and smell of epoxies during work in this industry remain hyper-sensitive for many years after leaving the industry and react immediately on re-exposure. Insufficient, accurate medical information is available on the results of VOC emissions from epoxy slabs when they are exposed to sunlight for long periods (at say a long kitchen benchtop in front of a window) within domestic units that may be closed up for the majority of the time, or when hot plates and other cookware are placed on top. Even though some material safety data sheets falsely imply stability of engineered stone to 1600^0C other manufacturers warn end-users not to exceed temperatures of 150^0C for some and 200^0C for others because of the potential damage to the product. Indeed, one manufacturer recommends that for dimensional stability the slabs should always be stored where temperatures do not exceed 135^0F (57^0C). It is not uncommon to achieve surface temperatures of that order on kitchen benches exposed to the sun. It is also enlightening to examine the unpleasant decomposition products of epoxies. Even though decomposition temperatures are not achieved in domestic situations, prolonged exposure to the sun will almost certainly release VOC's. One good indicator of this is the presence of a thin film on windows in much the same way as the film that forms on the windscreens of new cars when left in hot environments without ventilation. Water does not boil until temperatures of 100^0C are approached but one of the most fundamental and universal natural observations is the generation of water vapour (steam) at substantially lower temperatures.

Another example of the chemical instability of engineered stone is its propensity to fade when exposed to sunlight. Darker colours will fade more - and more-rapidly - that the lighter colours. For example, black engineered stone will turn to a medium grey within less than three years of exposure. Fading also occurs in coloured natural stone but imagine the uproar if black granite (mostly used externally for monumental purposes) faded to such light colours. Fading, together with prolonged exposure to the natural environment, is one of the principal reasons why engineered stone is considered unsuitable for external wall cladding. Why then is it promoted as being so superior to natural stone?

Not only do dark colours change but some of the light, white and off-white products discolour to a yellowish appearance. Even though each product is coded for colour, a mis-match in colour is possible in the event that a replacement is necessary for part of an earlier construction. This clearly defeats the original purpose of product selection by interior designers and architects who craved the consistency and uniformity that they could not obtain from natural materials.

Another workshop observation has been a difficulty to polish the edging of engineered stone to the same colour as the surface. Most of this has to do with tooling and workmanship in which any excessive heating from the tool (particularly where profiles are involved) caused some "burning" which resulted in a slight lightening of the colour. Additionally, and probably for the same reasons, some fabricators experienced difficulties in producing a polished surface of the standard that approaches natural stone.

Although most of the engineered stone products are quartz-based there are some that are marble-based. The rationale for the production of an engineered stone that is weak, brittle, highly reactive to numerous domestic food products, and requires a relatively high degree of maintenance, escapes me. Similarly, some quartz-based material incorporate substances such as mirror fragments and calcareous shells. Many of the mirror fragments expose the 2-layer reflective coating. How stable is this coating? Have a look at the base and edges of any of the older mirrors in your home or ask an Australian resort where limestone bar tops in front of large mirrors were "cleaned" using inappropriately chemicals. The shell fragments (up to fingernail-size) are made of recent calcium carbonate and they are highly sensitive and reactive to any liquids that are acidic (e.g. wine, champagne, natural lemon and orange juice, salad dressing containing vinegar, tomato sauce). Once in contact with the shells reaction is rapid and will continue until sufficient of the shell has been used in the neutralization process. Even with only one application of an acidic liquid it is interesting to "feel" the loss of material.

Dimensional stability

This involves mainly the change in the size and shape of the finished product. Many situations have been encountered where dimensional changes in engineered stone slabs and tiles have resulted in costly failures. The large majority of problems and failures arise from the fact that most of the engineered stone has a coefficient of expansion about four times that of natural stone. Such large changes in dimension have to be taken into consideration during construction from many viewpoints – from its geometry, overall space, location, joint width, type of adhesive, and storage. Because the maximum slab size is about 3100mm it is commonly necessary to have joints where the benchtop exceeds that length*. Joints facilitate movement and expansion so any confinement of the engineered stone slab (such as between walls) will lead to delamination, lifting and/or warpage. Another form of confinement occurs where tap-holes have been drilled accurately and tightly. Expansion of the slab can lead to a fracturing in the vicinity of the holes.

Uneven expansion is another common mode of benchtop failure. Distributors and fabricators have learned that it is unwise to manufacture corner units from a single slab. An uneven thermal distribution over part of the benchtop can lead to complex opposing stresses which frequently cause breakage of one of the slabs. An excellent example of this is where a benchtop is installed over a dishwasher. Some dishwashers have an external plumbing system that results in localized heating of the underside of the benchtop. Even where edges have been laminated for aesthetic appeal and added strength, differential expansive stresses can lead to a sudden, scary fracture of the benchtop.

An important aspect of the high expansion coefficient of engineered stone is the requirement to use an adhesive that matches the expansion rate of the slab when fixing the slab to the carcass. Where rigid epoxies have been used (as is common for natural stone) the carcass tends to fail because the MDF particle board or chipboard are relatively weak. However, where the slab has been epoxied to another solid masonry unit, failures can occur at a number of places. Irrespective of how and where failure occurs the result is a delamination or unbonding of the slab from the substrate with subsequent movement. Some disastrous failures involving engineered stone tiles have occurred in paving applications. One recent failure in QLD involved large tiles that were laid in the foyer of a new building. Within a short period the tiles warped and bowed and delaminated from the substrate, probably in response to differential expansion rates. They were replaced with stable, reliable, natural stone. Interestingly, one manufacturer of engineered stone warns that water can cause warping of tiles.

An uneven expansion of slabs can lead to bending and warping even prior to manufacture and installation. Fabricators are required to examine slabs for bending and warpage on delivery and in at least one instance a deflection of 4mm is allowed. It is noted in the warranty conditions that for the retention of dimensional stability storage conditions are very specific (including temperatures below 57^{0}C). Fabricators are also instructed that for cut-outs it is essential that they be some distance from any joints, that they allow additional space for expansion and that all corners must be prepared with a large diameter drill to minimize the complex mechanical stresses that can arise once installed.

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