Surface and Textured Finishes for Concrete and their Impact upon the Environment

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Synopsis: Concrete has a remarkable role to play in the shaping of the environment. This most versatile of materials has enabled the growth and wealth of modern society, as much as any other material factor. Yet concrete suffers from a frequently held perception that it is a dull, boring, and lifeless material. It is about this perception, and how it can be enlightened, that this paper is presented.

1.0 INTRODUCTION

In any examination of the visual impact of concrete on the environment, it is necessary to touch on the subject from a historical perspective, before proceeding to the present; and then, to speculate about possible developments for the future.

2.0 HISTORICAL INFLUENCE OF CONCRETE ON THE ENVIRONMENT

Concrete has been used in the service of mankind for a much longer period than is generally known. Even before it's use by the Roman Empire, it had been used by the ancient Egyptians, circa 3600 BC (ref 1) for columns, which are still standing, attesting to the durability of concrete. The ancient Greeks had easily available sources of marble which gave them no impetus to develop concrete. It was not until the advent of the Roman Empire that concrete came into widespread use. The Romans had need for a material that could harness the environment. They were fortunate in having ready access to natural pozzolana, (volcanic sand from nearby Mt. Vesuvius), which they mixed with lime. This material was capable of hardening without access to the air, as '*cementae*' in bonding large masses of small stones and broken brick. Their use of this material is said to originate circa 200 BC, appearing in civil works such as ports, aqueducts and bridges to harness the environment. The Roman concrete, *opus caementicium*, gave strength and durability, even though it differs from modern concretes. The rapid growth of their empire gave need for massive works of civil engineering, and requirements for much larger buildings to assemble the growing population. Yet, all the while, the Romans did not care for the appearance of concrete, or appreciate it's visual possibilities. Concrete was covered with colourful stone facings imported from the furthest reaches of their empire, and even the more humble buildings, such as apartment houses, and *horrea* (warehouses), were faced with brick. After the Romans, concrete was to be largely forgotten, even though it had been used in the Roman wall around London, and in other far reaching parts of the Roman Empire. All the while, the procedure for the making of concrete was widely known to classical scholars, through the writings of Vitruvius (ref 2) and Pliny , who clearly described the constituents of concrete.

We then jump a millennium to find concrete being used, again.

Portland cement was invented in 1824, but its laborious and expensive method of manufacture in wood fired vertical kilns precluded its widespread adoption. It needed a further invention before the use of concrete could become widespread. The invention that was to make possible the popularisation of concrete was made in 1885.

The name Frederick Ransom does not spring readily to the mind, but his invention of the rotary cement kiln was of true significance. It resulted in worldwide popularisation of concrete. Thus, it had a much greater effect on the world economy, and the environment, than almost any other invention.

What he had achieved, was to make the production of cement vastly more economic, and of vastly better quality, than anything hitherto. Within 18 months the production of cement had reached over 10 million tons per annum in the United States alone. Huge civil works like the Erie Canal, huge dams, the Suez and Panama Canals, were made possible. The environmental impact was enormous. With the advent of steel reinforcement, concrete began to be seen as being capable of ornamental and structural work, not just as a low grade mass material. Other than concrete used as artificial stone (or cement in stucco), concrete in general was viewed as not a worthy material for exposure to view. Brickwork was to predominate, as it does to this day.

"Reinforced concrete was a nasty material for the weather of London. It was dirty looking."

This statement was made in 1923 attributed to Leverton, W.H.J. (Ref. 3). And so, generations of architects and engineers followed suit, in their attitude to concrete. An attitude that prevails until this present era.

Yet, all the while, concrete was transforming the environment, and creating the world that we know today, with it's complex infrastructure and manifold buildings.

It was the 1930's that demonstrated, for the first time, the lyrical qualities inherent in concrete when used as a plastic material in graceful form and texture.

Robert Maillart produced elegant concrete bridges that embraced the environment, Pier Luigi Nervi produced innovative ferro cemento structures of daring proportions, and the master architects, Frank Lloyd Wright, and Le Corbusier produced concrete buildings of outstanding quality. Unfortunately architects of lesser standing tried to replicate the work of the masters, without understanding how to create elegant concrete structures, and without considering the effects of weather staining on the continuing appearance of the concrete buildings. Hence, the school of 'brutalism' of the 1960's with a slavish desire to replicate the qualities of board marked concrete. This was to be the nadir of concrete, as board marked concrete came to be used widely and indiscriminately on the crudest of buildings. The legacy of this period still haunts the concrete industry today. Couple this with unfavourable publicity given to corrosion problems in concrete buildings of the 1960's, and the social problems of high-rise precast concrete public housing apartment blocks. It is fair to say that concrete has taken a beating in the press, and that the press has coloured public opinion against concrete as a finished material.

All the while, unheralded and outstanding individual concrete structures were being produced, nowhere more so than in Australia. It might be said that Australia pioneered the rapid construction of concrete high rise buildings, with world leading slip-form, and jump-form practices. These innovations, coupled with table forms for flat plate floor construction, concrete pumping and the use of precast structural elements, permit floor construction cycles of not much more than 3 days. Australian concrete expertise for high rise building construction is sought after worldwide.

Australia has what is widely claimed as the finest expression of concrete construction in the world, being the Sydney Opera House. Credit for the inspired conception of the Sydney Opera House is due to a Danish architect, Jorn Utzon; and an English engineer, Sir Jack Zunz of Ove Arup and partners. The finished result is also the product of many Australian minds and hands as well. It is salutary to think that probably the only other concrete building to compare with the lyrical form of the Sydney Opera House is currently under threat of demolition. This is the famous TWA terminal at John F. Kennedy Airport in New York, designed by Eero Saarinen.

We may not see another new concrete building to compare with the Sydney Opera House in this millennium, so we can well examine the environmental impact of this concrete masterpiece. This can precede speculation on where progress may take concrete, in the macro and micro spheres of the environment in the coming millennium.

3.0 THE PRESENT

3.1 Surface and texture finishes for concrete and their effect upon the environment.

Representative of the crowning achievement of concrete construction to date, the Sydney Opera House, has important lessons to carry forward for the designers of future concrete buildings. Firstly, it is responsive to its environment. It forms a dialogue with the sails of yachts on the harbour created by the billowing white shell concrete roofs. Interestingly, Utzon states that he was inspired by palm trees, and not sails, when he drew his curved pencil lines describing the flowing form. Serendipity triumphed, as the form turns out to be perfect in its setting.

Secondly, by raising the shells upon a brown reconstructed granite precast panelled podium, the building is seen to soar, yet the base acts as a visual continuity of the natural rock face immediately behind the building. The desirability of maintaining a relationship with the environment can not be overstated. Across from the Opera House, is the Hyatt Hotel, on the other arc of Circular Key. Here the design intent has been to provide a horizontal banded facade in tan coloured precast concrete that successfully resembles the natural banded effect of the original sandstone cliffs. The Opera House has lessons everywhere one looks in the respectful use of concrete. Open drained joints are used between precast elements avoiding unsightly visible sealant runs, yet providing scale and the necessary tolerance requirements. Design for weathering to avoid run-off and staining of concrete elements is of high order.

Utzon had an inspired attitude to concrete. He divided concrete finishes into three orders.

The first, is where concrete is visible at eye level, or to the touch, in important public areas. Here, he set out to attain the highest possible quality, with sculptural forms for structural elements, and smooth concrete finishes. Precast panels use honed reconstructed granite with an etched surface, the edges being softly radiused and pleasant to the touch. The Opera House is developing a patina of touch from countless human hands caressing the exposed concrete surfaces such as one might see on the stonework of a medieval cathedral.

The second, is where concrete is seen in secondary public areas, ie, toilets, stairs, and other functional spaces. Here, Utzon used lightly board marked concrete, but with careful control of uniformity of appearance, although no attempt was made to lighten the natural colour of grey concrete. Utzon knew that the sparkle of the sun, or lights at night on water, would compensate for any dullness of the interior spaces. The result is an honesty and consistency that is unmatched, whilst conserving a tight budget by economising on finishes.

The third, is for those spaces that the public would never see, such as back of house spaces, plant rooms and the like. Here, he was content to accept very rough formwork, thereby conserving funds for the concrete finishes used elsewhere. In context the result speaks of clear intent of purpose and a testimony to the functional activity within these spaces.

3.2 Present Developments in Concrete Finishes

Developments in concrete finishes have the opportunity to affect the environment in a visual sense, and to excite the interest of future designers. The new generation of designers, with their enhanced environmental concerns, need confidence that they can access forthright and concise information on concrete finishes.

Space permits only the most popular of these to be examined in the following areas:

Integral colouring of concrete, **treated architectural surfaces**, **and coatings**.

3.2.1 Integral Colouring of Concrete

There is potential for a colour revolution with concrete, akin to that of the 19th century textile industry, where the development of aniline dyes produced bright colours, which were previously unobtainable.. Concrete need no longer be grey. Any colour is now possible in integrally coloured concrete. The development of synthetically produced inorganic mineral (metal) oxide pigments has made this possible

Synthetically produced metal oxides differ from natural iron, chromium, and manganese oxides, derived from natural mineral sources (rocks) without chemical alteration. Such naturally occurring colour oxides are one of the oldest forms of pigmentation known to mankind. Industry has now developed synthetically produced fine particulate iron and other metal oxides that have distinctly enhanced qualities compared to natural colour oxides. These allow us to obtain cleaner, brighter shades, better colour consistency and a much larger range of colour tones than with natural oxides. Synthetic mineral oxides also offer distinct advantages in colour strength and relative brightness over the naturally occurring type, with no loss in outdoor durability. The primary metal used is iron, which is dosed with other metals and oxidised to form a wide range of colours, ranging from red, to ochre, to tan, to black.

The low cost of iron makes these colours readily affordable. Other metals are also used to achieve colours: for instance, titanium is used to create white, cobalt is used to create blue. These colorants are compatible with cement, do not reduce strength, are UV stable, and are permanent. The concrete roof tile and shake/shingle industry has been quick to utilise these oxides, for both: through-coloured and surface-coloured products. Mineral oxide pigments are also widely used in coloured factory precast concrete products, terrazzo and cement and/or lime bound washes and renders. The acceptance by the public of pigmented concrete for walls and floors, driveways, other pavements and all the other uses for concrete is very high. This is simply because of its immeasurably better appearance than drab grey unpigmented concrete.

Oxide pigments are available in three forms:
1 Dry fine powders.
2 Liquids/dispersions.
3 Granulated powders.

The more commonly used form of oxide pigments is in the dry powder form. This colorant can be mixed with cement or directly mixed into plastic concrete. Liquid pigments are more expensive but are suited to automation by being non-dusting in concrete product factory conditions where convenience may dictate this choice. Granulated powders are available also at higher cost and offer the same benefits as the liquid version. Oxide dry powder colours are also available in degradable bags for direct application to pre-mix concrete transit mixers. Mixing for 10 minutes at the fast transit mixer barrel speed is sufficient to uniformly colour the concrete.

The selection of the cement colour greatly influences the final pigmented colour appearance. Grey cements will not lend themselves as well to bright pigment colours and the appearance of light, subtle pale colours, as will off-white cements, or where the budget permits, white cements. As all white cements are imported, our economy is benefited when locally produced off-white cements are used with Australian titanium white oxide pigment. However, when specifying blacks, dark browns, dark blues, or dark reds, then grey cement may be considered preferable. Grey cement tends to 'dirty' colours of brighter hue such as yellows, oranges, light browns, and bright reds. Yellow oxide used solely, regardless of dosage will become an olive green in hue when grey cement is used. The recommendations of the oxide manufacturer should be sought in regard to the final selection (Ref. 4 and 5). . White cement or white pigmented off-white cement (being more costly), is normally used only when extremely bright colour finishes are required, generally in factory precast building facing panels, granolithic and terrazzo toppings, for floors, pavements and concrete furniture.

It should be mandatory for an architectural sample of the particular coloured concrete required to be prepared by the contractor for approval of the architect or owner.

The proportion of oxide to cement will establish the intensity of colour. The manufacturer's advice should be sought on this as the content of oxide to cement may vary from 0.1% (extreme) to 10% (extreme). Results can be extremely different at varying percentages, the usual range is around 4%-8% of the cement by weight (Ref. 6). At this latter dose range the pigment tends to completely obliterate colour variation, occurring from variables associated with unpigmented concrete, eg. water cement ratio variance and variance in appearance due to differential curing.

Progressive architects are starting to experiment with the possibilities of using oxides in concretes and renders for marblised, striated, and mixed colour effects. An interesting development is the availability of pearlescent (nacreous) colours which show 'shimmering' colour through the optical effect of thin film light interference. The myriad effects attainable have the potential to be enhanced with the application of 'rag rolled' type paint finishes and clear glazes to provide a 'depth of colour' experience on concrete surfaces (Ref. 7). Perhaps the efforts devoted by so many in the concrete industry to avoid 'mottling' may turn out to be the opposite of what the new generation of architects want. With the correct advice, and a sharing of experience, the use of oxides can lead to a much wider appreciation of concrete for its delightful visual possibilities.

Integral colouring of concrete: paving.

Oxides are also widely used for the integral permanent colouration of concrete paving, roundabouts, speed humps, driveways, as well as for patios, malls, parking lots, footpaths, entertaining areas and floors in homes; anywhere there is a need for cast-in place concrete or concrete pavers.

Pavements are coloured by:

i Dusting oxide powder mixed in ideal proportions with cement and fine aggregate onto a freshly floated plastic concrete surface, often providing patterning by the use of stencils or pattern stamping

ii Spray application of an oxide coloured acrylic polymer modified cement/sand based coating, generally used in renovating and rejuvenating existing concrete surfaces. Again, stencils are often used with this process.

Although only surface coloured, the first alternative is proving very popular and has taken market share from asphalt, brick and tile pavements. A plastic coated thin cardboard stencil may be used to pattern the concrete surface by being placed into the plastic concrete. Then two coats of a factory prepared, cement-based oxide coloured 'shake' dry-mix are applied by the 'dust-on' method and worked in with a bull float to achieve the required texture. The paper stencil is then removed to reveal the 'mortar line' pattern, which can range from 'running bond' to purpose made artwork, thus providing a choice of hundreds of patterns. The concretor then applies a protective transparent sealer to the entire area. The latter needs to be maintained by regular re-coating, and is suitable domestic driveways, paths and patios.

Stamped finishes differ from this process with substitution of the stencil by patterned rollers or pattern stamping implements to provide (generally) deeper patterning effects. Usually these stamped finishes are coloured using the dry shake method, which may be enhanced by adding a second colour in the release agent. The release agent serves the purpose of stopping the concrete adhering to the stamping tool.

Integral colouring of concrete for floors
(Polished, Honed and Glaze Coated Concrete Floors)

Concrete floors can be coloured, polished and/or sealed to provide an affordable alternative finish to traditional flooring materials and finishes such as tiles, vinyl, carpet and cork (Ref 8). Modern colourful finishes include the use of polishes, latex (water wash-up) coatings, solvent (non-aqueous) sealers, grinding to expose the aggregates, after having used oxide colours integrally and often incorporating colourful coarse aggregates. The recommended Strength Grades of concrete are N25 or

N32 compared to N20 which provide a more wear resistant surface for improved durability. The provision of adequate steel reinforcement is vital, with RF 81 or RF 82 fabric being recommended for use in house slab-on-ground to ensure that, with the provision of adequate tooled jointing or saw cutting, there are no unsightly visible cracks. A bonded coloured concrete topping may be used instead of integrally colouring the whole slab. A topping thickness of 25-40mm may be used, with 10mm to 14mm aggregate used in the concrete mix design, together with the required amount of colour oxide. Oxides of only slightly different shades mixed with cement and fine aggregate in recommended proportions may be dusted into the wet concrete surface and floated in, to achieve striking effects. It should be noted that the cost of the extra labour, travelling costs, etc. to lay the special topping may exceed the cost of providing the colour right through the 'single-step' slab. The surface of the slab may then be ground in order to see the aggregate like terrazzo, or simply steel floated to a smooth surface. This surface is sealed using a suitable transparent coating ("sealer") to give a low sheen to a glassy gloss, or simply waxed and polished. Painted logos, 'decal' transfers etc. may be used for special effect under the clear seal coat. The end result is a cost-effective floor with a high gloss 'wet look', or low sheen waxed appearance; both allergy and bacteria free and highly suitable for this day and age.

3.2.2 Present Techniques for Treated Architectural Surfaces

Traditional architectural finishes for concrete within this category include:

- cast finishes off patterned forms
- casting in grooves and reglets
- surface retarded exposed aggregate
- high pressure water jet
- acid wash (etch)
- sand and grit blasted (wet and dry)
- tooling (bush hammered etc.)
- grinding (primarily for horizontal cast surfaces)
- honing, polishing (as above)
- scabbling

Apart from cast finishes the remainder involve the removal of the hardened cement paste to expose the aggregate from the concrete surface. By careful masking, it is possible to use combinations of these techniques on individual areas of concrete to provide distinctive margins, features or patterns. For instance, margins can be created around doors and windows. It is a common practice to provide banding or cast in grooving to wall surfaces to break up any visual monotony engendered by plain uniform surfaces. This provides relief to the wall, giving a sense of depth, and capturing a masonry quality. It also tends to disguise imperfections that could spoil the appearance of a plain wall surface. By breaking up wall surfaces with different colours and textures, the effect of atmospheric staining can also be minimised. Oxide pigments may be used to provide colour that highlights or contrasts with the aggregate colour to provide bright and striking effects. The finer finishes with low texture lend themselves well to factory cast concrete units for reliable uniformity and consistency.

Present Techniques for Exposed Aggregate Surfaces

Finishes where the concrete's coarse aggregate can be seen are referred to as exposed aggregate. These fall within the category of treated architectural finishes. They are easily obtained by methods ranging from the use of surface set retarders to polishing. They include terrazzo and 'no-fines' concrete. With Tilt-Up and factory precast there are common methods of attaining exposed aggregate finishes, either face up or face down. Quite different techniques are used for each type. Sand embedment is the normal method used for face down casting, where the selected aggregate is spread in a single layer and tamped into a thin bed of sand. After pouring and lifting the panel, the sand is simply brushed off to reveal the aggregate.

For face up panels, the usual procedure is to water wash the surface to expose the aggregate. This process provides an attractive finish at low cost. Select aggregates, usually of uniform size such as 10 to 14 mm or larger, are evenly spread over the surface of the concrete immediately after the surface has been floated. The aggregate is then embedded into the surface of the concrete by means of a trammel. When the surface concrete has hardened sufficiently (enough to retain the aggregate but not fully set), the aggregate is exposed by simultaneously brushing and washing the cement matrix away with water. Large areas may require the use of a surface sprayed chemical retarder to provide a workable surface. The importance of a test panel can not be too highly stressed, as the finished result is very dependent on timing.

In the selection of any aggregate finish the designer should be cautioned by the following extract from Professor Cowan's publication (Ref 9):

"We still have not mastered the relation between aggregate size and viewing distance. At close quarters some exposed aggregate finishes look good; but from a distance, where most people see building walls, the same surfaces may appear dreary or slightly dirty".

To overcome this possibility, proposed finishes should be viewed from a distance and under different lighting conditions. When making final selections sample panels therefore, should not be small. There is opportunity for developing large scale patterns using combinations of finishes including say; sandblasted areas with cast-in grooves, possibly with painted or tiled sections for coloured highlights. It is preferable not to mix different coarse aggregate sizes in the concrete mix design as the smaller sizes may settle to the bottom resulting in a non-uniform appearance. However, this can be avoided by specifying a lower than normal slump or obtaining an ideal consistency or viscosity by means of certain chemical admixtures such as superplasticisers. These allow concrete to be easily produced with ideal rheological properties preventing settlement and segregation of the coarse aggregate with less water.

The effects of weathering of these finishes needs be borne in the minds of the building's design team, as localised atmospheric pollution effects can lead to disfiguring staining. This will certainly be the case should there be run-off from external ledges onto walls. In urban areas subject to high levels of pollution it is desirable to use a concrete matrix that is darker than the exposed aggregate. This can be achieved with dark pigments of various hues. A range of clear sealers are available to minimise dirt build up, whilst a honed and polished surface is an assured method of avoiding this problem.

There are several suppliers of proprietary plastic form liners which are available in an extensive range of relief patterns which allow concrete surfaces to be permanently cast with the impression provided by the form liner.

A typical range is provided by the Burke Company of the USA (Ref 10), and available in Australia. This, and other companies, offer various types of form liners, in dozens of alternative patterns. Patterns include: timber boarded, brick, natural stone, slate etc.

Form liner types include:

1 Patterned PVC flexible sheeting, with a wide range of patterns (reusable up to 40 times).
2 Rigid ribbed PVC sheets, with various rib widths (reusable up to 10 times).
3 Disposable polystyrene patterned liners.

Some suppliers can source Australian made patterned liners of silicone rubber, foamed styrene and polyurethane, fibreglass, or metal types. Timber has been a traditional form used to profile concrete, via boarded or other means. In retrospect, after many years of persevering with timber and all the problems of variable results, the author is only too pleased to recommend that proprietary plastic formliners be used in lieu - even if a timber boarded pattern is required (now available in plastic).

Problems associated with timber formwork can include:

1 Variable porosity of the timber, leading to variable absorption of the concrete's mix water. This results in noticeably lighter and darker patches in the stripped concrete.

2 Difficulty of ensuring water tightness of the formwork, leading to leakage of mortar and a resulting disfigurement of the concrete.

3 Lignin and other organic substances in the timber can result in discolouration of the concrete.

4 When timber forms are reused several times with unpigmented plain concrete there may be a distinct variation in shade of the stripped concrete from dark on initial pours, to light on subsequent pours, as the form timbers absorb and retain bleed water from the face of the concrete. The use of certain multi-functional and water reducing admixtures, particularly superplasticisers, can help.

Plywood forms can be given sand blasted surfaces for the purpose of patterning concrete, but the extent of texture given to the concrete is hardly worth the effort. If timber is used it is considered essential to apply a suitable form release oil several times to 'take up' all the porosity.

3.2.3 Present Developments in Coatings for Concrete

Coatings for concrete may be conveniently classified as follows:

1 Mineral oxide pigmented opaque cementitious and/or lime based brushed washes or cement renders.

2 Conventional 100% acrylic or properly formulated high pH resistant paints.

3 Transparent or semi-transparent stains. For extended fade resistance these may be specified by the architect to contain UV resistant mineral oxide pigments (inorganic) as previously mentioned. Nothing can prevent coatings containing organic pigments from fading and/or darkening.

Coloured Oxides for Concrete Coatings
Coatings incorporating coloured oxide pigments are available for vertical and horizontal concrete surfaces in the form of washes and paint-on renders as well as for various applications for paving including those pavements which have been stencilled, stamped, and topped for 'polished' concrete floors.

Washes and Renders
Coloured washes and renders applied to walls were to fall into disfavour as exposed brickwork and solvent based ready mixed paints became dominant. Part of the reason for this may be the effect of efflorescence which sometimes occurs in and on cement based products. Cement based (cementitious) and lime based washes and renders may be subject to efflorescence, or white surface streaking. This is a thin surface deposit, which can produce the unsightly effect known also as calcium salt 'blooming'. This usually appears at early ages after setting, then ceases. It is especially prevalent where permeable cement/lime applied finishes of the traditional type are subject to constant wetting and drying. Parts of the world where there is a high level of acid rain pollution do not have the problem with efflorescence to the same degree, as this is removed gradually by the products of this pollution. Efflorescence can make black appear grey; and, red appear pink. Hence, the Victorian era's preference for stone coloured washes and renders, (being pastel coloured) are less prevalent to disfigurement by efflorescence. Although there is no definite process or product that will guarantee that efflorescence will not appear, there are products such as additives, which if combined with the process of curing (moisture retention) may significantly reduce the incidence.

Quality coloured cement based washes, brushable screeds, and paint-on renders are available as factory formulated products. The better types are impermeable, incorporate efflorescence inhibiting admixtures and contain moisture retention agents with permanent inorganic oxide colours bound in flexible polymer reinforced hard calcium and aluminium silicates. These are virtually maintenance free, have the advantage of being flexible to some degree, offer outstanding adhesion, and markedly improved resistance to efflorescence, compared to earlier generations of coloured washes and renders. Such finishes in natural ochre tones have recently shown a remarkable resurgence in the popularity of 'Tuscan' and 'Santa Fe' architectural styles now appearing at the expense of uncoated exposed brickwork (Ref. 11).

Paints as Coatings for Concrete
These are the predominant finishes for exterior concrete walls of building. This is bought about by the development in recent years, of reliable and durable surface coating systems. Painting of concrete in years past was unreliable due to the inability of earlier generations of paint films, based on organic resin or other organic binders, to be adequately resistant to UV, high pH surfaces and allow the transpiration of moisture without lifting or bubbling of the paint film. Pigments available at the time did not have the degree of colour fastness from the use of synthetic mineral oxides (which can be specified by the architect) that is expected in the exterior paints of today. The binders such as vegetable oils and resins made from these had poor resistance to alkaline surfaces such as concrete. Modern paint systems can vary from conventional acrylic paints having a low, dry-film, thickness to high-build elastomeric coating systems. Proprietary high-build (high dry-film thickness) coatings provide a range of textured finishes, ranging from fine to coarse. These can be sprayed, rolled, brushed, or trowel applied. Providing that the concrete surfaces are essentially flat and true, only minimal patching is required to fill blow holes and surface imperfections prior to application of the

selected coating system. Modern patching compounds are designed to be compatible with the matching paint system and allow feathering to imperceptible edges.

surface finish as per AS 3610 (Ref. 12). Class III requires considerable patching to achieve an acceptable surface finish. Hence, it is always preferable to specify Class II. Class I concrete finishes

Stains
There are a variety of chemical non film-forming stains for concrete, yielding finishes ranging from

of impregnating the concrete, especially in low strength, uncured concrete. These colour the hardened cement paste resulting in mottled and 'drifted' tones. With experimentation pleasant effects can be

Uniform colouration can be difficult to achieve due to the low and sometimes variable absorption of concrete. It is said that "the beauty of the chemical stain is that it is inconsistent" (Ref 13). Stains can

Stains have been used successfully in the USA on highway retaining walls, bridges and barriers because of the following environmental effects:

- stains can tie all the surfaces together with a more uniform colour effect.
- stains can increase the visibility of the concrete surfaces for safety.

Stains are designed to soak into the concrete, so the appearance can vary markedly, depending upon the absorbency of the concrete (which may not be uniform). Due to the inconsistency of the outcome, stains are unlikely to approach the popularity of other concrete finishes. However, for those who wish to experiment, they potentially offer considerable scope.

Coatings for concrete paving
Stains are a popular way to colour concrete paving, and new techniques are being developed to enhance the density of colour and evenness of application. Solid colour finish coatings are also available, such as the spray application of properly formulated sand/cement acrylic polymer (resin) modified coloured coatings. These are often used to rejuvenate existing concrete surfaces. In this case, success depends on ensuring a strong, sound dust-free, clean concrete substrate, generally using a three step cleaning process for existing concrete. New concrete surfaces require that any surface laitance be removed at a minimum of 24 hours after placement. Stencilling can be carried out using stencils made from materials such as plastic foam, polycarbonate, fibreglass, cardboard, paper or other suitable composite stencil patterns. Corporate logos and names may be included in the overall decoration. Following the spray application of the oxide pigmented coating, the stencil is removed, then two coats of a protective low sheen, satin or glossy clear coating is applied. This alternative process is more suitable for pedestrian traffic than vehicular due to the need to maintain the protective layer from wear. These methods can result in attractively finished coloured paving, having the benefit over segmented paving that weeds will not grow in the "joints".

Surface coloured patterned concrete finishes are now seen to be moving beyond paving, to their use in finishing tilt-up concrete walls, and to replace ceramic tiles. Ceramic wall and floor tiles are being replaced by decorative concrete paving with "tile' joints formed by tape prior to the application of the sprayed finish. – suitable for domestic balconies, bathrooms, laundries, and patios.

4.0 THE FUTURE INFLUENCE OF CONCRETE ON THE ENVIRONMENT

An exciting world of colour, texture, and form for concrete is becoming increasingly available to the architectural designer. There will be increasing future emphasis on the total environmental aspects of building; including the visual appearance of buildings but also, their effect upon the macro environment.

The author believes that the future of concrete can be seen through the eyes of students, with their heightened concern for the environment, and their expressive attitude to the use of materials. As a result of lecturing at the schools of architecture throughout Australia, the author finds the creativity of students to be amazing. Particularly exciting is the students free expression in colour and texture, using concrete. Students at the University of Queensland, and at the Royal Melbourne Institute of Technology now make sample concrete panels as part of their course. The students draw inspiration from disparate sources, producing concrete panels that reflect 'open heart surgery', 'onion rings', rusty surfaces, marble, etc. Architectural students are working in conjunction with engineering students to develop concrete mixes that utilise waste products such as rice husk ash, broken windscreen glass, and even macadamia nuts.

Apart from the visual impact of concrete on the environment, the materials used in building construction affect the environmental role of buildings themselves.
Buildings consume two-thirds of all the electricity produced in advanced countries, and account for two-thirds of carbon dioxide emissions (the materials of their construction have only a minor affect on the total energy usage over the life of a building). Concrete has natural advantages that will be called upon even more in future, such thermal storage, durability, recyclability, and avoidance of environmental damaging chemicals. Governments are responding to changed community attitudes to increasingly mandate environmental responsibility. Concrete has to be positioned as the material of choice, with its positive attributes promoted.

The opportunity exists for all concerned with the manufacture, site processing and specification of concrete, to achieve a bright future for concrete wherever so desired. The positive impact of concrete on the visual environment, and the environment as a whole, will only be enhanced.

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