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CORROSION RESISTANT FLOORING

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CORROSION RESISTANT FLOORING

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Previous papers[1,2] in this journal have dealt with the design and construction of concrete floors for commercial and industrial use. The aim of this paper is to illustrate the methods available to protect concrete floors under aggressive conditions, particularly corrosive conditions. Since most BRANZ (Building Research Association of New Zealand) experience has been with food industry flooring, particularly in the meat industry, there is a bias towards food industry practices. (In the course of BRANZ investigations a listing of New Zealand specialist flooring materials and their suppliers has been compiled[3]. Comparative tests (based on freezing works (i.e. export abattoir conditions)) on some named commercial materials have been made[4,5,6,7].

Factors which affect flooring include spillage, corrosion, abrasion, and fluctuating temperatures; in addition there is a requirement for slip resistance, and for hygiene (table 1). Corrosion of concrete flooring is a major problem. Acids, sugars and some salt solutions (e.g. sulphates) react with the lime ($Ca(OH)_2$) in the cement binder of concrete, weakening the bond to the aggregates and ultimately disintegrating the concrete. Strong alkalis will attack other constituents of the cement. Corrosion of the reinforcing steel within concrete caused by the penetration of water or salt solutions has been spectacular in some instances. The rate of attack varies, and is dependent on how rapidly corrosion products are removed (e.g. by washing or leaching) and the temperature (reaction rates approximately double with every 10°C temperature rise).

A comprehensive listing of the effects of chemical and food materials on concrete was recently compiled by ACI Committee 515[8] and is too long to reproduce here. A partial listing has been included in New Zealand Concrete Construction[1].

The various methods of concrete protection will be dealt with in turn. The major emphasis is on corrosion, although other properties will be indicated.

Concrete as a sacrificial topping

One solution to the problem of corrosion of concrete flooring is simply to replace the corroded concrete as necessary. This approach has been quite common in the past; in some dairy factories cement plaster floor toppings were replaced every one or two years because of lactic acid corrosion.

The sacrificial use of concrete has the advantage that flooring replacement is relatively cheap, and that the technology is widely known, which is useful in more remote areas. On the other hand unless processing is seasonal, a considerable disruption to production at frequent intervals is inevitable.

Sacrificial floor toppings should ideally be unbonded, with an impermeable membrane inserted between topping and base slab to prevent corrosion of the structural slab. Bonded toppings have been used in the past. This carries the risk of penetration of corrosion into the base concrete slab if maintenance is not carried out frequently.

The use of concrete as a sacrificial topping in the meat and dairy industries is now less common.

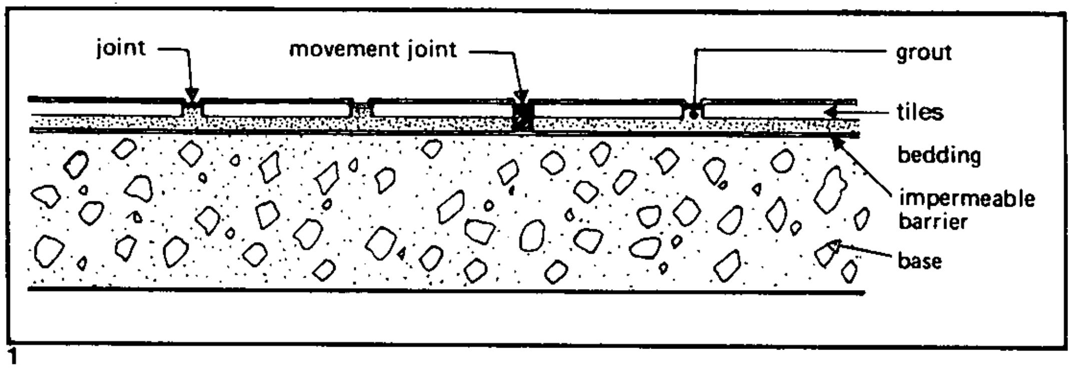
Surface hardeners

Solutions of sodium silicate, or magnesium or zinc silicofluoride, or drying oils (linseed or tung) have traditionally been used to increase the abrasion resistance of concrete floors, and lessen dusting. Current practice is to regard these treatments as emergency measures to treat poor quality floors, but their effect on a good quality floor is marginal. A surface hardener cannot turn poor concrete into good concrete. Similar comments apply to their effect on the corrosion resistance of a concrete floor; very little improvement in performance will be gained over an untreated floor.

Floor paints

Floor paints are usually based on chlorinated rubber, polyurethane resin, or epoxy resin. They are applied over the concrete by roller or spray, several layers being applied to ensure an adequate seal. Dried sand may be scattered into the paint between coats to provide slip resistance.

Floor paints have good adhesion to concrete and are resistant to mild chemical exposure. They are easy to maintain and have a considerable cost advantage over most sophisticated ceramic tile and polymer concrete flooring systems. The major limitation is the thin layer, which is easily damaged by impact or heavy abrasion. Chlorinated rubber paints have an upper temperature limit of 80°C, whilst prolonged exposure of epoxy or polyurethane paints to steam or high temperatures (over 100°C) will cause their failure.



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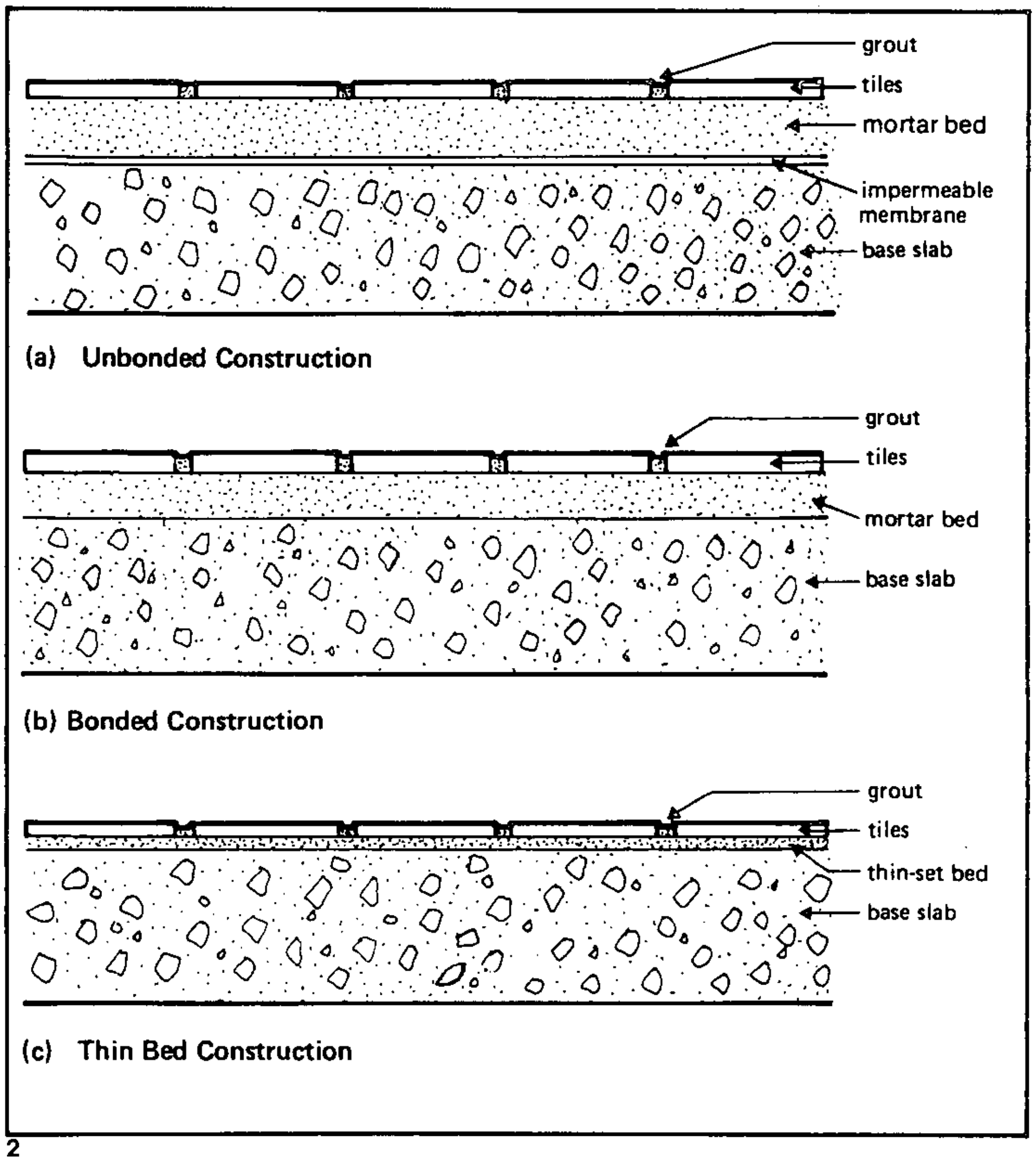

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Table 1. Process factors affecting floor toppings

Spillage	Water or liquids from processing or cleaning
Corrosion	Food materials, processing chemicals, cleansers and sanitisers
Abrasion	Handcarts, trolleys, forklifts — rubber, plastic and steel wheel shod
Impact	Load movement; dropping of product, packaging, tools, machinery
Fluctuating temperatures	Excessively high or low temperatures or sudden temperature changes
Slipperiness	An additional factor affecting personnel safety
Hygiene	Floors must be easily cleaned.

Fig. 1. Definitions.
Fig. 2. Ceramic tiled floor toppings.

Polymer or rubber latex cement toppings

These trowel applied toppings are up to 5 mm thick and bonded to the concrete base. They are based on either a thermoplastic latex (e.g. PVA, acrylic, polyvinylidene chloride), a thermosetting latex (epoxy or polyester), or a natural or synthetic rubber latex combined with either portland or high alumina cement. Since they contain cement, their use is restricted only to very mildly corrosive conditions although they do provide enhanced resistance to abrasion and impact.

Latex/cement toppings are easy to lay, and also are comparatively cheap.

Toppings containing PVA or polyvinylidene chloride are water sensitive, and break down under prolonged wetting, which limits their use to dry conditions or intermittent immersion. The use of thermosetting latexes results in a more durable topping but at greater expense.

Ceramic tiles

The traditional method of preventing corrosion of concrete floors was to instal a protective layer of ceramic tiles over the concrete. Terminology commonly used in ceramic laying is given in figure 1.

Ceramic tiled floors are less popular than formerly, mainly on cost grounds, but they still find considerable use in the dairy industry and in institutional kitchens. Polymer concretes have largely replaced the use of ceramic floor tile systems in freezing works.

Materials

Ceramic tiles in general are resistant to chemical attack. A ceramic tiled system will therefore only be as corrosion resistant as its bedding and jointing materials; these should consequently be chosen with care. The abrasion and impact resistance of ceramic tiles increases with their degree of vitrification. This is traditionally measured as being inversely proportional to water absorption. Where different brands of ceramic tile unit may be of equal vitrification, thicker units provide more protection.

Ceramic tile types: Ceramic floor tiles can be divided into several types (see BS 1286[9], BS 3921[10]).

1. Floor tiles are up to 20 mm thick, have a relatively smooth surface, and are normally manufactured by dry pressing. Floor tiles are too thin to be used in abrasion or impact prone areas. Their use should be confined to foot traffic or light rubber wheeled trolley areas where there is little risk of impact. Fully vitrified or vitrified unglazed tiles can be used.

2. Quarry tiles (or floor quarries) are up to 35 mm thick, and usually have more surface texture than floor tiles. They are made by extrusion. Thicker units, which are manufactured in the same way as quarry tiles, are sometimes known as paviors. Quarry tiles can be used in areas of moderate, soft wheeled traffic which may have a high density of foot traffic. Areas subject to heavy, steel wheeled traffic should be paved in units with a water absorption no greater than 5%, and a thickness of 75 mm or greater.

3. Engineering brick is a special thick (> 50 mm), vitrified ceramic unit used in areas of severe abrasion or impact.

Slipperiness in wet situations can be countered by laying tiles with special profiles such as nibs, studs or pyramids. In general, smaller patterns are more effective than coarse; flat topped projections more than pointed. Most patterns pond water and may be difficult to clean.

Bedding and jointing materials: There are a number of types of bedding and jointing materials available for ceramic tile systems. The simplest of these are based on portland cement concrete. Slightly more acid resistance can be gained by substituting high alumina cement for portland. Rubber latex cement based mortars offer more protection than straight cement/sand mortars. Better corrosion resistance still is offered by epoxy, polyester or furan mortars, which comprise synthetic resin plus an inert mineral filler. These polymer mortars are expensive, and more difficult to use.

A general guide to the corrosion resistance of mortars is included in table 2. The performance of commercial materials of any particular type (e.g. epoxies) is highly dependent on their formulation. Experience of individual commercial materials is obviously of value in this area.

Laying methods

There are several methods of laying ceramic tiles which take into account varying degrees of resistance to corrosion, impact and abrasion. BRANZ has described laying methods in general[11]. Hertl[12], and the British Ceramic Tile Council[13] have covered the specification of corrosion resistant ceramic tiled floors. The main laying methods are outlined below, and illustrated in figure 2.

In unbonded construction an impermeable membrane (asphalt, rubber or plastic) is laid over the concrete base to protect it from corrosive liquids. On top of the membrane is formed a bed of mortar between 12 and 20 mm deep into which the ceramic tiles are laid (fig 2a). The bed may be composed of cement/sand, latex/cement, or a polymer mortar depending on the degree of corrosion resistance required. Grouting may be carried out using the same material as the bed. Alternatively a common practice is to a use cement/sand or latex/cement bed and a polymer mortar grout to give corrosion resistance at a lesser cost than using polymer mortar throughout. If the grout is damaged, however, corrosion of the bed may be rapid.

Bonded construction may be carried out using the same methods as above, but eliminating the impermeable membrane so that the mortar bed is bonded directly to the concrete base slab (fig 2b). In this case there is no second line of defence against corrosion of the base and it is very important that the tile grout and bed remains intact.

Latex/cement or polymer mortars can be used to lay ceramic floor tiles in a thin (5 mm) bed direct onto the base slab, or onto a levelling screed (fig 2c). Grouting is normally carried out with the same material. Again it is important that the grout and the bed are not breached, since corrosion of the concrete base will follow.

Polymer concretes

Background

The terms 'polymer mortar' and 'polymer concrete' describe mortar or concrete-like materials in which aggregates are bound by synthetic resin rather than by portland cement. Polymer mortars use sand as aggregate, whereas polymer concretes incorporate larger aggregate as well. As well as the basic polymer, modifiers such as plasticisers, thixotropes or diluents may be included in a flooring formulation. The general term polymer concrete is often used to describe both types. They have found widespread use in food processing over the past 15 years.

Polymer concretes are applied to a concrete base, by means of brushes, rollers or sprays for thin coatings, and trowels or floats for thicker ones. Preparation of the material for laying can be a three-component operation involving the combination of resin, hardener (or "catalyst") and aggregate, but two-component mixes, where the hardener is incorporated with the filler during manufacture, are also available.

The corrosion resistance of polymer concretes in general terms is

Table 2. Guide to resistance of floor toppings and ceramic tile bedding and jointing materials to corrosive liquids

	Water	Organic acids	Mineral acids Dilute	Mineral acids Conc.	Alkali	Sul-phates	Animal and vege-table oils	Organic solvents	Sugar
Portland cement mortar	VG	P	VP	VP	G	P	P	G	P
High-alumina cement mortar	VG	P-F	VP-P	VP	F	G	F	G	F
Polymer/latex cement	P-G	F	P-F	P	P-F	G	F	P-G	F
Rubber/latex cement	G	F-G	G	P	G	F-G	F	P	F-G
Chlorinated rubber	VG	P-F	G	P-F	F-G	G	P	F	G
Epoxy resin	G	F-G	G	F	F-G	G	G	F-G	G
Furan resin	VG	G	G	F-G	F-G	G	G	G	G
Polyster resin	G	F-G	G	F	F-G	G	G	P-F	G
Polyurethane resin	VG	G	G	F	VG	G	G	F-G	G

VG = Very good; **G** = Good; **F** = Fair; **P** = Poor; **VP** = Very poor.

the same as outlined in table 2. As a rule, polymer concretes do not respond well to prolonged exposure to temperatures in excess of 100°C, particularly when that exposure is wet (steam or boiling water).

The influence of formulation on the properties of the finished polymer concrete topping should be borne in mind. For these systems, in particular, evidence of a successful installation in the same or a similar processing environment is of great value.

Materials

Polymers. The polymers commonly used are epoxies, polyesters or polyurethanes. These materials have many basic features in common. They harden in a short time (1-2 hours) after mixing with the catalyst or hardener, the hardening rate decreasing with decreasing temperatures. Hardening is an exothermic (heat releasing) process much more critical in bulk (i.e. mixers) where heat output and hence hardening rate can increase, than in thin layers (floors).

Amine-cured epoxies have good chemical resistance (alkalis, acids, solvents), but are moisture sensitive during laying. Amide-cured epoxies are more moisture resistant, withstand physical abuse (abrasion, impact) and have better adhesion than amine-cured. They do not have the same degree of chemical resistance.

Polyesters are cheaper than epoxies or polyurethanes and have a higher acid but lower alkali resistance than those materials. Polyesters cure more quickly, however their adhesion is poorer. Their greatest limitation in the past has been excessive shrinkage. In practice, with highly filled materials such as polymer concretes, and new formulations, this has largely been eliminated.

Polyurethanes may be formulated as thin, unfilled elastomeric coatings which are flexible enough to bridge hairline concrete cracks, or as thicker filled toppings. These can also incorporate a degree of flexibility.

Aggregates. High grade aggregates such as silica, aluminium oxide (corundum) or silicon carbide (carborundum) are usually used. Good quality natural aggregates may be employed for some applications. The purpose of the aggregate is twofold. It serves to dilute the expensive polymer, reducing the cost of the end material. It also reduces the coefficient of thermal expansion of the material to a value closer to that of concrete (unfilled polymer may have up to three times the thermal expansion coefficient of concrete). Aggregates also affect the handling characteristics of the topping.

The proportion of polymer to aggregate ranges between 1:2 and about 1:8 in most commercial formulations. Higher ratios (e.g. 1:12) are difficult to mix and apply. They may also be porous because there is insufficient polymer present to fill the voids between the aggregate. This porosity would make the concrete base susceptible to attack and reduce the mechanical properties of the topping. Even where such a topping is surface sealed, there is risk attached since great reliance is placed on a thin polymer surface layer which can be impacted or abraded.

Laying methods

There are three normal methods of laying this type of floor topping, depending on the composition and filler level of the resin. Recommended practices for the laying of polymer concrete flooring have been issued[14,15]. Concrete surface preparation, and workmanship are of great importance in obtaining a successful installation; most failures observed in New Zealand have been due to preparation/workmanship short-comings rather than material faults.

A number of considerations bear on

Table 3. Summary of floor treatments/properties

Flooring material	Abrasion	Corrosion (see also Table 2)	Impact	High temp. (100°C)	Ease of application	Ease of repair	Cost
	Property (Resistance to)						
Concrete (sacrificial)	P	P	F	G	VG	P	L
Surface hardeners	P	P	F	G	VG	P	L
Latex cement	F	P-F	F	P-F	F	F	L
Floor paint	F	F	P-F	P	VG	VG	L-M
Ceramic tile systems							
floor tiles	F	VG*	F	VG*	P	P	M-H
quarry tiles	G	VG*	G	VG*	P	P	H
engineering brick	VG	VG*	VG	VG*	P	P	H-VH
Polymer concrete							
self-levelling	F	G	F	P	F-G	G	M-H
trowelled (< 6mm)	F-G	G	F	P-F	P-F	F-G	H
trowelled (> 6mm)	G	G	G	P-F	P-F	F-G	H

P = Poor; **F** = Fair; **G** = Good; **VG** = Very good; **L** = Low; **M** = Medium; **H** = High; **VH** = Very high.

* Resistance dependent on selection of jointing and bedding materials.

the selection of the laying method. The major factor is that under no circumstances should the topping be breached, since it is in effect a resistant "skin" over a less durable material, concrete. If thin (less than 6 mm thick) coatings are selected they may readily be perforated by impact or abrasion damage. At the very least, this would mean accelerated impact or abrasion damage to the base, however, the way is also opened for corrosion of the concrete base. Hosing damage, where high pressure water can penetrate the topping/concrete interface, is also likely. Thus, if thin toppings are selected they should be associated with a high degree of inspection and maintenance. Thicker trowelled toppings provide more protection, at greater initial cost but with less maintenance.

Thin layers (surface coatings) are essentially floor paints. These were described earlier.

Self-levelling polymer mortars have a polymer:aggregate ratio not more than 1:4. They may be poured onto the floor and squeegeed or trowelled roughly to level. Subsequent flow of the topping levels it completely, removing all trowel and squeegee marks and leaving a layer up to 3 mm thick. This system is more expensive in resin content, but has lower laying costs. Care is required in establishing floor levels before laying. Slip resistance may be obtained by incorporating sand, or scattering coarse (0.3–1 mm) sand, carborundum, or aluminium oxide over the surface. A balance must be found between slip resistance and cleanability.

Trowel applied polymer mortars or concretes are more heavily filled with an aggregate content of 1:4 to 1:9 (polymer:aggregate) and are laid in beds up to 10 mm thick. To ensure their adhesion to the base, a priming coat of the unfilled polymer/hardener may be applied to it, and the topping laid over it while it is still tacky. These toppings are hand trowelled for small areas, or on larger areas a vibrating trowel, vibrator, or screed vibrator may be used. A sprinkled non-slip layer of aggregate may be incorporated if the final finish will not provide sufficient slip resistance. Often a sealing coat is applied to the finished topping.

Concluding comments

An attempt has been made to illustrate the range of protective treatments available for concrete floors subject to adverse conditions, with an emphasis on corrosion resistance. The various treatments and their general properties are summarised in table 3. More detailed descriptions of the methods are available in the references.

The degree of protection required by any floor depends upon adequate determination of the operations taking place which are liable to damage it. Meat industry and dairy industry conditions have been summarised[16,17,18,19].

The final selection of a protective system must include considerations such as: first cost against maintenance, availability of materials/standard of workmanship locally (ceramic tile and polymer concrete systems are highly specialised), possible alternate uses of the building space, and projected life of the processing facility or building.

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