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An investigation into the feasibility of formulating 'self-cure' concrete

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To achieve good cure, excessive evaporation of water from a freshly cast concrete surface should be prevented. Failure to do this will lead to the degree of cement hydration being lowered and the concrete developing unsatisfactory properties. Curing can be performed in a number of ways to ensure that an adequate amount of water is available for cement hydration to occur. However, it is not always possible to cure concrete satisfactorily. This paper is concerned with achieving optimum cure of concrete without the need for applying external curing methods. The feasibility of curing concrete by adding water-soluble chemicals during mixing that reduce water evaporation in the set concrete, making it 'self-curing' is discussed. The chemicals' abilities to reduce evaporation from solution and to improve water retention in ordinary Portand cement was monitored by measuring weight-loss. x-Ray powder diffraction and thermogravimetry measurements were made to assess whether any improvement in water retention was matched by an increase in degree of cement hydration. Initial surface absorption tests and compressive strength measurements were made to determine surface permeability and strength development, respectively. The scanning electron microscope was used to determine the influence of the admixtures on cement paste microstructure. It was found that two of the chemicals studied had a significant 'self-curing' effect. One of these chemicals enhanced hydration further than simply by means of water retention. A possible explanation of this behaviour is given.

1. INTRODUCTION

To achieve the most beneficial properties of a concrete, it is necessary for it to be cured properly [1]. Poor curing can reduce significantly the performance expected from the specified water/cement ratio and cement content. Although the codes of practice [2] and other national specifications [3] make provisions for 'adequate curing', it is generally recognized that there are major practical difficulties in achieving even the minimum specified curing on-site [4]. This paper is concerned with achieving optimum cure without external assistance.

Enough water needs to be presented in a concrete mix such that sufficient hydration of the cement can take place. An adequate degree of hydration is attained by having a w/c ratio of a least 0.38 [5]. However, even if a mix contains enough water, any loss of moisture from the concrete will reduce the initial w/c ratio and result in incomplete hydration of the cement. This may lead to detrimental concrete properties.

When concrete is left in air, water evaporates from its surface. A number of factors influence the rate of evaporation. These factors include air temperature, wind speed, relative humidity, type of cement, w/c ratio, and the initial temperature of the concrete [6, 7]. Evaporation of water from freshly placed concrete results in detrimental features such as plastic cracking and a friable surface [8]. The poor surface characteristics lead to high permeability in this region. Work conducted previously in these laboratories has found that the near-surface characteristics of concrete influence durability strongly [9–11]. High surface permeability increases the risk of carbonation occurring and heightens the susceptibility of any embedded steel to corrosion, especially in high chloride environments, and increases the risk of sulfate attack.

After the concrete has set, evaporation can lead to shrinkage cracking [8]. However, the main problem is that of 'self-desiccation' [5]. The unhydrated cement particles rely on capillary pathways running throughout the concrete to supply them with water. If the concrete loses water the capillaries within it can dry out or become cut off by shrinkage. The reduction in the water transportation capability of the concrete is never fully reversed by the addition of more water [12].

Poor concrete strength and surface quality can be avoided by good curing practices. This can be achieved in a number of ways, with varying degrees of effectiveness. Curing methods involve either the introduction of additional water to the concrete surface for a period of time after placing or the reduction in the rate of evaporation from the surface.

Water may be introduced by ponding (the immersion of the exposed concrete surface), spraying or by using coverings of wet hessian or burlap [13]. Ponding and spraying are the most effective curing techniques, although they present a number of practical problems. The use of coverings is an expensive technique both in terms of the materials used and labour [4].

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One way of reducing the rate of evaporation of water from a concrete surface is by covering with plastic sheeting [12]. This technique is, however, limited to horizontal surfaces, and sheeting is liable to be displaced by wind if inadequately applied. Delaying the removal of formwork can also be used to retain some water, although it is seldom practical to do this for any length of time. Water retention is best achieved by the application of curing compounds that act as a barrier to evaporation. These compounds are usually solutions of resin in solvent or emulsions of resin in water and are applied by spray, brush or roller [14]. The time at which the compounds are applied is critical [4], and application to inaccessible areas, such as vertical surfaces, can be difficult, if not impossible.

A common feature of all the existing curing techniques is that they require 'external action' to ensure that they are correctly applied and maintained [15–17]. A significant improvement may be achieved, however, if an 'internal curing system' can be adopted for concrete. An internal curing system would have several advantages, primarily the production of a better quality concrete surface, greater turnover and the reduction in costs of operatives. It is conceivable that such a system could be created by the introduction during the mixing state of a chemical that would reduce water evaporation in the set concrete and make the concrete effectively 'self-curing'.

2. BASIC PRINCIPLES

In a situation where a pure liquid A is held in a container a certain quantity of molecules of A will evaporate until the vapour pressure is such that the liquid and vapour phases are in thermodynamic equilibrium. This is shown in Fig. 1(a). Equilibrium is achieved when the chemical potentials (free energy) of these two phases are equal. The relationship between the chemical potential of the liquid phase and the vapour pressure above it is given by the equation

$$\mu_A^*(l) = \mu_A^\theta + RT \ln(p_A^*/\text{atm})$$

where $\mu_A^*(l)$ is the chemical potential of the liquid, μ_A^θ is the standard potential, R is the gas constant, T is temperature, p_A^* is the vapour pressure of pure A, and atm is atmospheric pressure [18]. If this closed system is opened, then molecules of A will be free to escape beyond the original container boundaries, as shown in Fig. 1(b). As the vapour molecules disperse, further evaporation of molecules is required to maintain equilibrium.

The depression of the chemical potential of a solvent by a solute was the basis of the work conducted. With two components, solvent A and solute B, the reduced chemical potential of component A is given by the equation

$$\mu_A(l) = \mu_A^* + RT \ln(p_A/p_A^*)$$

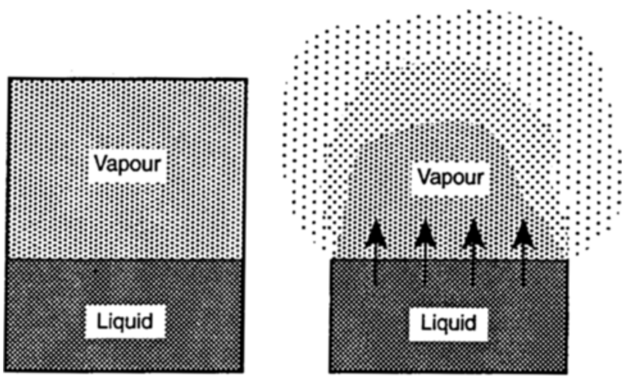
where $\mu_A(l)$ is the chemical potential of component A in the mixture, and p_A is the partial vapour pressure component A above the mixture. This equation was developed further by Raoult, who stated that, in the case of an ideal solution, the partial vapour pressure of a component in a mixture is equal to the vapour pressure of the pure component multipled by its mole fraction x_A in the liquid; thus, Raoult's law is

$$p_A = x_A p_A^*$$

Only ideal solutions, in which the interactive forces between all solution molecules are equal, obey Raoult's law over all compositional ranges, although all solutions obey it when the composition of the mixture approaches pure A or pure B.

Fig. 2 shows how the vapour pressure p of an ideal solution and the partial vapour pressures of its components alter with the mole fraction of component A when component B has a lower vapour pressure in its pure state than pure A. If component A is the water in a concrete mix and component B is a water-soluble chemical, it is apparent that, theoretically, the addition of such a chemical would lead to a reduction in the vapour pressure of water above the concrete. This would lead to less water being lost from the surface.

It was also anticipated that the reduction in solvent



a. In a closed system the vapour pressure above a liquid reaches a level at which the two phases have equal chemical potential and are therefore in equilibrium.

b. When the closed system is opened the vapour disperses. Continuous evaporation takes place in an attempt to reach equilibrium.

Fig. 1 Closed and open liquid–vapour systems.

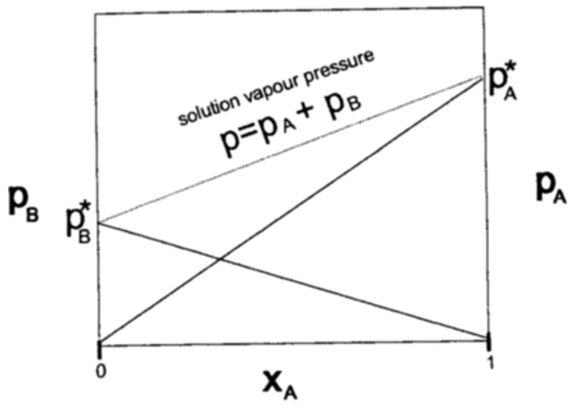


Fig. 2 Variation of total vapour pressure p of ideal solution and partial vapour pressures of solution components (A, B) with mole fraction of component A.

Table 1 Summary of main characteristics of chemicals

Chemical	Main characteristics of chemicals				
	Type	Molecular weight	Maximum solubility at 20 °C (wt%)	Functional group	
				Hydroxyl –OH	Ether –O–
A1	Synthetic	200	100	Yes	Yes
A2	Synthetic	1 500	100	Yes	Yes
A3	Synthetic	5 000	100	Yes	Yes
A4	Synthetic	10 000	60	No	Yes
A5	Synthetic	20 000	65	Yes	Yes
A6	Natural	>20 000	5	Yes	Yes

partial vapour pressure would be reduced further if hydrogen bonding existed between solute and solvent molecules. A hydrogen bond is a weak bond that is formed between hydrogen atoms in a compound and strongly electronegative atoms in other molecules [19]. The slightly positive charge which the hydrogen atom develops makes it capable of being electrostatically attracted to electronegative atoms. Hydrogen bonding is particularly strong between hydrogen atoms and atoms possessing lone-pairs of electrons, such as oxygen. For this reason, the chemicals selected for the purpose of lowering water loss from concrete were water-soluble polymers possessing either hydroxyl (–OH) or ether (–O–) functional groups. The way in which hydrogen bonding occurs between these functional groups and water molecules as shown in Fig. 3. This chemical associated reduces the chemical potential of the molecules involved, and therefore leads to a reduction in vapour pressure.

Selected chemicals are discussed in this paper and will be referred to as chemicals A1, A2, A3, A4, A5, A6. Chemicals A1–A5 are synthetic water-soluble polymers, whereas chemical A6 is a natural chemical. The characteristics of these chemicals are listed in Table 1. These chemicals were added to water at a range of concentrations. The results presented for each chemical are those obtained with the concentration that produced the optimum results.

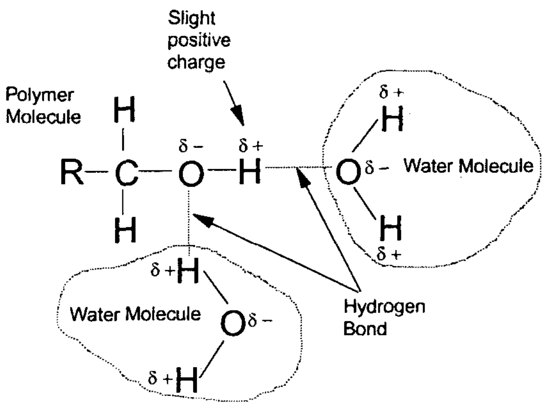


Fig. 3 Hydrogen bonds between water molecules and an –OH group on a polymer molecule.

3. THE RESEARCH PROGRAMME

Before beginning to plan a programme of testing, it was considered important to define the functions of a self-cure chemical. It was felt that any improvement in water retention produced by a chemical should also lead to

(a) an increase in the degree of cement hydration, and
(b) improved physical concrete properties achieved as a consequence of (a).

It was also considered important to determine whether any improvement in water retention was due to the combined effect of Raoult's law and hydrogen bonding, or whether interaction of some sort between the cement paste and the chemical additive was in some way responsible.Therefore, water retention was assessed by measuring weight loss due to evaporation both from solutions containing the chemicals and from ordinary Portland cement paste cubes.

Degree of hydration measurements were performed on cement paste samples that had been frozen at predetermined ages to stop hydration and then freeze-dried to remove the free water. The degree of hydration was measured using x-ray powder diffraction (XRD) and thermogravimetry (TG) methods [20].

To determine whether any improvement in degree of hydration led to concrete having better physical properties, tests were conduced on concrete containing the chemicals. An ordinary Portland cement concrete of 28 day design strength 30 N/mm^2 was used throughout. The most important physical properties in this instance were considered to be compressive strength and permeability. Compressive strength tests were conducted along with the initial surface absorption test (ISAT). ISAT measurements give an indication of concrete surface quality [21] and hence the concrete's potential durability [9–11].

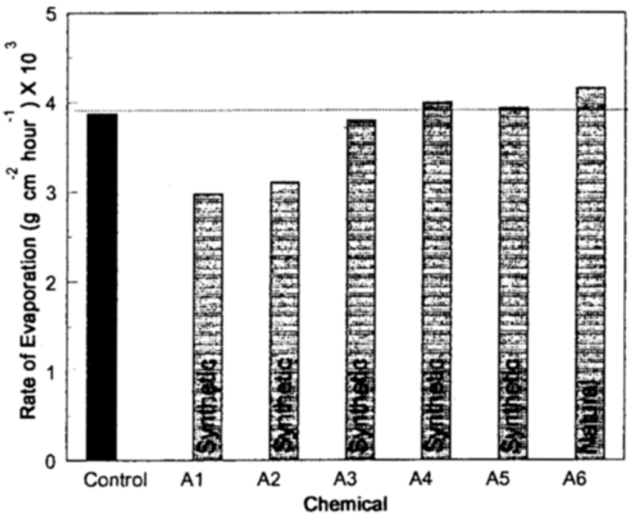


Fig. 4 Evaporation rates measured over a 24 h period from solutions kept at 20°C and 15%RH.

4. EVAPORATION FROM SOLUTION

The rates of evaporation from solutions containing the chemicals kept at 20°C and 15% RH are compared with the control in Fig. 4. It is apparent that the behaviour of some solutions does not match that anticipated. High molecular weight chemicals do not alter the rate of evaporation from solution, and in some cases produce an increase in rate of evaporation. This suggests that the behaviour of solutions containing such chemicals deviates a great deal from that of an ideal solution, and consequently the solutions do not obey Raoult's law.

Low rates of evaporation are displayed by solutions containing low molecular weight admixtures, with solutions containing chemical A1 having the lowest rate of solution evaporation. It would appear that the solutions containing lower molecular weight chemicals do obey Raoult's law.

5. EVAPORATION FROM CEMENT PASTE

Fig. 5 shows the weight loss caused by the evaporation of water from paste cubes kept in air at 20°C/55% RH over a 28 day period. It also shows the weight loss measurements obtained for three control pastes. These controls were either stored in air, or cured in water or sealed in plastic film.

The evaporation trends displayed by the solutions are not reflected in these paste results. Although the best results are still obtained by the use of chemical A1, the ability of the intermediate molecular weight polymers (i.e., A3 and A4) to produce increased water retention is improved in pastes. Whereas only solutions containing chemicals A1, A2 and A3 showed lower evaporation rates, the addition of all 6 chemicals to pastes led to some degree of improvement in water retention. The extent to which water is retained is also increased: the rate of evaporation from a solution containing chemical A1 is approximately 25% less than the control, whereas the weight loss from a paste containing the same chemical is almost 50% less than the air control.

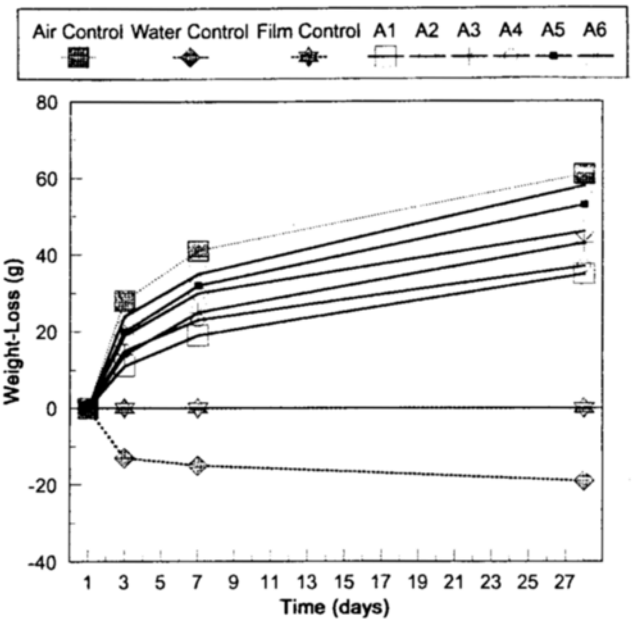


Fig. 5 Weight loss from paste cubes.

The difference in moisture-loss behaviour observed in pastes compared with that observed in solutions suggests that water retention mechanisms other than those occurring in solutions are effective in pastes. One possible way in which water is being retained in pastes by the higher molecular weight chemicals is by physical blockage of pores. Chemicals A2, A3, A4, A5, and A6 are solids at room temperature. Therefore, as water evaporates from a cement paste, these chemicals will come out of solution in the surface pores, as shown schematically in Fig. 6. The build-up of these polymers would probably restrict the pathways for further moisture

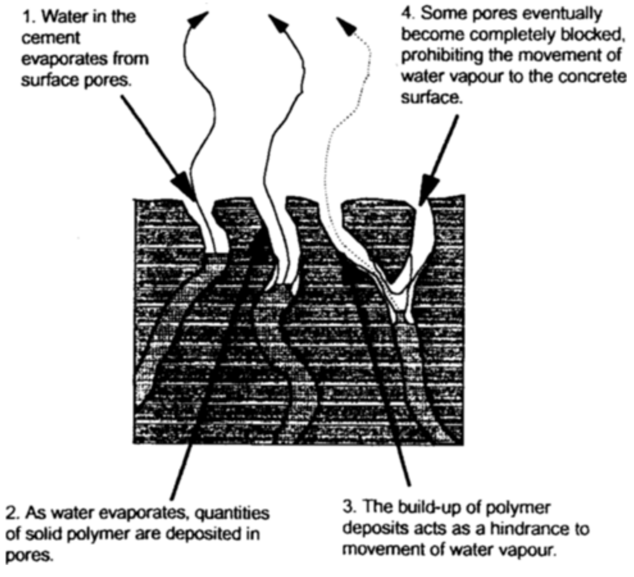


Fig. 6 A possible water retention mechanism for solid water-soluble polymers.

loss, and water retention would be increased. Furthermore, the lower molecular weight polymers exhibit hygroscopic properties which further prevent moisture loss from the capillaries or pores.

6. DEGREE OF HYDRATION

A measure of degree of hydration can be obtained by monitoring the hydration of the alite phase (impure C_3S) in ordinary Portland cement by XRD. Fig. 7 shows how the C_3S phase content of pastes containing the chemicals changes over a 28 day period as the phase reacts with water. The plots were obtained by measuring the intensity of a C_3S x-ray diffraction peak obtained from paste specimens relative to an aluminium external standard peak. The change in C_3S content for the 3 control pastes is also shown.

The weight loss produced by dehydration of calcium hydroxide (CH) between 500 and 600°C was measured using TG. From these measurements the percentage of CH present, with respect to the weight of cement paste sample at 1000°C, could be calculated. The results are shown in Fig. 8. CH is a product of hydration of the alite (C_3S) and belite (C_2S) phases, and so this measurement can be used to determine the degree of hydration. It should be noted, however, that CH undergoes carbonation and so the quantity present begins to decline after some time if the paste is exposed to carbon dioxide in air. The carbonation of CH also means that pastes stored in air cannot be compared with pastes cured in water or sealed, since these are not in contact with carbon dioxide.

Most of the XRD and TG measurements correlate reasonably well with each other, although the measurements obtained from paste containing chemical A5 do not. It was found that this was because chemical A5 vaporizes at around the time that CH dehydrates during TG measurements. This means that the TG measurement of CH is not valid. For this reason, the comments made concerning the hydration performance of pastes containing this chemical are based only on XRD data.

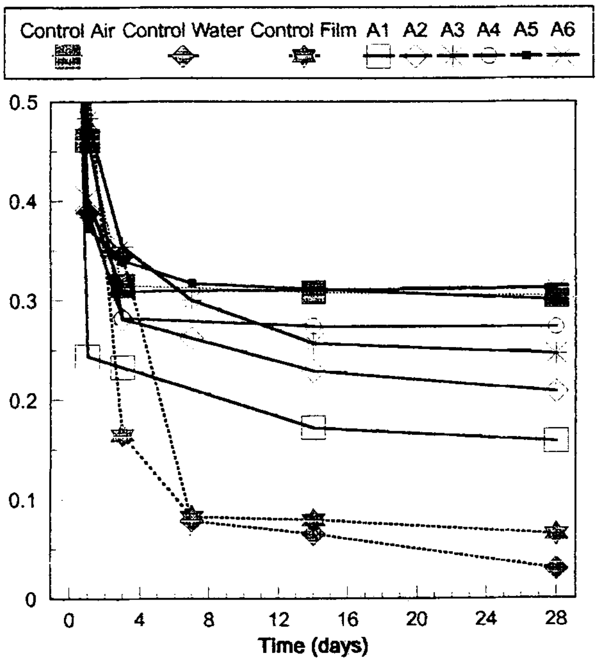


Fig. 7 Alite peak intensities measured by XRD.

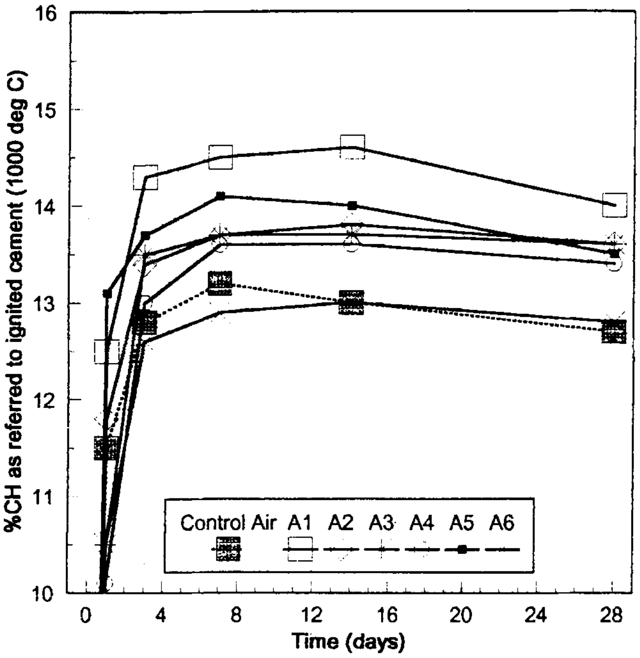


Fig. 8 Percentage of CH in cement pastes measured by TG.

Hydration of C_3S in the air cured control paste has ceased after 3 days due to lack of water. Hydration proceeds until around 7 days in the sealed control paste, whereas hydration is still taking place after 28 days in the paste cured in water.

What is immediately apparent from these results is that increased retention of water does not necessarily lead to a higher degree of hydration. For instance, although chemical A5 produces excellent water retention in the cement paste, it achieves a degree of hydration only slightly greater than that of the air cured control. However, the addition that has the best effect on water retention, chemical A1, is also the one that produces the best increase in degree of hydration.

It is important to note that the increase in degree of hydration displayed by the paste containing chemical A1 is somewhat greater than the improvement in water retention. This suggests that chemical A1, as well as increasing the degree of hydration by the retention of water, is also enhancing cement hydration in some other way such that more of the retained water is taking part in hydration reactions. A possible mechanism will be discussed later. The paste with chemical A1 shows the most C_3S phase hydration (Fig. 7) and the most CH content (Fig. 8). It is probable that chemical A1 is advantageously altering the hydration of the cement either by retaining water and /or changing the mechanism of cement hydration. Pastes containing chemical A1 would be expected to have the least porosity and hence carbonate to a lesser degree, compared with the control.

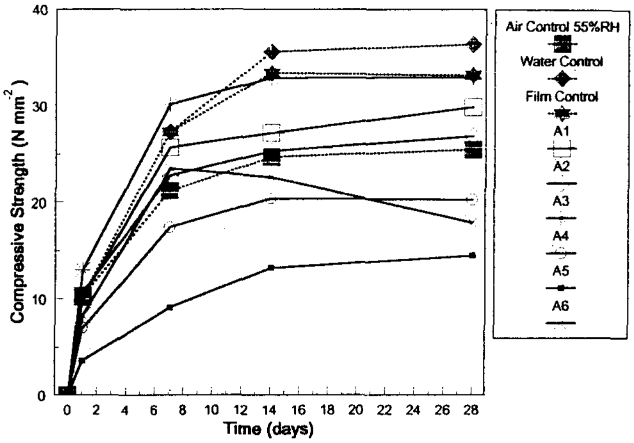


Fig. 9 Development of concrete compressive strength at 20°C.

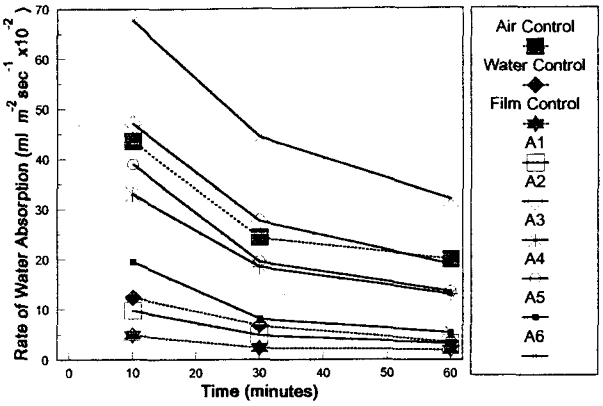


Fig. 10 ISAT measurements (28 days).

7. COMPRESSIVE STRENGTH DEVELOPMENT IN CONCRETE

The development of compressive strength in concrete cubes containing the chemicals and also in controls stored in air, cured in water or sealed in film is shown in Fig. 9. The presence of chemicals A4, A5 and A6 in concrete have a detrimental effect on concrete strength compared with the air cured control. Chemical A2 appears to have little effect on concrete strength, despite the increased degree of hydration produced. The improvement in strength development observed in the concrete containing chemical A1 is as would be expected considering the improvement in degree of hydration. Chemical A3 has the effect of increasing compressive strength throughout the 28 day period, and the strengths attained are comparable with those of the film sealed control. The reasons for this outstanding improvement cannot, however, be attributed wholly to a self-curing effect, since the water retention and improvement in hydration produced by this chemical are not high enough to be solely responsible.

8. CONCRETE SURFACE QUALITY

ISAT measurements performed on 28 day old concrete cubes at 10, 30 and 60 min subsequent to the start of the test are shown in Fig. 10. The sealed control shows the lowest rate of water absorption, indicating the best quality concrete surface. The addition of chemical A1 to a concrete has a remarkably good effect on surface quality. It produces a surface which is almost as impermeable to water as the film-sealed control, and superior to the water cured control. Chemical A5 also has a very favourable influence on the concrete surface. However, since it did not produce an increase in the degree of hydration, the improvement is most likely due to the physical presence of the chemical at the concrete surface. Both chemicals A3 and A4 also produce a reduction in surface water absorption, and this reduction corresponds well with the increase in degree of hydration that is achieved by their addition. The presence of chemical A2 has little effect on surface quality in comparison with the air cured control, and the natural product, chemical A6, has an undesirable effect.

9. SUMMARY OF RESULTS

The results of the paste water retention, degree of hydration, compressive strength and ISAT measurements are summarized in Table 2. Although the addition of any of the chemicals leads to at least one favourable cement paste or concrete attribute, the only chemicals to perform all the functions expected of a 'self-cure chemical' to a significant extent are chemicals A1 and A3.

Table 2 Effect of the chemicals in paste or concrete with respect to the air stored controls

Chemical	Cement paste/concrete attributes			
	Water retention	Degree of hydration	Compressive strength	Surface quality
A1	Very good	Large increase	Large increase	Extremely good
A2	Good	Increase	Slight increase	No change
A3	Good	Increase	Considerable increase	Improvement
A4	Very Good	Slight increase	Decrease	Improvement
A5	Slight improvement	No change	Very poor	Very good
A6	Slight improvement	No change	Poor	Poor

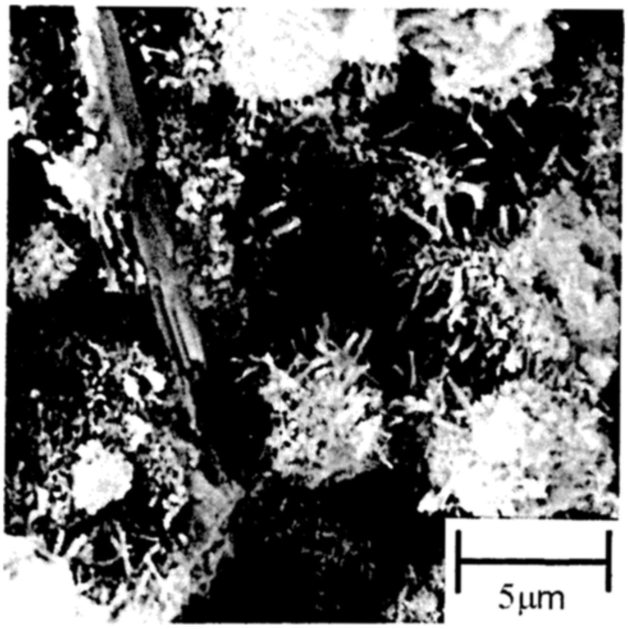


Fig. 11 Fracture surface of the control cement paste after 1 day at 20°C.

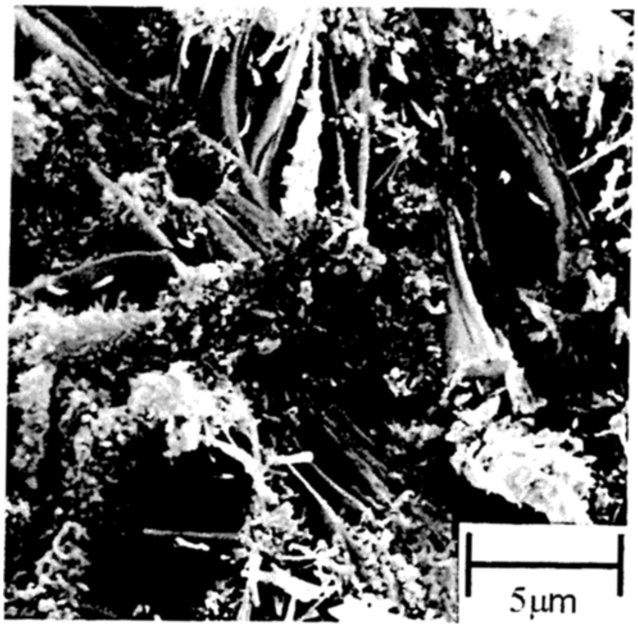


Fig. 12 Fracture surface of a cement paste containing chemical A1, after 1 day at 20°C.

10. EFFECT OF THE CHEMICALS ON CEMENT MICROSTRUCTURE

During the cement hydration study it became apparent that the nature of CH was being altered by the addition of chemical A1. It was felt that determining the influence of the chemical additions on cement paste microstructure could aid in explaining some of the observations made previously. Fracture surfaces of 1 day old freeze-dried paste specimens were examined in the SEM.

Fig. 11 is an SEM micrograph showing the microstructure of the control cement paste. The smooth, flat structure running from the top to the bottom of the picture is a crystal of CH edge on. Around this crystal can be seen the cement grains, covered with hydration products. Figs 12–16 are micrographs of cement pastes containing chemicals A1–A5, and Figs 17 and 18 are both of cement paste containing admixture A6. Comparing the micrographs of pastes containing chemicals A2, A3, A4 and A5 with the control it can be seen that they have little effect on the cement paste microstructure in terms of the morphology of the hydration products. However, chemicals A1 and A6 are noticeably different from the control, and these micrographs are discussed below.

The nature of the CH crystals in the paste containing chemical A1 is significantly different from that of the control. In the control the CH crystals have a hexagonal plate-like morphology. However, in the presence of chemical A1 the crystals are thinner, having an almost flake-like morphology, and appear to be more numerous. The increase in number and morphology of CH crystals suggests that the presence of chemical A1 has an effect on the way that this compound comes out of solution and forms in the paste. This could well explain the additional hydration enhancement produced by the use of this chemical.

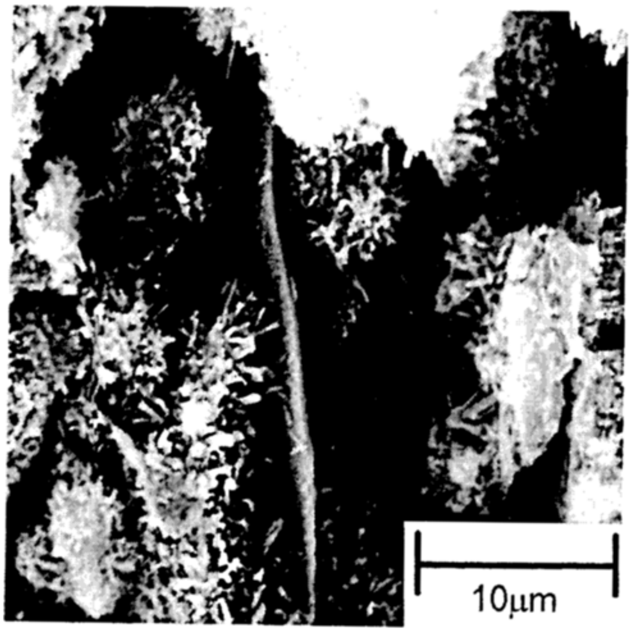


Fig. 13 Fracture surface of a cement paste containing chemical A2, after 1 day at 20°C.

Normally CH comes out of solution when its concentration in water reaches a point of supersaturation [22]. It is possible that chemical A1 has the effect of reducing the concentration at which CH comes out of solution and that consequently the nature of the crystals produced is altered by this change. Lowering the concentration at which CH begins to come out of solution would encourage the further formation of CH. This would explain the improvement in degree of

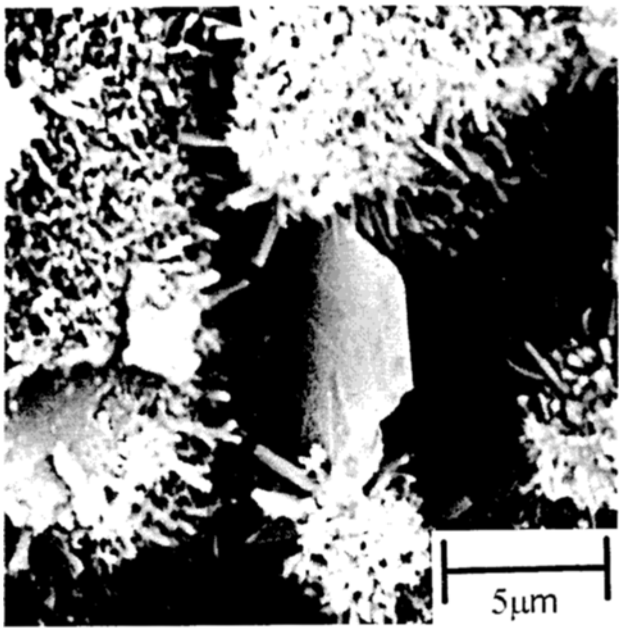


Fig. 14 Fracture surface of a cement paste containing chemical A3, after 1 day at 20°C.

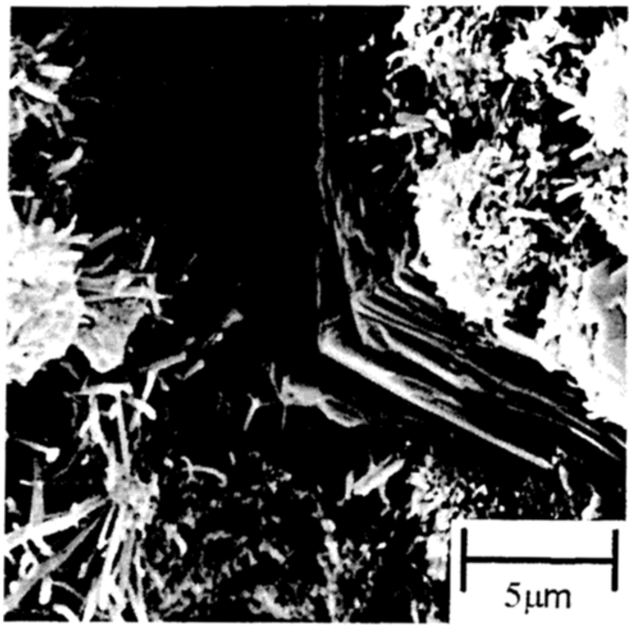


Fig. 16 Fracture surface of a cement paste containing chemical A5, after 1 day at 20°C.

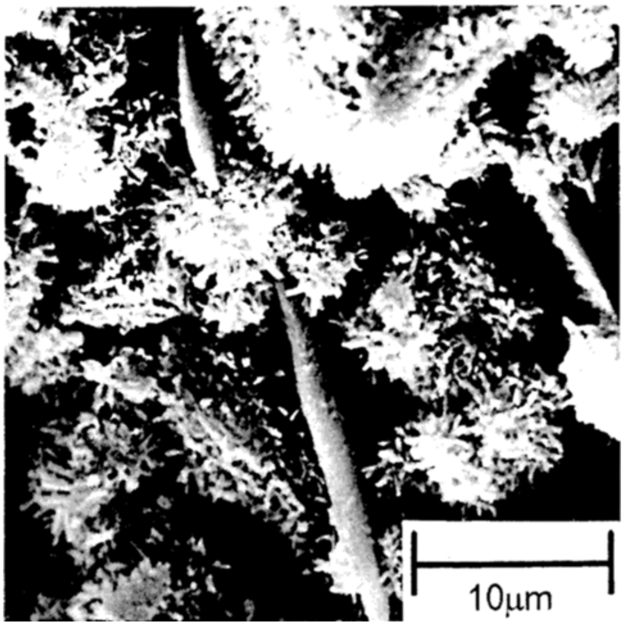


Fig. 15 Fracture surface of a cement paste containing chemical A4, after 1 day at 20°C.

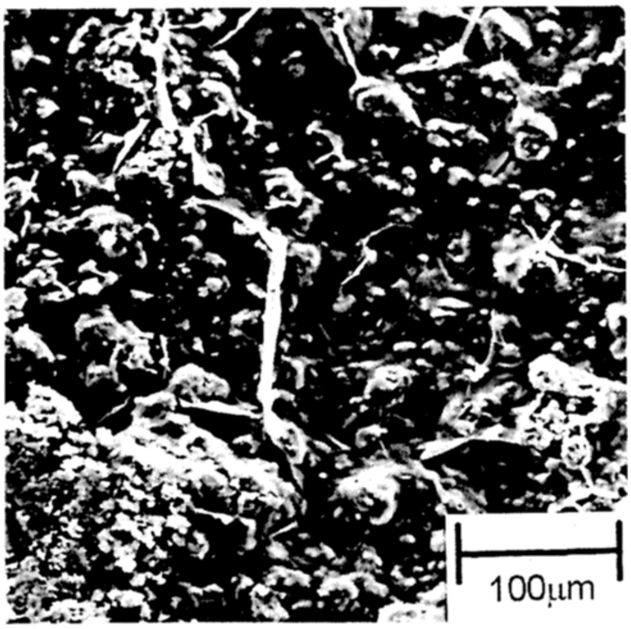


Fig. 17 A film-like material covering cement grains in a cement paste containing chemical A6, after 1 day at 20°C.

hydration beyond that expected when this chemical is used.

Figs 17 and 18 are SEM micrographs showing the microstructure of cement paste containing the natural polymer, chemical A6. There is a film-like material (presumably consisting mainly of chemical A6) covering large portions of the cement paste fracture surface, as shown in Fig. 17. This film appears to be acting as a physical barrier to cohesion between adjacent hydrating cement grains. Cement grains in close proximity to the film seem to have hydrated very little. Fig. 18 shows a number of cement grains in contact with the film. These grains have fewer hydration products on their surface compared with those of the control (Fig. 11). It seems reasonable that this film is largely responsible for the low compressive strength measurements and poor ISAT results observed with concrete containing this chemical.

The strength of concrete containing chemical A6 decreases after 7 days, as shown in Fig. 9. This is possibly due to two effects that weaken the concrete microstructure. First, the presence of the film preventing free movement of moisture within the concrete leads to

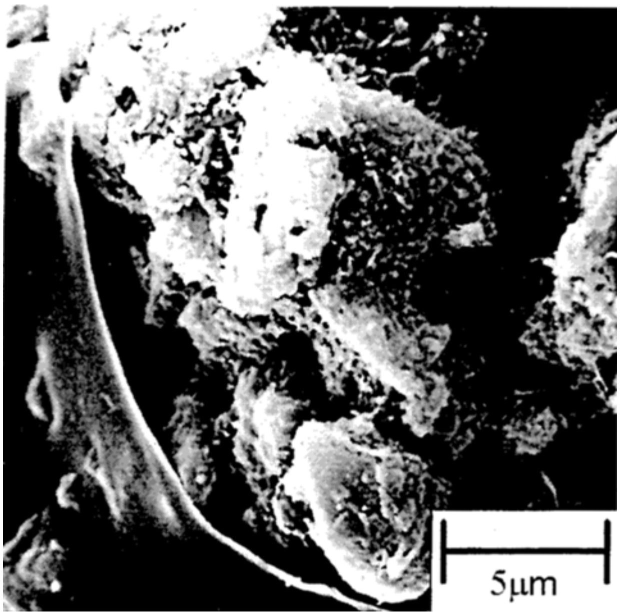


Fig. 18 Cement grains in contact with film present in cement paste containing chemical A6, after 1 day at 20°C.

inadequate hydration of the cement. Second, desiccation of the film itself by the hydrating cement grains in its near vicinity weakens the binding character of the hydration products.

11. CONCLUSIONS

1. It is possible to improve the retention of water in cement paste by means of a chemical addition to the mix.
2. Improved water retention does not always lead to a proportional increase in the degree of cement hydration and hence better concrete properties, although in many cases it does. The two chemicals which perform all the functions of a 'self-cure chemical' are A1 and A3.
3. A number of the chemicals improved concrete surface quality greatly. In particular, chemical A1 has a highly favourable influence on the surface characteristics.
4. The increase in degree of hydration of the cement in pastes containing chemical A1 in relation to the control is higher than the improvement in water retention that this chemical produces. Therefore, it appears that the presence of this chemical is enhancing hydration beyond that achieved by water retention alone.
5. Chemical A1 is probably enhancing hydration by reducing the concentration at which CH begins to come out of solution.

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RESUME

Etude de la possibilité d'établir une formulation permettant d'assurer la cure du béton

Pour réussir une cure satisfaisante, il faut empêcher une évaporation d'eau excessive à la surface d'un béton fraîchement coulé. Faut de quoi, le taux d'hydratation du ciment se trouvera abaissé et le béton manifestera des propriétés défavorables, tels une qualité superficielle médiocre et un développement insuffisant de la résistance à la compression. La conservation peut s'effectuer de différentes façons en sorte d'assurer une teneur en eau suffisante pour que l'hydratation du ciment puisse se produire. Cependant, il n'est pas toujours possible, pour des raisons économiques, d'assurer une cure satisfaisante du béton.

Dans cet article, on traite de l'obtention d'une cure optimale sans recourir à des méthodes extérieures de protection. On discute de la possibilité de protéger le béton de l'évaporation d'eau au moyen de produits hydrosolubles incorporés au moment du malaxage, assurant ainsi une 'auto-cure' du béton. En mesurant la perte de poids, on a contrôlé la capacité des adjuvants chimiques à réduire l'évaporation de la solution et à améliorer la rétention d'eau de pâtes de ciment Portlant ordinaires. Les éprouvettes ont été congelées en atmosphère sèche à des âges prédéterminés afin de stopper l'hydratation, et on a effectué des mesures par diffraction X (XRD) et thermogravimétrie (TG) pour évaluer si une amélioration de la rétention d'eau était assotie d'une augmentation du degré d'hydratation du ciment. On a mené des essais d'absorption initiale de la surface (ISAT) et mesuré la résistance à la compression sur des cubes de béton dans le but de déterminer respectivement la perméabilité de la surface et le développement de la résistance. On a observé la fissuration dans la pâte de ciment à l'aide du microscope électronique à balayage afin de déterminer l'influence des adjuvants sur la microstructure de la pâte.

On a trouvé qu'on pouvait améliorer la rétention d'eau par un adjuvant chimique. Cependant, il est aussi apparu que le degré d'hydratation de la pâte de ciment n'augmentait pas forcément dans une proportion correspondante. Deux des adjuvants chimiques étudiés ont eu un effet d'auto-cure significatif. L'un d'eux améliorait l'hydratation au-delà de la rétention d'eau. Ceci peut s'expliquer de la façon suivante: cet adjuvant abaisse la concentration à partir de laquelle l'hydroxyde de calcium (CH) n'est plus en solution, permettant ainsi une hydratation supplémentaire. On a remarqué que les cristaux CH observés au microscope électronique SEM dans la pâte de ciment contenant l'adjuvant chimique étaient de nature très différente de ceux observés dans le contrôle, ce qui renforce l'idée que la formation de cristaux CH est affectée. On a observé par SEM que l'un des adjuvants chimiques impropre en tant que mélange 'auto-conservant', formait, à l'intérieur de la pâte de ciment, un film qui semblait réduire le degré d'hydratation des particules de ciment en contact.