Magazine of Concrete Research, 1997, **49**, No. 178, Mar., 69–72

Discussion on paper published in *Magazine of Concrete Research* 1995, **47**, No. 171, June, 103–111

Influence of cement type and curing on the drying and air permeability of cover concrete

L. J. Parrott

Contribution by B. K. Nyame

It was impressive to find the reliable data from Dr Parrott's paper on air permeability of cover concrete. Drying, curing and air permeation occur simultaneously and competitively for water vapour. The moisture transport in cover concrete was vividly shown on Dr Parrott's Fig. 1, by the changes in cavity relative humidity. Dr Parrott has probably overcome the problems of calibrating the humidity probes, as cited by Dhir and co-workers.[1]

Henceforth, all comments refer to Dr Parrott's controlled mix having free w/c = 0·59, cement content = 320 kg/m^3. Figs 1, 2, 3, etc., are Dr Parrott's graphs. Figs D1, D2 and D3 are my graphs as drawn from Dr Parrott's data in Tables 1, 2 and 6. The D-series of graphs reveal the influence of lime/silica ratios in cement on air permeability, strength and the slump of concrete.

Choice of variables

Dr Parrott selected the appropriate variables for

(*a*) drying and curing for 4-day weight loss and the history of cavity relative humidity on Figs 1–4, 6 and 9, and
(*b*) air permeability on Figs 5–9, strength and slump in Table 1. Dr Parrott therefore interpreted most of his data on drying, very clearly and successfully. Illston[2] has emphasized the need to use porosity, age, cement type and microstructures in everyday concrete technology, with the minimum of complicated algebra. Dr Parrott has used the weight loss to approximate capillary porosity.

Cement type

Dr Parrott considered that the *17 cements* used:

(*a*) differ mainly by the limestone and ggbs contents;
(*b*) had significant variation on air permeability as found from the ratios of the extreme permeability values;
(*c*) had little effect on the changes in the cavity relative humidity during drying.

Regrettably, Dr Parrott's interpretation for cement type was not as comprehensive as for drying and curing because:

(*d*) *no appropriate variable* was chosen for the cement type;

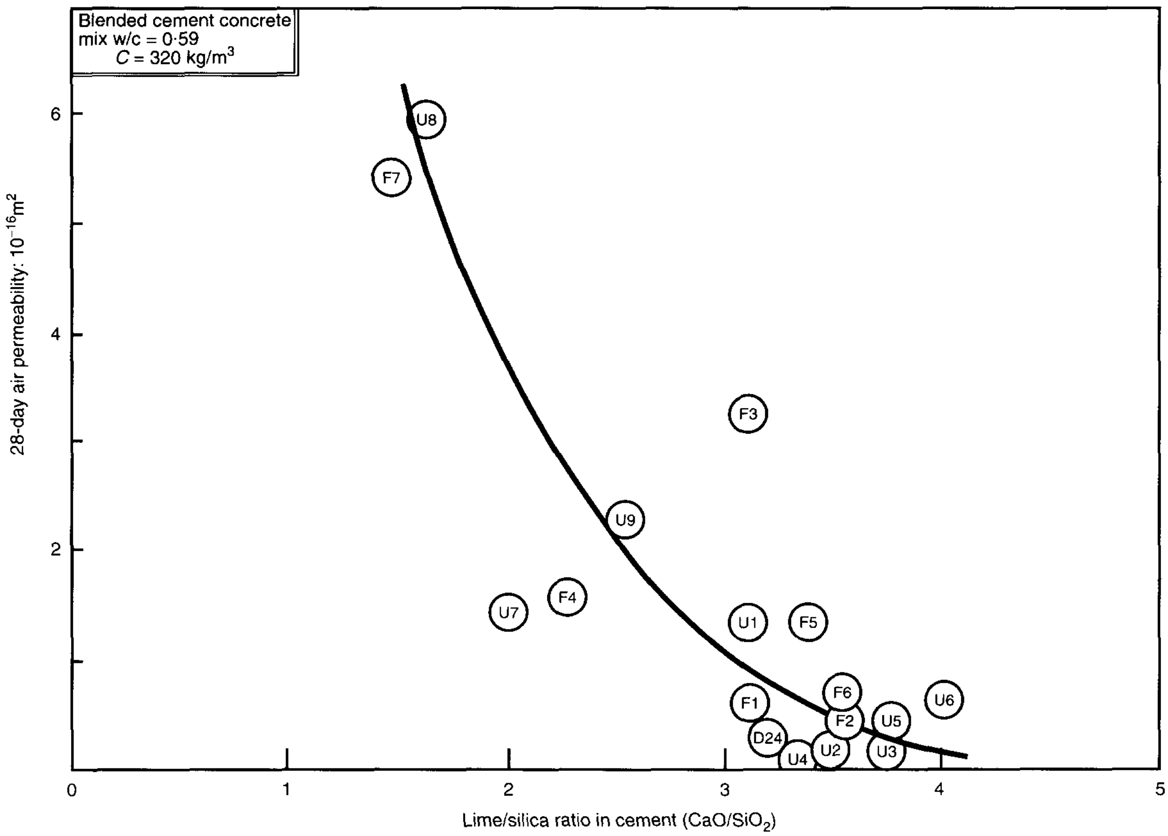

Fig. D1. The influence of lime/silica ratio in cement on air permeability

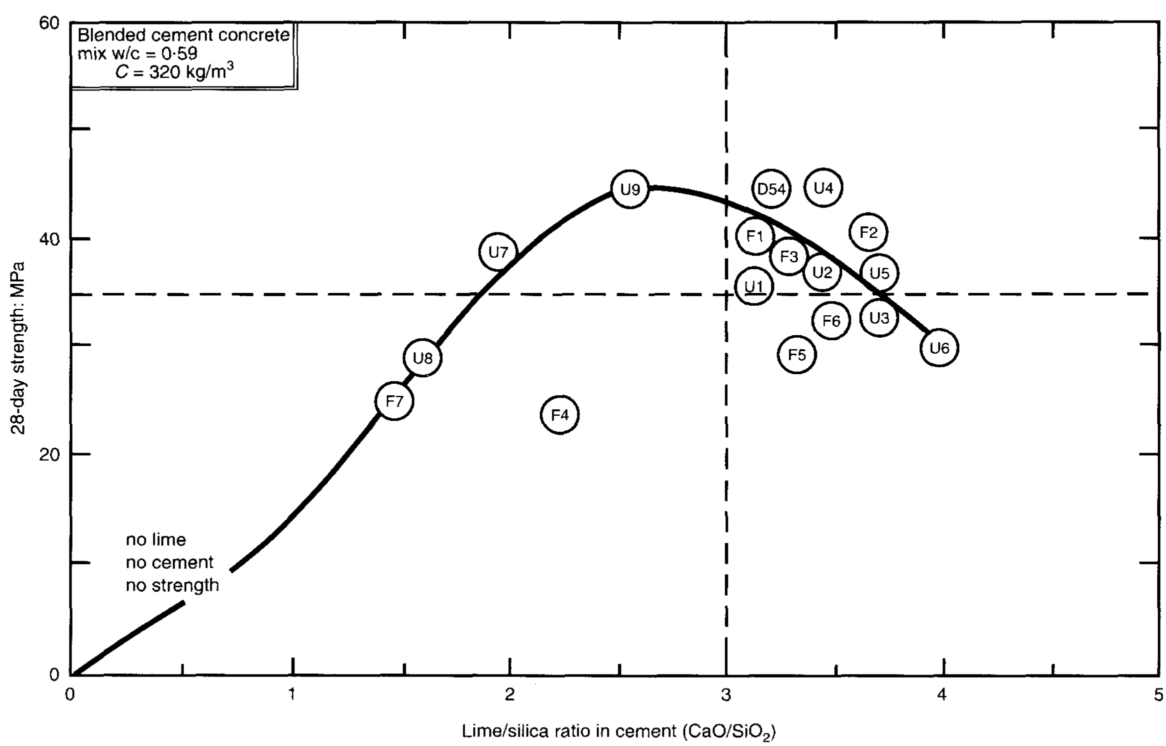

Fig. D2. The influence of lime/silica ratio in cement on strength

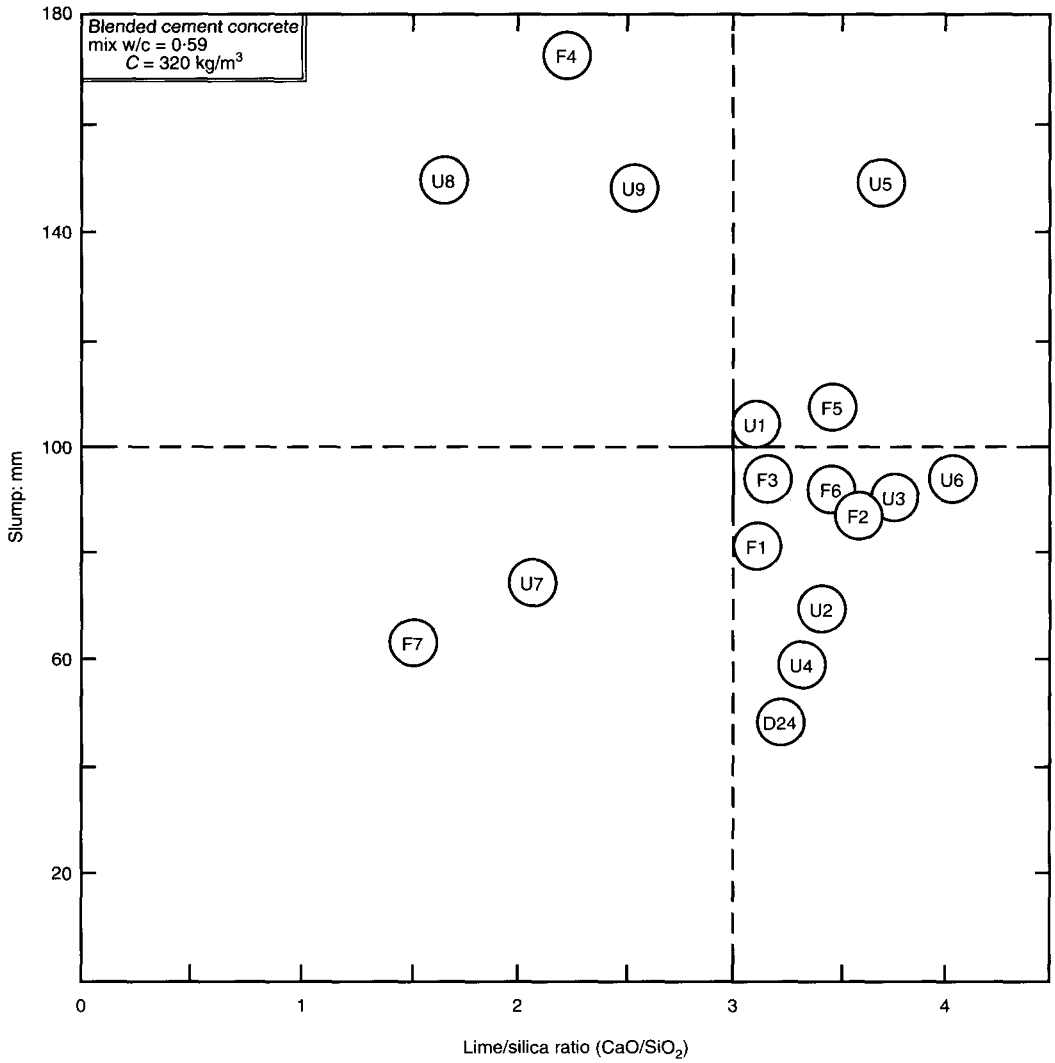

Fig. D3. The influence of lime/silica ratio in cement on slump

(*e*) the significant range of slumps of 60 mm to 175 mm was neither explained, nor regarded as *important*.

Using Dr Parrott's reliable data from Tables 1, 2 and 6, this discussion *highlights* the influence of cement type on the quality of cover concrete.

I suggest that the cement type should be idealized by the lime/silica ratio. This variable is estimated as the weight ratio of the oxides CaO/SiO_2 from Table 1. Evidently, if the *lime/silica ratio exceeds 3.0*, in cements, then

(*f*) Figure D1 shows that air permeability will reduce below the value of 2×10^{-16} m^2.

(*g*) Figure D2 seems to indicate that the 28-day strength is optimized to exceed 35 MPa.

The scatter on Fig. D3 would seem to indicate that cements F4, U5, U8, and U9 are suitable to *reduce the free water content*. Quality begins afresh for the hardened concrete. Consequently, these cements, can be specified to improve the quality and reduce the cost of cover concrete. That is, by the reducing either the free w/c ratio or cement content so as to lower the free water content for the same slump.

The conclusion from Fig. D1 and 9, or Fig. D2 and 3, 4 is that the variable, *lime/silica ratio* apparently idealizes the complex *chemical structure*, just as the drying *weight loss* simplifies the *physical structure* of hardening cements in concretes.

Popovics[3] related concrete strength to the Bogue[4] compound composition of C_3S in concrete. The ratio of calcium silicates to calcium aluminates may simplify both the effects of bonding and hydrate density for the microstructure of cements.

Questions

What does Dr Parrott find from data on cover concrete about:

(*a*) Scheduling for surface coatings during construction?

(*b*) Influence of slump on air permeability?
(*c*) Control of workability by cement type?
(*d*) Importance of lime/silica ratios in quality control?

Reply by the author

I appreciate Dr Nyame's interest in my paper and give the following brief response to his contribution.

The relative humidity probe was calibrated during use against saturated salt solutions; this procedure yielded a standard deviation of 1·5% relative humidity.

The proposed use of a lime/silica ratio based upon the oxide analysis of a cement is presumably intended to account for the potential of a cement to form calcium silicate hydrate and thus reduce capillary porosity. There are a number of reasons why such use may not be reliable:

(*a*) the lime/silica ratio does not account for differences of reactivity;
(*b*) the lime associated with a limestone filler is not sufficiently reactive to form a significant volume of hydration product; and
(*c*) the trend in Fig. D1 suggests that, contrary to expectation, permeability increases as the lime/silica ratio decreases.

Although not stated by Dr Nyame, Fig. D1 seems to employ only the permeability results for 28 days of curing. The already poor correlation would have been worse had the results for 1 and 3 days of curing been included. Bearing in mind that only one water/cement ratio was used, the practical utility of the lime/silica ratio for estimating or controlling air permeability of a wide range of concretes appears limited.

The experimental points for 28-day strength in Fig. D2 do not exhibit any strong correlation with lime/silica ratio; the basis for the curve shown on the figure is not clear but it does not seem to represent a best statistical fit.

I agree with Dr Nyame's implied suggestion that a further stage in assessing the relative performances of the different concretes would be to undertake tests at the same workability.

Dr Nyame raised the question of scheduling for surface coatings during construction. In exposure conditions where the likeliest form of deterioration is carbonation-induced corrosion it is normally possible to select depths of cover, mix proportions, cement and curing such that surface coatings, and the associated inconvenience and expense, are unnecessary.

References

1. Dhir R. K., Hewlett P. C., Byars E. A. and Shaaban K. A new technique for measuring the air permeability of near-surface concrete. *Mag. Concr. Res.*, 1995, **47**, No 171, 167–76.
2. Illston J. M. Aspects of the behaviour of the cement paste phase of composite materials, with reference to the practical problems of concrete technology. *Proceedings of International Conference on Hydraulic Cement Pastes*, University of Sheffield, 1976, pp. 232–247.
3. Popovics S. Extended model for estimating the strength developing capacity of Portland cements. *Mag. Concr. Res.*, 1981, **33**, No 116, 147–53.
4. Bogue R. M. *Chemistry of Portland Cement*, Reinhold, New York, 1955.