Table I. Mix proportions

	Concrete	Mortar
w/c	0.9	0.485
a/c	7.5	2.75
aggregate type 1	builder's gravel 5.47 builder's sand 2.03	Ottawa sand

18 month old, water cured mortar was tested in the second part of this study. Mix proportions are given in Table I.

Results

The results for both concrete and mortar samples showed that in the permanently saturated state the permeability did not vary with time. Once the specimens were dried and resaturated, dramatic self-sealing of the sample was observed during testing. The severity of drying determined the extent of the increase in initial permeability and subsequent self-sealing during testing. Figure 3(*a*) shows a typical permeability curve for a sample before drying. The outflow (represented by □) is essentially constant. The inflow curve (represented by a solid line) occurs in irregular steps, due to the friction between the inflow piston O-rings and the cylinder walls. However, if the areas under the inflow and outflow curves (i.e., the total amount of water going into and out of the permeability cell, represented by $\int_0^t D^*$time vs time) are compared, the inflow and outflow are essentially equal (Fig. 3(*b*)).

For the dried and resaturated specimens the permeability curves obtained were very different in nature. The initial permeability was orders of magnitude higher than that of an unconditioned sample, and the permeability of the sample dramatically decreased during the length of the test. Figure 4(*a*) shows the permeability curve for the sample, shown in Fig. 3, after drying and resaturating (for clarity only outflow is plotted). The area under this curve plotted against time ($\int_0^t D^*$ t vs t) gives a good indication of the trend in permeability (Fig. 4(*b*)). For the non-dried specimen, a straight line was obtained (Fig. 3(*b*)), indicating that permeability remained constant with time. The integral plot of the dried and resaturated sample (Fig. 4(*b*)) has a pronounced negative curvature, indicating decrease in permeability with time.

Thus, the result of drying was an initial increase in overall permeability, followed by a rapid decrease due to self-sealing. A partially dried sample (in vacuo over desiccant) showed the same tendency, but to a lesser extent than the oven dried sample. Figure 5 shows three graphs for a sample, which had been tested in unconditioned, partially dried, and oven dried states. Initial permeabil-

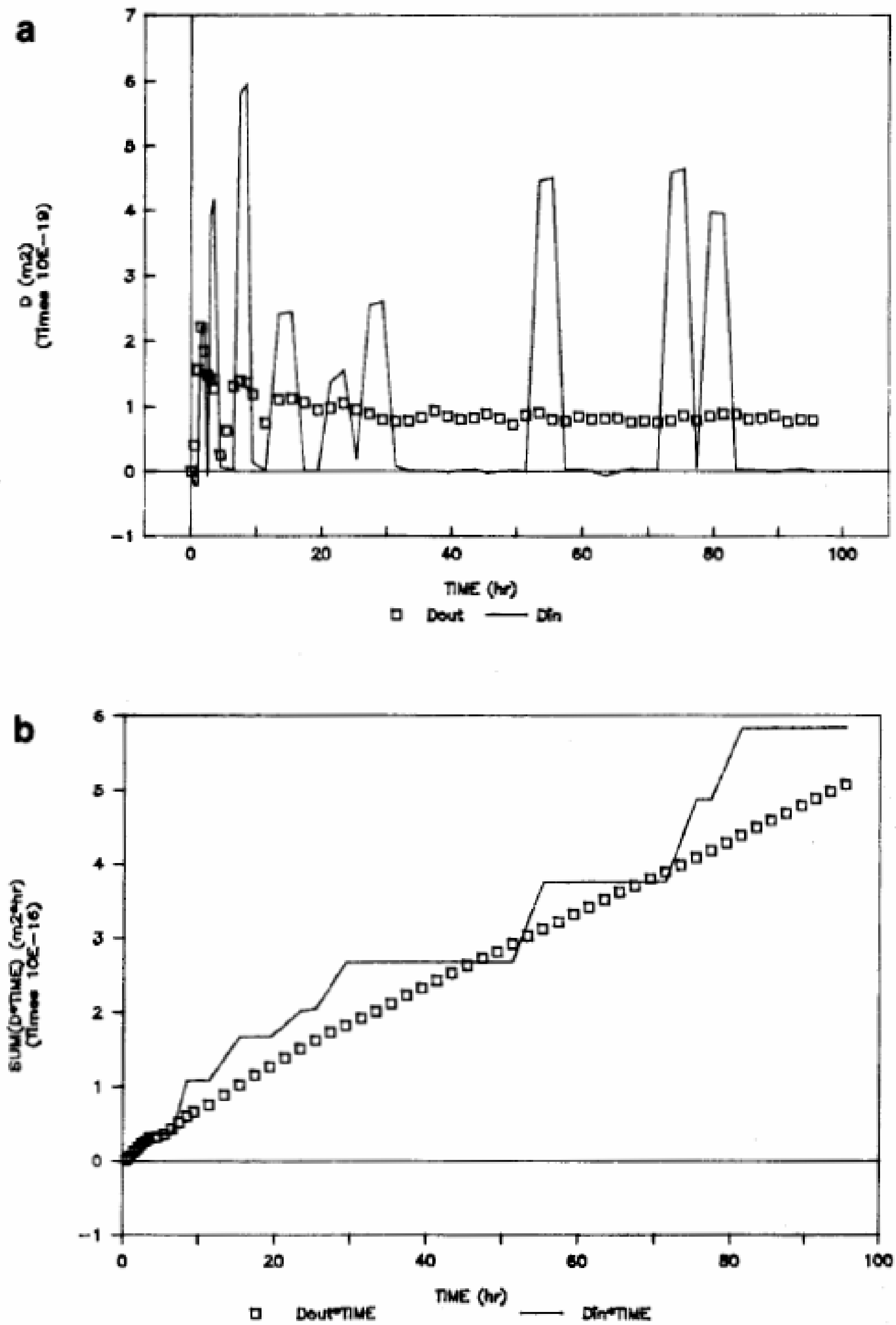

Fig. 3. (*a*) Inflow and outflow permeability (D) vs time for a non-dried sample; (*b*) areas under curves in Fig. 4(*a*) vs time.

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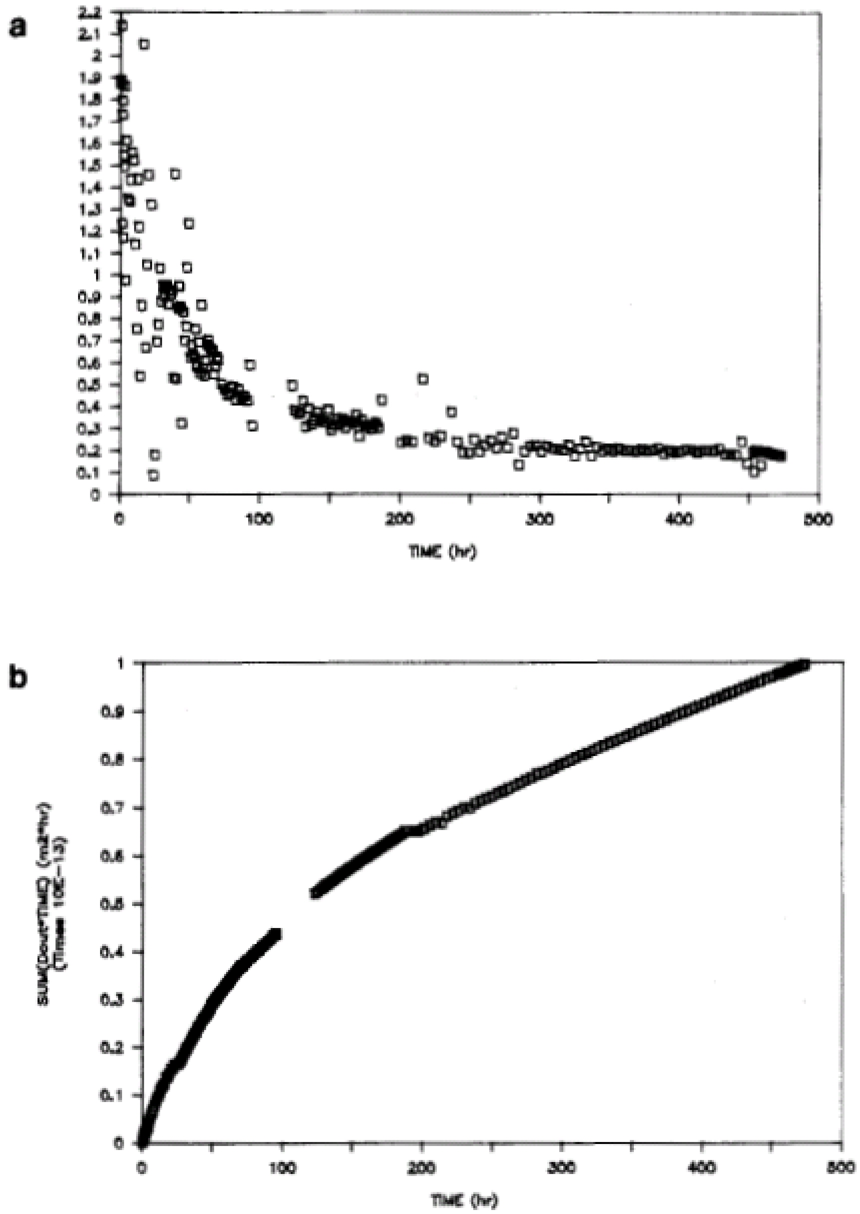

Fig. 4. *(a)* **Permeability vs time after drying and resaturating;** *(b)* **area under the curve in Fig. 5*(a)* vs time.**

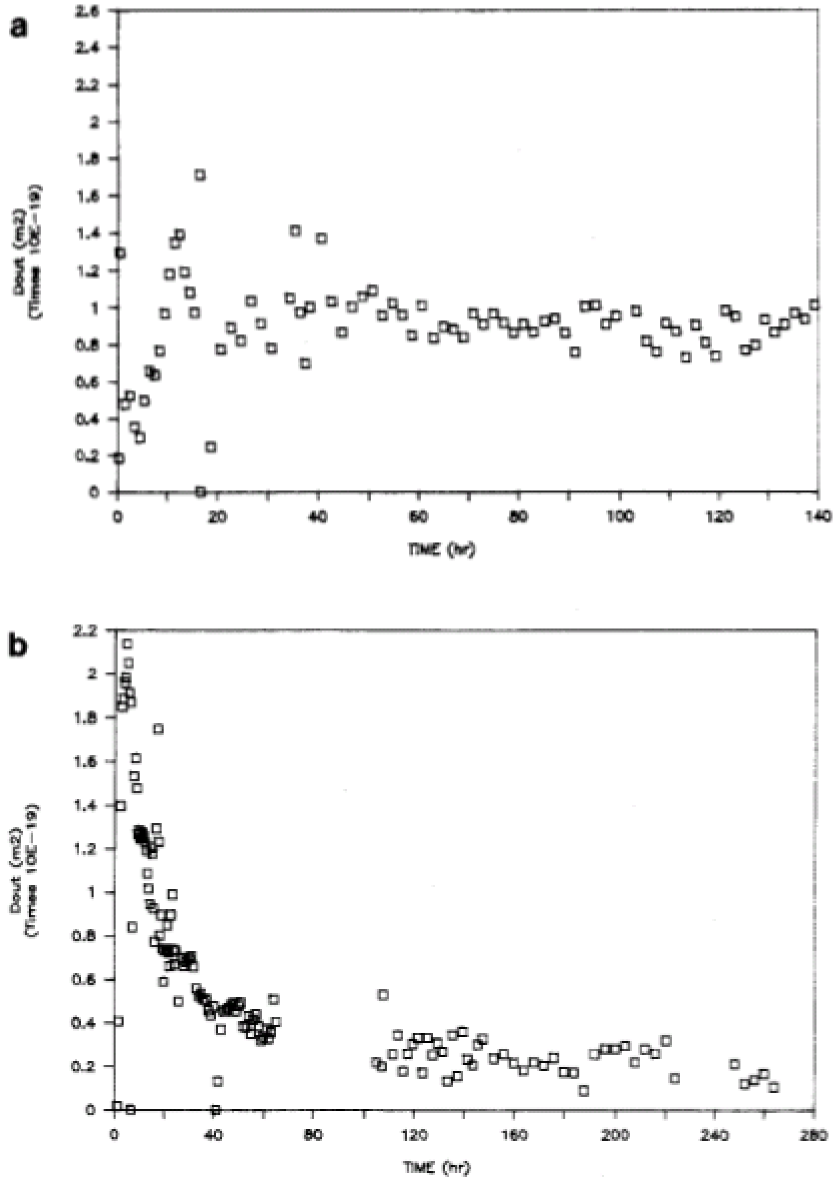
a
Dout (m2)
(Times 10E-19)
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
TIME (hr)
b
Dout (m2)
(Times 10E-19)
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
40
80
120
160
200
240
280
TIME (hr)

Fig. 5.

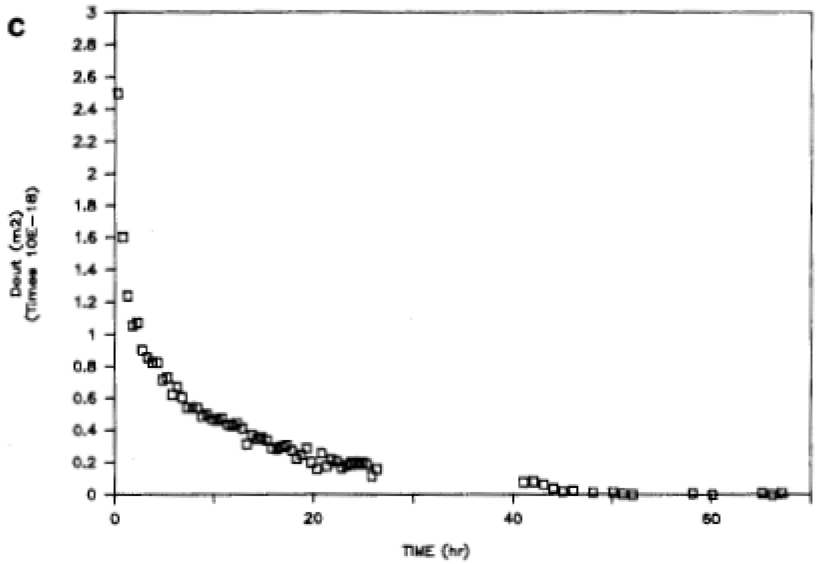

Fig. 5. Permeability vs time before drying (*a*), after partial drying (*b*), and after oven drying (*c*).

ity and the subsequent change depended on the extent of drying. After partial drying, the change in permeability was an order of magnitude (from 2.2×10^{-19} m^2 to 2×10^{-20} m^2), while after oven drying the permeability falls from the initial level of 2.5×10^{-18} m^2 to permeability less than 10^{-20} m^2.

The increase in permeability after drying is not unexpected since the drying process causes shrinkage cracks throughout the hardened cement matrix. The overall result is an increase in interconnected porosity and thus increased permeability. The triggering of the sealing mechanism by drying and re-saturation is more difficult to explain. Some combination of the three possible self-sealing mechanisms, namely physical clogging of pore system, chemical activity, and swelling of the cement paste may explain this decrease.

Discussion

No strong experimental evidence exists to point to a specific mechanism as a cause of self-sealing in concrete. Even extensive work by Glanville did not produce clear results. So far, this set of experiments does not support the view