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Factors influencing relative humidity in concrete

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Many aspects of concrete durability and performance are influenced by relative humidity and moisture. An accurate prediction method for the determination of internal relative humidities within drying concrete is thus of importance. The paper presented by Parrott continues work presented in an earlier paper,¹ in which he presented a simple formula for the prediction of moisture profiles throughout drying concrete:

$$\left. \begin{aligned} \text{RH} &= \text{RHA} + (100 - \text{rha}) \times f(t) \\ f(t) &= 1/(1 + t/b) \\ b &= d^X(Y - e)(w - Z)/W \end{aligned} \right\} \quad (1)$$

where RH is the predicted relative humidity (%), RHA is the ambient relative humidity (%), t is the drying time (days), d is the depth from drying surface (mm), e is the OPC replaced by PFA or GGBFS (%), and w is the water/binder ratio. W , X , Y and Z are constants. Parrott then assigned values to the four parameters, such that $W = 8$, $X = 1.35$, $Y = 70$ and $Z = 0.19$.

Work by McDonald² showed that Parrott's original formula was suitable for use with a large data set; this work will be described. Data from Abrams and Orals,³ Monfore,⁴ Hansen,⁵ Abrams and Gustaferrero,⁶ as well as data used in the formulation of Parrott's original model were used. Altogether 394 humidity measurements during drying were used in the investigation.

The mixtures investigated and the specimen sizes observed are shown in Table 1.

Figure 1 shows the humidities predicted using Parrott's original model, plotted against the measured humidities. The prediction model, although accurately predicting Parrott's own data, over-estimates the large body of data.

The parameters in equation (1) were adjusted to improve the accuracy of Parrott's original model to the entire data set. Least-squares criteria were used to minimize prediction errors; the values of parameters that minimized the prediction errors were $W = 11.40$, $X = 0.85$, $Y = 128.00$ and $Z = 0.03$.

The predicted relative humidities, using the adjusted equation (1), are plotted against the measured relative humidities are shown in Fig. 2. This prediction method provides a more accurate fit for the large body of data. The predicted humidities are typically within 10% of the measured data.

In the most recent paper by Parrott, a significantly different series of equations was produced for the same purpose. It would be interesting to add the data provided by Parrott in the most recent paper to the large data set. From the large data set it may be possible to compare the two methods provided by Parrott and to compare results with those calculated from non-linear diffusion equations, which have been suggested by others as suitable for the prediction of internal relative humidities during the drying process.

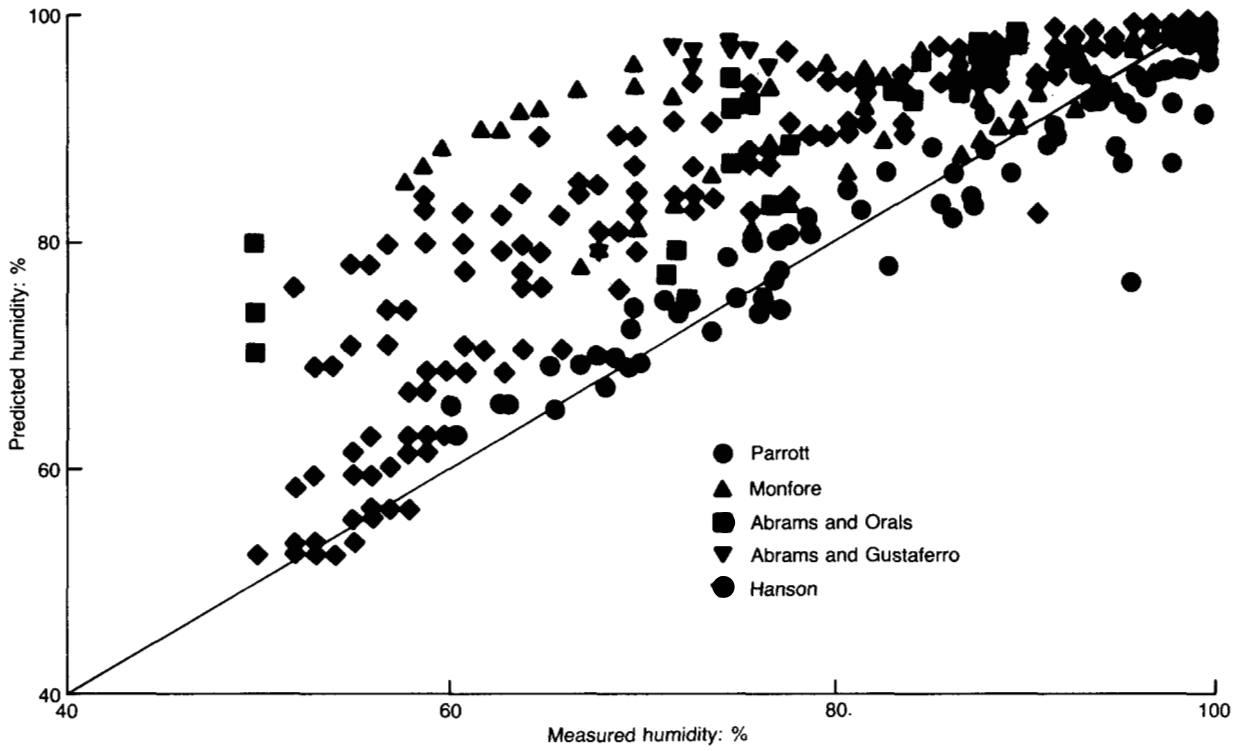


Fig. 1. Internal relative humidity; measured data and those predicted by Parrott (equation (1))

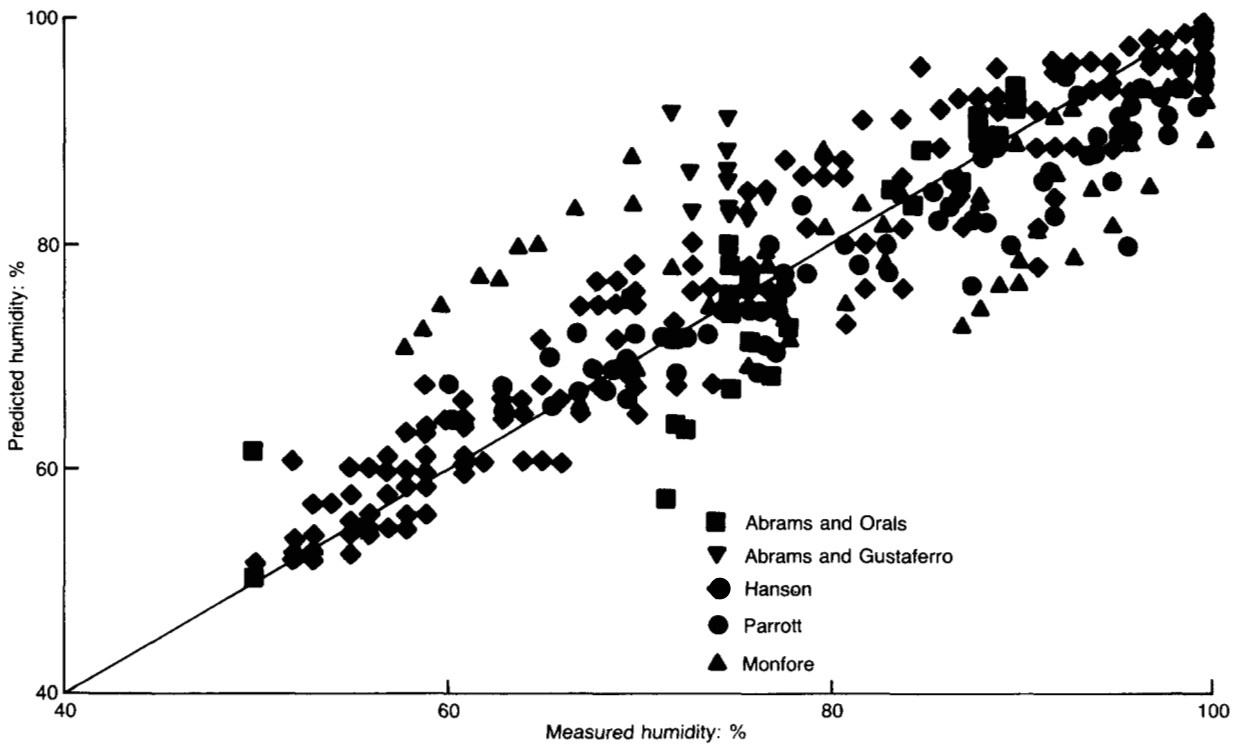


Fig. 2. Internal relative humidity; measured data and those predicted by equation (1) using adjusted parameters

Table 1. Internal humidity data

Source	Specimen size: mm	Curing period: days	w/c ratio	Ambient relative humidity: %
Monfore	18, 75, 150 cylinders	7 and 84	0.4 and 0.6	50
Abrams and Orals	915 × 915 × 150 slabs	7	0.6	10, 35, 50 and 75
Abrams and Gustaferro*	450 × 450 slabs, thicknesses 45–175 mm	7	0.55 and 0.63	30
Hansen†	150 × 300 cylinders	3, 7, 14 and 28	Lightweight aggregate 0.74, normal-weight aggregate 0.66	50

*Carbonate and silicious aggregate used.

†Lightweight and normal-weight aggregates used.

References

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Reply by the author

I am grateful to Dr McDonald and Professor Roper for exploring the application of equation (1) from my earlier paper to such a large body of experimental data. The results are surprisingly good considering

that the equation is based upon a relatively small data set with only one exposure humidity, one drying path length, two water/cement ratios and 180 days of drying. It should be noted that only the surface layers of concrete dry during the first 180 days of exposure.

The more recent paper, which is the subject of this discussion, is based upon a larger amount of experimental data extending over two years. The effects of the water/cement ratio and the slow variations of relative humidity in the interior of the concrete were not well represented by equation (1), so an improved representation was developed. The effects of drying path length and exposure humidity still require investigation and, in these respects, it would indeed be instructive to undertake comparative analyses, as suggested by the discussers.

There is a limit to the sophistication of analysis that is warranted for outdoor exposure, because fluctuating weather conditions can dominate behaviour, as indicated in Fig. 5 of the paper. Measurements on a range of buildings also show that the seasonal fluctuations of the weather conditions strongly affect the relative humidity at depths of about 25 mm within a concrete element.