Discussion on paper published in

Magazine of Concrete Research

2003, 55, No. 2, April, 171–176

Mechanical properties of old concrete using destructive and ultrasonic non-destructive testing methods

I. N. Prassianakis and P. Giokas

Contribution by W. P. S. Dias

Department of Civil Engineering, University of Moratuwa, Sri Lanka

I would like to thank the authors for focusing attention on the ultrasonic non-destructive testing of *in situ* concrete, a subject that deserves to be treated with care. I would like to make a number of queries and observations on their paper.

At the outset, I wonder why the authors used a fairly complicated and non-intuitive form for their equation (2), which relates pulse velocity to strength, namely

$$\sigma_f = \exp(9810 - 17713/c_1) \quad (2)$$

In any case, there seems to be a printing error in the equation: could the authors clarify please?

Most other workers (apart from those who have used power law relationships) have used equations of the form

$$\sigma_f = a \exp(bc_1) \quad (i)$$

where a and b are constants, b being the slope of a semi-log plot between σ_f and c_1 . The form of this equation clearly conveys the idea that strength increases logarithmically with pulse velocity. If the authors' data are fitted to the above equation, the resulting value for slope b is 0.866, and the r^2 value is 0.967, virtually

identical to the authors' r^2 value for a much more complicated equation.

I have obtained¹⁹ values of 1.19 and 1.24 for b (i.e. the slope of the semi-log plot) for laboratory cube specimens at ages from 1 to 43 days, either stored in water or drying in the laboratory respectively over that period (85% RH and 30°C). This can be compared with the value of 1.1 obtained by Facaorau²⁰ and those of 1.54 and 1.69 obtained by Tommsett.²¹

The point, however, is that the various investigators have obtained different values for slope. As the authors say, it would be instructive to study the influence of various factors on the slope of the correlation. However, because of such slope variations, merely shifting the correlation line parallel to a rather arbitrary reference line must be done with care—for example by ensuring that the differences between the reference and the *in situ* concrete are minimal and (hopefully) confined only to differences in moisture condition.

Using such an approach for *in situ* pulse velocity correlations in Sri Lanka,²² we have obtained values for a of 0.100 for the 1- to 43-day-old dry cured laboratory specimens and of 0.194 for 12-year-old *in situ* concrete, when b was held constant at 1.24. The

increase in the value of a is due to the drying of concrete: the same pulse velocity in a drier concrete will indicate higher strength. It would be instructive to know whether the authors have pulse velocity data for their 28-day (or 90-day)-old specimens, as they have for their 28-year-old ones. If so, have they observed a parallel shift in correlation curves with age?

In order for actual *in situ* strength correlations to be made, of course, at least a few cores have to be taken. If a significant number of cores are taken, the value of b could be obtained from an independent regression analysis. Other criteria could also be used to find the value of b : for example the criterion that the ratio between the maximum and minimum estimated strengths from pulse velocity readings should be the same as the ratio between the maximum and minimum strengths obtained from core testing. Such an approach employed by Dias and Jayanandana²³ resulted in a value for b of 0.9, reasonably close to but sufficiently distinct from the value of 1.24 used above. Hence parallel shifts in correlation curves may not always be the best solution for obtaining correlations of *in situ* strength with pulse velocity.

As the authors state, there is much work that has yet to be done on the use of pulse velocity for estimating *in situ* strengths.

Reply by the authors

We would like to thank Professor Dias for his interest in our paper. Furthermore, we are happy that he agrees with our main result that there is yet much work that can be done on the use of pulse velocity for estimating concrete strength.

In our work we use a special type of 28-year-old concrete constructed in our laboratory and conserved in perfect condition. The objective of this study is concrete strength evaluation using ultrasound. For this pur-

pose, after the regression analysis from the 10 mathematical models:

- (a) linear: $y = b_0 + b_1x$
- (b) logarithmic: $y = b_0 + b_1 \ln(x)$
- (c) inverse: $y = b_0 + b_1/x$
- (d) quadratic: $y = b_0 + b_1x + b_2x^2$
- (e) cubic: $y = b_0 + b_1x + b_2x^2 + b_3x^3$
- (f) power: $y = b_0x^{b_1}$
- (g) compound: $y = b_0b_1^x$
- (h) S-curve: $y = e^{(b_0+b_1/x)}$
- (i) growth: $y = e^{(b_0+b_1x)}$
- (j) exponential: $y = b_0e^{b_1x}$

the S-curve model was selected, as for our results (Table 3 of the paper) it satisfies the criterion that the quantity R^2 should take the nearest value to unity and simultaneously the quantity F should take the higher value.

Equation (2) includes a printing error. Although it was correct in the galley proofs, in the final paper it is wrong. The correct form is:

$$\sigma_f = e^{(9.810-17.713/c_t)}, R^2 = 0.97$$

References

19. DIAS W. P. S. The correlation of non-destructive test results with concrete strength. *Engineer*, 1991, **19**, No. 1, 3–13.
20. FACOARU I. Non-destructive testing of concrete in Romania. In *Non-destructive Testing of Concrete and Timber*. Institution of Civil Engineers, London, 1970, pp. 39–49.
21. TOMMSETT H. N. The practical use of ultrasonic pulse velocity measurements in the assessment of concrete quality. *Magazine of Concrete Research*, 1980, **32**, No. 110, 7–15.
22. DIAS W. P. S. Structural appraisal of reinforced concrete buildings from in-situ material properties: some issues and insights. *Transactions, Institution of Engineers, Sri Lanka*, 1994, pp. 129–145.
23. DIAS W. P. S. and JAYANANDANA A. D. C. Condition assessment of a deteriorated cement works. *ASCE Journal of Performance of Constructed Facilities*, 2003, **17**, No. 4, 188–195.