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DISCUSSION ON TECHNICAL NOTE 404

Investigations of the engineering properties of OPC/pulverized fuel ash concrete: strength development and maturity

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In the study (Chin[19]) of the published results of Klieger,[20,21] Ackroyd and Rhodes,[22] McIntosh,[23] Ashworth,[24] Gonnerman and Lerch[25] and Shideler,[26] it was found that the relationship between strength and age or maturity of concrete was better represented by the rectangular hyperbola

$$D/q = mD + C \tag{1}$$

where q is the strength at age D or maturity M; and C and m are constants.

23. If D/q is plotted against an abscissa of D, equation (1) becomes a straight line

$$y = mx + C \tag{2}$$

where $y = D/q$ or M/q and $x = D$ or M.

24. The maximum strength that the concrete will attain with age or maturity can be obtained from the inverse slope, i.e. the value of $1/m$, of equation (2). Indeed, theoretically from the strengths at two different ages or maturities, the strength at any age or maturity could be computed.

25. The test results published in Table 5 of the Paper show good compliance with equation (1). The relation between D/q and D shows high degrees of linear association for the whole range of age of 3 to 365 days. The moment correlation coefficients r are very close to the value of 1·0, as shown in Table 9.

26. As the Authors are interested in strength development, from equation (1)

$$\frac{dq}{dD} = \frac{C}{(mD + C)^2} \tag{3}$$

This gives the rate at which strength changes with age or maturity.

27. When D is zero, that is at the moment when the concrete begins to develop its strength

$$dq/dD = 1/C \tag{4}$$

The value of $1/C$ is therefore the initial and also the maximum rate at which concrete develops its strength (Chin[8]).

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It is certainly the case that, as *Dr Chin* states, the equation

$$D/q = mD + C$$

gives a very accurate representation of the relationship between concrete strength and age. The correlation coefficients which he has calculated and presents in Table 9 are indeed statistically very significant, as would be expected for the analysis of data from individual curing conditions.

29. However, the purpose of maturity relationships is to enable prediction of strength for any combination of (curing temperature × age). As was stated in the Technical Note, there is not a single relationship between strength and maturity for all curing temperatures for OPC/pfa concrete. This is still true for the relationship suggested by *Dr Chin*.

30. Even though a statistically acceptable correlation results when all the data for the lowest strength concretes (Mix M1) under all curing conditions are taken together, it can be seen from Fig. 6 that the divergence shown in Fig. 5 still holds.

Table 9

Mix	Curing water temperature, °C	Age at test *D*, days	Compressive strength *q*, N/mm²	*D/q*	Product moment correlation coefficient *r*
OPC Mix M1	5	3	4·0	0·75	0·99895
		7	6·7	1·05	
		28	12·3	2·28	
		90	18·3	4·92	
		180	21·1	8·53	
		365	23·3	15·67	
Pfa Mix M1	5	3	4·4	0·68	0·99667
		7	6·7	1·05	
		28	11·3	2·48	
		90	15·7	5·73	
		180	18·4	9·78	
		365	21·4	17·06	
OPC Mix M1	80	3	8·7	0·34	0·99008
		7	9·9	0·71	
		28	12·7	2·21	
		90	16·7	5·39	
		180	20·0	9·00	
		365	25·0	14·60	
Pfa Mix M1	80	3	22·6	0·13	0·99943
		7	23·1	0·30	
		28	23·8	1·18	
		90	24·7	3·64	
		180	25·6	7·03	
		365	27·2	13·42	

While OPC concrete does appear to obey a maturity 'law', at least for temperatures from 5–40°C, for OPC/pfa concrete a separate relationship results for each curing temperature.

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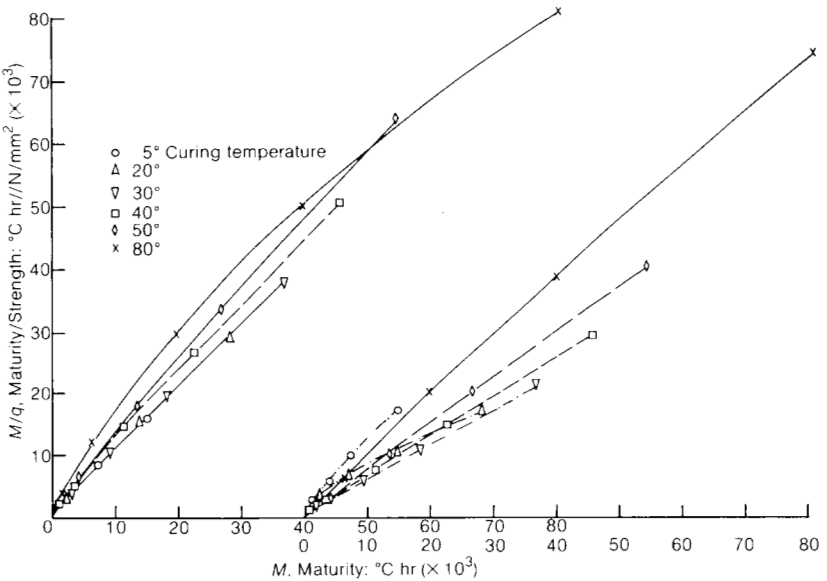

Fig. 6. Relationship between maturity and strength development using Chin's equation