

SETTING OF HYDRAULIC LIMES AND NATURAL CEMENTS—DIFFERENTIATION OF HYDRAULIC AND PUZZOLONIC FUNCTIONS OF SETTING CHARACTERISTICS

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THOUGH many qualitative relationships between setting characteristics and chemical composition of hydraulic and puzzolonic cements have been established,¹ no quantitative empirical correlation of data has yet been obtained.² In the present investigation, a method has been developed to quantitatively evaluate the hydraulic and puzzolonic constants of setting, which may be further used to elucidate the increment of change in setting characteristics that occurs with a small variation in chemical composition.^{3,4}

The incorporation of 15-30% aluminium silicate as clayey matter with natural lime induces considerable modifications in its setting characteristics, indicative of a broad differentiation into hydraulic and puzzolonic functions. Under constant operating conditions, it is possible to obtain specific values of these functions capable of being directly correlated with the amount of retarders and other variables.

Experimentally, the setting curves of a large number of naturally occurring hydraulic limes contained in a 4 cm. high Vicat mould were determined by the usual methods.⁵ A consideration of the mathematical nature of the curves, obtained by plotting the unpenetrated distance, ϵ , against the time period, θ , indicated their conformation to the general equation:

$$\theta = a\epsilon^m + b\epsilon^n.$$

With each sample, small variations in amount of water used, ranging from 80-90% on the weight of sample, were found to considerably affect the numerical values of exponential constants, the value of one of them being in all cases greater than unity.

It was our observation that there exists a definite relationship between the values of m and n , such that adjustment of water percentage to a proper level in all cases reduces the general equation to the form:

$$\theta = a\epsilon^2 + b\sqrt{\epsilon}.$$

It is also found, moreover, that at $m=2$, a definite percentage of water is used, depending upon chemical composition and the results obtained with larger amounts of water are not capable of exact reproducibility. Fig. 1 shows three typical curves, obtained by using 83%,

82% and 85% water with samples A, B and C respectively. Since the slope of the curve, given by its first derivative

$$d\theta/d\epsilon = 2a\epsilon + \frac{1}{2}b\epsilon^{-\frac{1}{2}}$$

passes through a minimum at the point of inflexion

$$d^2\theta/d\epsilon^2 = 2a - \frac{1}{4}b\epsilon^{-\frac{3}{2}}.$$

Hence

$$\theta = 0.5625 a^{-\frac{2}{3}} b^{\frac{4}{3}} \text{ and } \epsilon = \left(\frac{b}{8a}\right)^{\frac{2}{3}}$$

at this point, which is indicative of what may be defined as the maximum set point. The co-ordinates of this point (θ' , ϵ'), uniquely determined by the constants a and b , are graphically evaluated by plotting $\delta\theta/\delta\epsilon$ against θ or ϵ . Since there is no sudden hardening, the slope at θ' , ϵ' is not asymptotic to the ϵ -axis, but is given by the expression $1.50 a^{\frac{1}{3}} b^{\frac{2}{3}}$.

It is found that the puzzolonic-set characteristic function, θ_1 , and the hydraulic-set characteristic function, θ_2 , may be expressed in the form $\theta = \theta_1 + \theta_2$, where $\theta_1 = a\epsilon^2$ and $\theta_2 = b\sqrt{\epsilon}$. At the maximum set point,

$$8\theta_1 = \theta_2 \text{ and } a\theta^3 = 0.178b^4.$$

These characteristic functions are thus determined by the independent variables a and b .

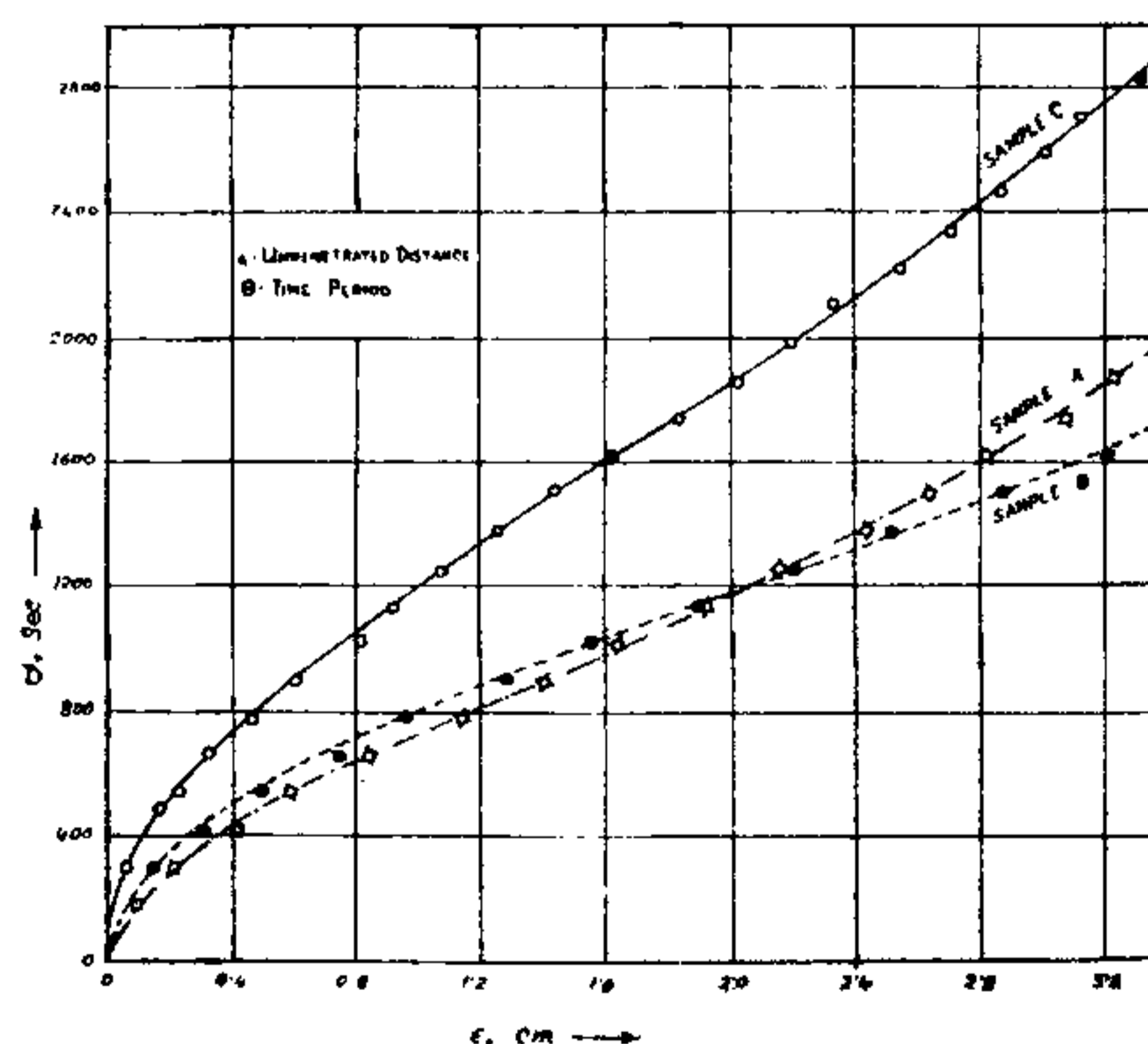


FIG. 1. Graph between time period (θ) and unpenetrated thickness (ϵ).

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They may be numerically evaluated by solving the general equation

$$\theta = a\epsilon^2 + b\sqrt{\epsilon}$$

for the two sets of experimental values of θ and ϵ from a setting curve, preferably in proximity to the maximum set point, or approximately by substituting the values of θ_i , the initial setting time, and θ_f , the final setting time, in the following equations:

$$a = 0.0654 \theta_f - 0.1850 \theta_i$$

$$\text{and } b = 5.918 \theta_i - 0.925 \theta_f.$$

Experimental values for these functions have been obtained in a number of cases. Under specified operating conditions, these, such as are given in Table I, may be related to the chemical composition of a particular series of hydraulic limes.

TABLE I

Differentiation of setting characteristics

Sample	Water %	Max. set point		Characteristic Functions at θ', ϵ'		a	b
		θ'	ϵ'	P-Set	H-Set		
		Sec.	cm.	θ_1	θ_2		
A	83	812	1.2	90	722	62.7	659
B	82	1223	2.1	136	1087	30.8	750
C	85	1598	1.6	178	1420	69.4	1123

1. Ferrari, F., *Cemento Armato*, 1937, 51.
2. Malquori, G., *Ricerca Sci.*, 1936, 7 (2), 440.
3. Santarelli, L. and Guzzini, A., *Ind. Ital. Cemento*, 1951, 21, 83.
4. —, and Senesi, A., *Rend. Soc. Mineral. Ital.*, 1949, 6, 119.
5. Lea, F. M., *J. Inst. Civil Eng.*, 1936-7, 278.

SOME THEORETICAL AND APPLIED ASPECTS OF THE PHYSIOLOGY OF UNSTRIATED MUSCLE*

COMPARATIVELY speaking, more attention has been devoted by physiologists to striated than to unstriated muscle, though the disorders of former muscles are rarer. We are ushered into this world by the contraction of unstriated muscle, and disorders of the unstriated muscle of the alimentary canal and other tubular structures are common ailments. The modern stress and strain of life leads to the contraction of the unstriated muscle of the blood vessels, which in turn damages the kidneys and the heart, so that the problem of heart disease in coronary attacks is really the problem of blood vessels and their smooth muscle. Similarly, some disorders of the nervous system are due to vascular spasm, local and general.

CHEMICAL COMPOSITION OF UNSTRIATED MUSCLE

Interest in this subject has increased in recent years owing to its relation to hypertension. It is now generally recognised that ionic imbalance results in hypertension. Sodium causes contraction of the contractile mechanism by direct effect on its proteins. Retention of sodium would therefore result in hypertension. Intracellular potassium, besides being a suitable medium for the actomyosin system of the muscle, also maintains the normal excitability.

Potassium has a relaxing effect on the contractile mechanism of unstriated muscle, so that the fall of blood pressure due to retention of potassium is likely to be due to this effect. Intracellular calcium would be responsible for accommodation or adaptation of muscle. Calcium also causes contraction of the contractile mechanism. As there is a natural increase of lime salts in the arteries of the aged, the action of calcium might be responsible for the physiological increase of blood pressure with age. Calcium also causes extrusion of sodium.

EXCITABILITY

Unstriated muscle can be stimulated both electrically and chemically but in some unstriated muscles the properties of these two types of responses differ whether they be inhibitory or excitatory. In these muscles, therefore, it is possible to decide whether a particular response has been produced by electric current or a chemical substance. The application of this finding can be used to decide between the electrical and chemical theory of nerve transmission in certain situations. It is possible to say, therefore, whether a particular response has been produced by the action potentials of the nerve or by some humoral substance secreted by it. Experiments on the nerve-smooth muscle preparation of dog's and frog's stomach suggest that the action of the vagus nerve is produced by secretion of acetylcholine and

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