

# Discussion on articles published in the

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## Quality control in prestressed concrete production\*

by O. J. Masterman, B.Eng., A.M.I.C.E., A.M.I.Struct.E.

Contribution by Ing. Miloš Vorlíček,  
Cand.Tech.Sc.

(Czechoslovak Academy of Sciences, Prague)

In an investigation into how the quality of concrete could be controlled we analysed the mechanical properties of concrete, and the following contribution gives some of our results.

Any measurable property of a material can be plotted as a distribution curve, and a "minimum value" of the property can then be chosen so that a small part  $P$  of the area at the lower end of the curve is neglected; in other words we choose a probability  $P$  that a smaller value than the minimum value will occur. The value of  $P$  (usually between  $10^{-2}$  and  $10^{-6}$ ) is chosen such that for all practical purposes smaller values of the particular property will not occur. The coefficient of homogeneity (or control factor) of the material is defined as the ratio of the minimum value of the property to the average value.

It will be obvious that to estimate the minimum value and the coefficient of homogeneity we must know the shape of the relevant probability curve.

The property normally used to indicate the quality of concrete is the compressive strength. Unfortunately the normal Gauss-Laplace distribution† law does not apply to the compressive strength in many cases, and another curve must be sought.

An attempt was made to determine the frequency distribution of the strength of concrete on a theoretical basis. The strength depends on a number of factors—quality and proportions of the component materials, method of mixing, curing, etc.—and we used established formulae relating the strength to these various factors. Four independent analyses were made based

on the formulae of Bolomey, Feret, Graf, and Bendel, and since these formulae do not include all the principal factors which affect the strength of concrete we extended them by a number of secondary factors. In all four cases we concluded that the distribution of the compressive strength was best expressed by a Pearson's type III curve. This theoretical result was supported by the results of a considerable number of tests carried out both in Czechoslovakia and abroad.

A Pearson's type III curve has the great advantage of representing a distribution with various degrees of skewness, and when the skewness is zero it degenerates to the Gauss-Laplace curve. The skewness is estimated directly from the test results, and together with the average and the standard deviation determines the shape of the distribution curve; in contrast, for example, in the logarithmic normal distribution, the degree of skewness is a function of the average and the standard deviation only.

Using the probability  $P$  of the occurrence of a smaller value than the minimum strength, we determine the minimum strength from the relation

$$\text{minimum strength} = \text{average strength} - t_{min} \times \text{standard deviation}$$

where the value  $t_{min}$  is taken from a Pearson's type III curve. The coefficient of homogeneity is then determined as the ratio of the minimum strength to the average strength.

From this theoretical basis we deduced a method which enables us to determine the coefficient of homogeneity of the concrete in a structure by means of non-destructive tests with an adapted Poldi hammer, and useful results have already been obtained from quite a small number of tests.

We have also applied the Pearson's type III curve to other mechanical properties of concrete and to other building materials, and the agreement between the theoretical conclusions and the experimental results has in all cases been found to be very close.

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\*Pages 57–62 of *Magazine* No. 29.

†Usually known in Great Britain as the "Normal or Gaussian distribution".