factor of unsuitability. An 0–6–0 locomotive of moderate power could be more severe on the track laterally if run at high speed than would be a correctly designed Pacific of much greater power.

Mr. Cox fully approved Mr. Willox's plea for full-scale experimental work on the subject of the Paper; but he could not agree that such trials were immediately practicable. It was not so much difficulty in obtaining staff to conduct them as the interference with traffic and the withdrawal of test locomotives from useful work which were inadmissible at the present time.

Mr. Dewhurst's remarks were of particular value as coming from one with a very wide experience of extreme conditions, and it was interesting that he confirmed the view that a certain amount of information of value could be gained merely by riding on the footplate, given sufficient familiarity with the process.

Certain engines in Great Britain were balanced on the plan advocated by Mr. Dewhurst, namely, to have a higher proportion of the reciprocating balance applied to the intermediate coupled wheels. Examples were the 0–6–0 Cl. 4 freight engine on the London, Midland and Scottish Railway, and the "Lord Nelson" on the Southern Railway. Usually it was done with the object of reducing the variation of load on the leading coupled wheels from a safety point of view, but except in the case of front coupled engines, for example, 0–6–0, 0–8–0, etc., it was doubtful whether any real advantage could be shown, whilst on engines nearing the limits of permissible axle-weights, it was essential to divide the balance equally to ensure the least possible weight on each individual wheel and axle.

Paper No. 5270

"A Laboratory Study of London Clay." †

By Leonard Frank Cooling, M.Sc., and
Alec Westley Skempton, M.Sc., Assoc. M. Inst. C.E.

Correspondence.

Mr. A. H. D. Markwick observed that London Clay occurred over wide areas in the lower Thames and the Thames estuary, and also in parts of the Hampshire Basin. Some indication of its extent in the Thames valley was shown in *Fig. 16*, which had been kindly furnished by the Geological Survey and Museum. The clay was not always exposed on the surface: in many cases it was covered by alluvial deposits and gravels of varying thickness. Towards the west it thinned out and was partly replaced by sands.

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† Journal Inst. C.E., vol. 17 (1941–42), p. 251 (Jan. 1942).

The particulars of the index properties and the " clay "-content of samples obtained by the Road Research Laboratory from the points indicated in *Fig. 16* were given in Table A. The data supplemented information given by the Authors in Table VI. All the values in Table A were within the limits quoted by the Authors in Table VII, and the values of the " clay "-content and plasticity indexes were those that would be

Fig. 16.

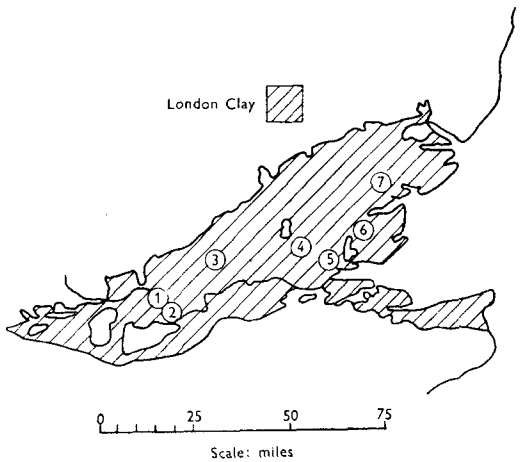

TABLE A.—TEST RESULTS ON LONDON CLAY.

	Site.	Liquid limit: per cent.	Plastic limit: per cent.	Plasticity index.	Clay content: percentage $<2\mu$.	No. of samples.
1	Wraysbury (Middlesex) .	71	26	45	—	1
2	Staines (Middlesex . .	64	23	41	52	1
3	Kingsbury (Middlesex) .	83	29	54	—	1
4	Brentwood (Essex) . .	88	27	61	59	7
5	Laindon (Essex) . . .	81	25	56	54	2
6	Latchingdon (Essex) .	69	22	47	—	1
7	Layer de la Haye (Essex)	85	30	55	—	1

expected from the respective liquid limits of the samples, assuming the average relations shown in *Figs. 3* (p. 257, *ante*) and *4* (p. 258, *ante*). The agreement was especially close in the case of *Fig. 4*. The results indicated that London Clay retained its general character over wide areas, and suggested that the other properties studied by the Building Research Station would also probably fall within the limits stated.

Another matter arising out of the Paper appeared to be of interest.

It was well known that the results of the geodetic levelling undertaken by the Ordnance Survey indicated that the general level of the ground in the Thames basin was progressively sinking[1]. Did the Authors think that that was due to any extent to consolidation of the London Clay following the drop in water-pressure in the artesian basin beneath the clay? That drop had been progressing for the past 100 years.

Mr. E. G. Walker observed that the large expenditure on civil engineering works and on buildings constructed in and on the London clay justified the fullest investigation of its properties and the dissemination of data thereon. The results of the Authors' work were more valuable in that the information had been collected as the result of an investigation made as part of the development of an important public undertaking. Thus practical ends had been in view in a way which might have been absent from a more purely abstract study.

An important general deduction from the investigation was the proof it afforded of the large range of variation, both in the mechanical analyses of the clay and in those properties with which the Authors dealt under the name "index properties." In regard to the mechanical analyses the triangular chart (*Fig. 1*, p. 255, *ante*) showed that very clearly. The Authors had cited the variation (from 42 to 71 per cent.) in the fractions of the smallest particles, which were the most important in giving the clay its characteristic properties. The variations in relation to range in the fractions of intermediate and coarse particles were relatively greater, that of the coarse being the greatest. The magnitude of those variations might afford the reason for the irregular differences shown by the tests of samples at 2-inch intervals reported in Table I, p. 259, *ante*.

The evidence afforded by *Fig. 5*, p. 260, *ante*, indicated a more general uniformity over depths of a number of feet, and gave promise that careful collation of measurements of the Atterberg limits made at frequent intervals over the depth of a borehole or trial pit might enable a reliable record of the variations in the quality of the clay bed to be made, although involving more experimental observation than was usually given to such examination. It seemed clear from *Fig. 5* that the limits were not influenced much by the natural increase of pressure in the clay with increase of depth.

The large variation in the values of the limits which the Authors proposed to use as index properties might discount their suitability for the purpose. The values of the liquid and plastic limits given in Table VII (p. 274, *ante*) showed a variation of the former of 47 per cent. of the mean, and of the latter of 41½ per cent. Variations in the compressibility and coefficient of consolidation exceeded 60 per cent. When those quantities were plotted against one another in *Figs. 9* and *10* (p. 266, *ante*), the dispersal of the plotted points was so wide that the drawing of fair curves

[1] Longfield, T. E., "The Subsidence of London." Ordnance Survey Professional Paper, New Series, No. 14, London, 1932.

to represent a definite relationship was of very doubtful justification. It would seem that much had yet to be done before quantitative relationships could be established that would be reliable in their application.

The shear tests plotted in *Fig. 12* (p. 269, *ante*) were remarkably consistent, but the attempt to use the liquidity index as an index property against which to plot shear strength was not so successful. No doubt the Authors were right in stating that the use of the selected index properties was justifiable as " an indication of the consistency of clays ", but in the present state of knowledge it was an approximate indication only, and not a measure.

The Authors, in reply, thanked Mr. Markwick for the test results given in Table A. They afforded additional data from different sites to supplement that given in Table VI, and it was of interest that the results fitted in with correlations given in the Paper and supported the contention that London clay retained its general characteristics over wide areas.

However, as Mr. Walker had rightly observed, the variations within the stratum were fairly large, in regard to particle-size distribution, " index-properties ", and mechanical properties. Whilst, for the consideration of practical engineering problems, the determination of the mechanical properties and their variation was the important requisite, the Authors had explored the possibility of using " index-properties " for the purpose of variation-study because they were much easier to carry out than a mechanical analysis, and very much easier than consolidation tests.

The fact that the liquid limit varied over a wide range made it more, rather than less, suitable as a means of studying variation, and the correlation between the liquid limit and the percentage clay fraction shown in *Fig. 3* indicated the success with which that simple property reflected the type of clay, namely, " silty clay ", " fat clay ", etc. Although the variation in silt and fine sand fractions would have some effect, the Authors thought the correlation indicated that the variation in the clay fraction was the most important.

As Mr. Walker had pointed out, the correlation between the " index-properties " and the mechanical properties was not very close, but the Authors considered that it was significant. Close correlation could hardly be expected, since the factor of soil structure which helped to govern the mechanical properties did not exert an influence on the " index-properties." However, it was considered that by using those correlations to supplement the results of mechanical tests on a limited number of samples more reliable representative values for the mechanical properties could be obtained.

In reply to Mr. Markwick, the Authors considered that the subsidence of the London area was probably due to an important extent to the progressive lowering of the water-table in the artesian basin by pumping. The problem was susceptible to mathematical analysis, and by using the test results given in the Paper calculations of the rate of subsidence could

be made. A Paper † on the subject had been presented to The Institution by Messrs. Guthlac Wilson, M. Inst. C.E., and Henry Grace, Assoc. M. Inst. C.E.

The results given in the Paper represented only a beginning in the study of the mechanical behaviour of London clay. Additional data were being collected as opportunity permitted and the Authors hoped that engineers would contribute data which they obtained, so that a body of information could be built up.

† "The settlement of London due to Underdrainage of the London Clay." Not yet published.

CORRESPONDENCE
ON PAPER PUBLISHED IN FEBRUARY 1942 JOURNAL

Paper No. 5276.

"Relative Merits of Wire and Bar Reinforcement in Pre-stressed Concrete Beams." †

By Rhydwin Harding Evans, M.Sc., Ph.D., Assoc. M. Inst. C.E.

Correspondence.

Dr. K. W. Mautner observed that the surface-area of the forty-four wires in the wire beams with a maximum initial stress of 103·2 tons per square inch, as compared with the initial stress (29 tons per square inch) of the bar beams (diameter of bar 1 inch), was 3·5 times that of the reinforcement stretched to $\frac{1}{3{\cdot}55}$ of the stretched bars. It was useful to take such a highly exaggerated example for test purposes, but that wide difference in diameter and stresses did not exist in practice. Except for small elements with small external forces no wire of less than S.W.G. 11

† Journal Inst. C.E., vol. 18 (1941–42), p. 315 (Feb. 1942).