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Road Research Laboratory

THE LABORATORY TESTING OF SOILS FROM SIX SITES IN KENYA

by

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SUMMARY

Laboratory tests have been carried out on samples of subgrade soil from a number of sites in Kenya, which have been the subject of a detailed investigation to determine the changes in moisture conditions which take place beneath bituminous surfaced roads. Tests have also been carried out on two samples of nodular gravel-sand-clay which occurred in the road construction at two of the sites.

The tests carried out comprised the following:-

(i) Particle size distribution

(ii) Atterberg limits

(iii) Specific gravity

(iv) Compaction tests at three levels of compaction

(v) C.B.R. tests on the compacted tests specimens.

The results of the classification tests were in good agreement with those obtained in the field. With some soils, different specific gravities were obtained, depending on whether soil was dried prior to the tests or used at its natural moisture content

The C.B.R. value, at optimum moisture content and maximum dry density for British Standard Compaction, seldom exceeded the in situ values obtained in the field investigation and this would appear to be a suitable basis for design. However, in view of the rapid change in C.B.R. with moisture content at this point, and the difficulty in making up a specimen to a specific moisture content, it is recommended that a procedure similar to that adopted in this investigation should be used in defining the characteristics of different soil groups. The C.B.R. values, in situ in the field, were in fair agreement with those inferred from the iso-C.B.R./density/moisture content curves.

THE LABORATORY TESTING OF SOILS FROM SIX SITES IN KENYA

Introduction

To obtain a better understanding of results obtained in a field investigation into the moisture conditions in Kenya, samples of the subgrade soils from six of the sites investigated, and two nodular gravel-sand-clays (bases at two of the sites) have been examined at the Road Research Laboratory.

The principal objects of the present investigation were:-

(i) to record laboratory test data for the soils encountered in the field investigation, and where applicable to compare these with results obtained in the field.

(ii) to provide laboratory C.B.R. data which could be compared with the in situ data obtained from the field investigation.

In addition to the present investigation, soil moisture suction tests are being carried out on undisturbed samples taken from the field sites, and these will be reported in a later note.

Location of samples

The samples were obtained during the investigation of the moisture conditions under roads in Kenya and were taken during June and July 1959. The location of the samples is given in Table I. The samples were sent to the Laboratory in sealed 40 gallon drums at their in situ moisture contents. Care was taken to prevent the samples drying out prior to test.

TABLE I

Laboratory Sample No.	Site	Subsite	Soil type
830	Limuru 'A' Route	(b) Cut	Red clay
831	Thika-Sagana Road	(b) Cut	Red clay
834	Mombasa Road Mile 27	(b) Fill	Black sandy clay
835	Naivasha	(a) Level	Ash and pumice
836	Nakuru	(c) Level	Ash and pumice
837	Ngong Road	(a) Level	Black clay
832	Thika-Sagana Road	(c) Fill	Nodular gravel sand clay (base)
838	Ngong Road	(a) Level	Nodular gravel sand clay (base)

On arrival at the Laboratory, the large samples were riffled into a number of smaller samples, approximately 5 Kg each, to reduce to a minimum the variation between the samples used in any one of a series of tests.

/Laboratory

Laboratory tests carried out

(a) Particle-size distribution. The particle size distribution for all the samples was carried out in two parts, using tests 6A and C of B.S.1377 (1960)(2)

The results of the coarse and fine analyses are given in Figs. 1-3 and Table II.

Notes on particle size distribution:-

(i) Apart from the pumice soils, the percentage of silt and clay estimated from the coarse analysis was in very close agreement with that found from the pipette analysis. With the pumice soils, the percentage of silt and clay was some 7 per cent higher in the case of the pipette analysis. This may have been due to break-down of particles in the mechanical stirer but, since the particles would be likely to be broken down to at least as great an extent in the plasticity tests, the higher figure is taken for the silt and clay contents.

(ii) The two red clays had very similar gradings and contained some 20 per cent more clay-sized particles than the black clay.

(b) Atterberg limits. The liquid and plastic limit tests were determined according to tests 2(A) and 3 of B.S.1377 (1960) except that the soils were not dried at all prior to test. In the case of samples No. 830 and 837, it was not possible to pass them through a No. 36 mesh sieve at their natural moisture content, and the whole sample was used, coarse grains being removed by hand. This procedure was adopted because it is known that drying soils can cause changes in the test values, and it was required to obtain values comparable with the soils as they existed in the field. The results are given in Table III and Fig. 4.

Notes on Atterberg limits:-

(i) The Atterberg limits obtained from the field investigation are given in Fig. 5, and apart from sample 830, the remaining samples are within the range of values obtained during the field investigation. Sample No. 830 had a higher liquid limit and plasticity index than was obtained in the field, but the point plots in broadly the same relationship to the A line on the Casagrande chart as the points obtained in the field.

(ii) When comparing the plasticity tests of soils, it is useful to consider the clay content in relation to the fraction passing the 36 mesh sieve, and consider the activity of the clay, i.e. the plasticity index divided by the clay content of the fraction on which the test is carried out. These figures are given in Table III. There is not much difference in the activities between the soils apart from the pumice soil from Nakuru (No. 836). In general, the red soils give a value of 0.6, while the black soils give a value of 0.8. The high value obtained with the Nakuru soil of 1.1 is probably due to the fact that the working given to the material in the plasticity tests, broke it up considerably more than occurred in the mechanical analysis.

(iii) The high values of the liquid and plastic limits for the Nakuru soil would indicate a porous particle which acts as a water reservoir.

/TABLE II

TABLE II

Grading Analyses

Soil No.		830	831	834	835	836	837	832	838
Origin		Limuru Route "A" sub-site "b"	Thika-Sagana Road sub-site "b"	Mombasa Road mile 27 sub-site "b"	Naivasha* sub-site "a"	Nakuru* sub-site "a"	Ngong Road* sub-site "a"	Thika Sagana* Road sub-site "c"	Ngong Road
Type		← Red clay →		Black sandy clay	← Pumice →		Black Clay	← Nodular gravel sand clay →	
Percentage finer than	B.S. Sieve No. ¾ in.	-	-	100	100	100	-	100	100
	¼ in.	-	100	99	97	87	100	92	96
	No. 7 mesh	100	99	98	92	73	99	73	78
	" 25 "	99	-	89	84 (87)	60 (67)	98 (98)	48 (49)	53
	" 36 "	-	-	82	81	57	-	45	49
	" 72 "	98	98	65	72 (74)	54 (60)	97 (94)	41 (44)	42
	" 200 "	96	97	49	59 (67)	47 (54)	95 (91)	35 (38)	34
	0.02 mm	94	95	40	52	40	85	32	24
	0.006 mm	90	89	34	37	22	76	24	18
	0.002 mm	89	86	27	23	9	67	19	13

*Figures in ( ) were obtained from the pipette analysis

/TABLE III

TABLE III

Classification Test Data

Soil No.	830	831	834	835	836	837	832	838
Origin	Limuru Route "A" sub-site "b" (cut)	Thika-Sagana Road sub-site "b" (cut)	Mombasa Road Mile 27 sub-site "b" (fill)	Naivasha sub-site "a" (level)	Nakuru sub-site "a" (level)	Ngong Road sub-site "a" (level)	Thika-Sagana Road sub-site "c" (fill)	Ngong Road (level)
Type	⟵ Red clay ⟶		Black sandy clay	Ash and pumice		Black clay	Nodular gravel and clay	Nodular gravel and clay
Liquid Limit (per cent w.)	109	89	49	50	67	103	89	41
Plastic Limit (per cent w.)	53	40	22	28	50	43	27	19
Plasticity Index	56	49	27	22	17	60	25	22
Specific Gravity at 25/25°C: at natural moisture content	2.86	2.96	2.63	2.60	2.57	2.69	3.13	3.06
Specific Gravity at 25/25°C: oven-dried	2.86	2.92	2.62	2.52	-	2.59	3.16	3.03
Specific Gravity at 25/25°C: pycnometer (using compacted soil)	-	-	-	2.61	2.46	-	-	-
Organic matter (per cent w.)	0.7	0.5	12	2.3	2.2	2.3	0.5	0.6
Percentage of material finer than 0.002 mm as percentage of material passing a No. 36 mesh sieve (= P%)	90	87	33	28	16	71	42	26
Activity (= $\frac{P.I.}{P\%}$)	0.6	0.6	0.8	0.8	1.1	0.8	0.6	0.8

/(c)

(c) Specific gravity. The specific gravity was determined by test 5 (A) of B.S.1377 (1960) except duplicate determinations were made on both oven-dried material and material at its natural moisture content. In the latter case, the dry weights of material used were found by oven drying at the conclusion of the tests. This was done because it was known that, with certain soils, oven drying causes a difference in specific gravity is for use in determining the zero air voids line, it is necessary to use material at or as near its natural condition as possible. The clay soils, samples 830, 831 and 837, were passed through a No. 7 mesh sieve, sample 836 was ground to pass a No. 72 mesh sieve, while the remainder were ground to pass through No. 36 mesh sieve. In addition, duplicate pycnometer bottle determinations (Test 5B of B.S.1377) were made on the pumice soils, Nos. 835 and 836, after being compacted once at the optimum moisture content for the modified AASHO compaction level. The results are given in Table III.

Notes on specific gravity determinations

(i) With 6 out of the 8 soils tested there were small but significant differences between the specific gravities measured on samples at their natural moisture content and samples which had been oven dried. The largest difference occurred in the case of the black clay from Ngong road and was 0.1.

(ii) One of the red clays, sample 831, showed a difference in specific gravity between soil oven-dried and at its natural moisture content, while the other did not. It also had a higher specific gravity, probably indicating a higher iron content.

(iii) The Nakuru soil has a lower specific gravity when measured by a pycnometer after compaction than when ground up and measured in a specific gravity bottle. This would indicate that the soil contains a number of porous particles which are not broken up even during compaction.

(iv) The specific gravities of the red soils obtained in the laboratory are about 0.04 higher than those obtained in the field investigation. This is probably a function of the thoroughness in removing the final traces of air in obtaining the weight of the sample in water.

(d) Organic matter. Organic matter determinations were carried out by Test 7 of B.S.1377 (1960). The results are given in Table III.

Notes on organic matter determination:-

(i) The organic matter contents of all the soils were low, with the red soils being of the order of ½ per cent, and with both the black clay and pumice soils, just over 2 per cent.

(e) Compaction tests. Compaction tests were carried out in accordance with the general procedure of Test 10 of B.S.1377, (1960) except that 6 in. diameter by 5 in., high moulds were used. Care was taken to ensure that the amount struck off did not exceed ¼ in. In addition to the two levels of compaction given in the standard, an intermediate level was also used. For clarity, the compactive efforts used were as follows:-

/(i)

(i) B.S. compaction - 56 blows of $5\frac{1}{2}$ lb hammer dropping through 12 in., on each of 3 equal layers.

(ii) Intermediate compaction - 30 blows of a 10 lb hammer dropping through 18 in., on each of 5 equal layers.

(iii) Modified A.A.S.H.O. compaction - 56 blows of a 10 lb hammer dropping through 18 in., on each of 5 equal layers.

The compaction was carried out in an automatic compaction machine, the hammer head being 2 in., in diameter.

Separate samples were taken from the bulk sample for each point, and wetted up or dried out to the desired moisture content from the as received moisture content. When the desired moisture content was reached, the sample was sealed for 24 hours to allow the distribution of moisture to become uniform throughout the sample.

The maximum dry densities and optimum moisture contents for the different compactive efforts are given in Table IV and the results are plotted in Figs. 6-13. Also given in Table IV are the results of the compaction tests carried in the field investigation.

Notes on compaction tests:-

(i) Apart from the red clay from the Limuru site, sample 830, the results of the B.S. compaction tests are in very close agreement with those obtained in the field investigation. Sample 830 has a significantly lower maximum dry density and higher optimum moisture content, which would be expected from the differences which have already been noted in the plasticity tests.

(ii) Except for the two pumice soils, the peaks of the compaction curves lie approximately on the 5 per cent air voids lines. For the Nakuru soil, sample 836, the compaction curves are very flat, and the compacted soil on the wet side of the curves only approaches the 10 per cent air voids line. This suggests that with this soil there is air trapped within the soil particles when the material is wet. The samples compacted on the wet side of the optimum moisture content were spongy. The high optimum moisture contents would also indicate porous particles which just hold water, as already mentioned in the plasticity tests.

(f) California bearing ratio tests. C.B.R. tests were carried out on the top and bottom of each of the compacted samples. In the case of samples compacted at moisture contents greater than just below the optimum for the particular compactive effort, the moulds were sealed for 24 hours to allow positive porewater pressures, which may have been produced during compaction of the soil, to dissipate.

The C.B.R. values used were the highest given at penetrations of 0.1 or 0.2 in., after any necessary correction had been made.

In order to build up a picture of the C.B.R. density moisture content relationship for each of the soils, the C.B.R. values have been plotted on a log scale against moisture content, below the compaction curves in Figs. 6-13, and these have been used to draw in iso-C.B.R. lines on the compaction curves. From these it is possible to interpolate the C.B.R. value which the sample can be expected to have at any given moisture content and density. A similar approach has been used by a number of other workers in Australia(3), America, South Africa, Kenya and elsewhere, some workers using unsoaked samples, and others using a soaking procedure.

/TABLE IV

TABLE IV

Compaction Optima

Soil No.		830	831	834	835	836	837	832	838
Origin		Limuru Route "A" sub-site "b"	Thika-Sagana Road sub-site "b"	Mombasa Road Mile 27 sub-site "b"	Naivasha sub-site "a"	Nakuru sub-site "a"	Ngong Road sub-site "a"	Thika Sagana Road sub-site "c"	Ngong Road
Type		← Red Clay	→	Black Sandy Clay	← Pumice	→	Black clay	Nodular gravel sand clay	Nodular gravel sand clay
Optimum Moisture Content (%w)	B.S.	47 (38)≠	38 (36)	21 (21)	29 (29)	52 (50)	45 (42)	23	18
	Intermediate	41	36	18	25	44	41	21	15
	Mod. AASHO	39	34	17	24	34	32	19	15
Maximum Dry Density (lb/ft^3)	B.S.	72 (79)	82 (84)	98 (100)	83 (82)	58 (56)	70 (72)	107	116
	Intermediate	76	86	103	88	62	77	110	121
	Mod. AASHO	81	89	106	91	65	83	114	124

≠ Figures in brackets are results obtained during the field investigation.

/Notes

Notes on the results of the C.B.R. tests

(i) With the black clay from the Ngong road, the C.B.R. v. moisture content curves tend to run together as the clay approaches saturaturation regardless of the level of compaction used.

(ii) With the red clay from the Thika-Sagana road and the black sandy clay from the Mombasa road, there is a tendency for the curves to cross, though since the tendency is not very pronounced, the curves have in fact been run together.

(iii) The tendency for the C.B.R. v. moisture content curves to cross as the soils approach saturation becomes more marked with the red clay from Limuru and the Naivasha soil, and is most pronounced with the Nakuru soil. The reason for this is not fully understood. When specimens are compacted to near saturation, positive pore pressures are sometimes induced during compaction. If the specimen is tested before these pressures have had a chance to be dissipated, a low strength value is likely to result. Increasing compactive effort would be likely to develop increasing positive pressures and hence lower C.B.R. values. This effect is likely to be most marked in clay soils in which the pressures would take longer to be dissipated because of the low porosity. In this work, keeping the samples sealed for 24 hours before testing probably allowed most of such excess pressures, which may have been developed during compaction, to be dissipated. Also the effect was most marked in the granular soils, and the cause may well be related to the differing soil suction v moisture content characteristics of the soils at the different levels of compaction.

As a soil is compacted, there is an increasing component of strength due to inter-granular friction(4). There is a further component of strength due to the suction forces, but this decreases as the particles become closer together and with increasing moisture content. The first component of strength is predominent in granular soils provided they are unsaturated, i.e. air voids greater than 10 per cent. As the air voids are decreased below this level either by increasing moisture content at a given density, or by increasing density at a given moisture content, the loss of strength due to reduced soil suction forces far exceeds any gain that can be produced by increased intergranular friction, and owing to the steepness of suction curves in this region, a very small reduction in voids results in a large loss of strength. This is illustrated by the Nakuru soil Fig. 10. With an homogenous saturated clay, soil moisture suction forces are the main component of strength and, since density does not affect the soil moisture suction curve, it would be expected that once the air voids are reduced to a level at which the soil is effectively saturated, the soil suction will be the same for a given moisture content regardless of the compactive effort. (Assuming that the samples are on the same wetting or drying cycles).

/Remoulded

Remoulded specimens, such as C.B.R. samples, are not in general composed of homogenous saturated clay, but of aggregations of saturated lumps. Such samples approach the homogenous state on the wet side of the compaction curve when they become effectively saturated. In the unsaturated state, the strength of the lump is the ultimate strength of the clay, and it is greater than the strength of aggregations of lumps separated by air voids. At a given moisture content increasing compactive efforts will give increasing densities by reducing the major voids between lumps of clay until effective saturation is reached. As these voids are reduced, the strength of the specimen will increase approaching the strength of the saturated lump. This is illustrated by the Ngong Road soil Fig. 11. The Limuru red clay and the Thika-Sagana Road soil, Figs. 6 and 7, have characteristics of a granular soil which is a further indication of the aggregated nature of the clay.

(iv) The curves for the two nodular gravel-sand-clays are interesting in that the iso-C.B.R. lines are much closer together than those of the soils, and they suggest that, unless both densities and air voids are high, strength will drop very rapidly. They also indicate how sensitive the strengths of these gravels are to small changes in moisture contents.

More detailed comments on the C.B.R. tests and the shape of the load penetration curves are given in Appendix 1.

Discussion of results

The classification tests indicate that the samples tested in the laboratory were in general representative of the sites sampled in the field investigation, with the possible exception that the sample from Limuru was probably rather finer than the general run of the material encountered in the field.

In the discussion of the results of the field investigation(1), it was suggested that under the climatic and drainage conditions prevailing at the sites investigated, the C.B.R. value obtained at the maximum dry density and optimum moisture content for B.S. compaction could be used for the purposes of design.

In Figs. 14 to 19, the in situ C.B.R. results have been plotted against the moisture contents obtained in the field. Also on the figures is shown the interpolated C.B.R. value at B.S. optimum moisture content and maximum dry density. In each case this figure was 10 per cent C.B.R.

The figure of 10 was in general conservative when compared with the in situ figures obtained except at -

(i) The Mombasa road mile 27 site. Here a number of the results obtained at depths between 22 and 24 in were between 5 and 10 per cent C.B.R., and the level of compaction was only 95 per cent B.S. Three of the remaining results were below 10, but here again the compaction was only 95 per cent B.S.

(ii) The Naivasha road site. Here two results of 9 per cent C.B.R. and one of 6 were measured. The level of compaction at this site was of the order of 90 per cent B.S.

/(iii)

(iii) The Ngong road site. Here a number of results at depths of over 20 in. lay between 6 and 10 per cent C.B.R., but all the results at depths between 13 and 20 in. were over 10 per cent C.B.R.

An attempt has been made to compare the values of C.B.R. inferred from Figs. 6-11 at the measured moisture contents, for the average level of compaction found at the sites with the measured in situ C.B.R. values.

The average levels of compaction found in the field are given in Table V and the interpolated or extrapolated C.B.R. v moisture content lines for these levels of compaction have been drawn in on Figs. 14 to 19.

TABLE V

Average levels of compaction found during the field investigation

Site		Relative compaction % B.S.*
Limuru A Route	Subsite A	97
	" B	88
	" C	90
Thika Sagana Road	" A	91
	" B	93
	" C	98
Mombasa Road Mile 27	" A	97
	" B	95
Naivasha		90
Nakuru		95
Ngong Road		98

* Relative Compaction is defined in Soil Mechanics for Road Engineers as "The percentage ratio of the dry density of the soil in situ to the maximum dry density of that soil as determined by the standard compaction test".

As would be expected, there is a considerable scatter in the in situ C.B.R. values plotted against moisture content. The general shape of the relation between the results obtained in situ, and the inferred value from the laboratory tests is similar, though the laboratory tests suggest somewhat higher results for the clay soils than were found in situ.

The reasons for the differences between the inferred values from the laboratory work, and the results from the field were not investigated but the following will all be contributory.

(1) The inferred values from the laboratory tests depend on considerable extrapolation.

(2) Field densities were not obtained at the site of each in situ C.B.R. test, or at exactly the same time as the C.B.R. tests were taken. Also while the C.B.R. tests are probably more influenced by the density in the surface, the field densities were measured over an average depth of 5 in.

/(3)

(3) The restraining effect of the mould would be expected to give a difference between laboratory in situ results, particularly with the gravelly soils.

Similar figures have been prepared for the two gravel sand clay materials in Figs. 20 and 21 and the in situ C.B.R. values measured agree very well with those inferred from the laboratory tests.

Conclusions - see Summary.

REFERENCES

(1) O'REILLY, M.P., and F.H.P. WILLIAMS. Investigation to study moisture conditions under roads in Kenya. Department of Scientific and Industrial Research, Road Research Laboratory Note No. RN/3807/MPO'R. (Unpublished).

(2) BRITISH STANDARDS INSTITUTION. British Standard No. 1377:1960. Methods of testing soils for civil engineering purposes. London, 1960 (British Standards Institution) (In the press).

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(4) BLACK, W.P.M. The calculation of laboratory and in situ values of California bearing ratios from bearing capacity data. Geotechnique, Lond., March, 1961 (In the press).

/APPENDIX 1

Road Research Laboratory,
February, 1961,
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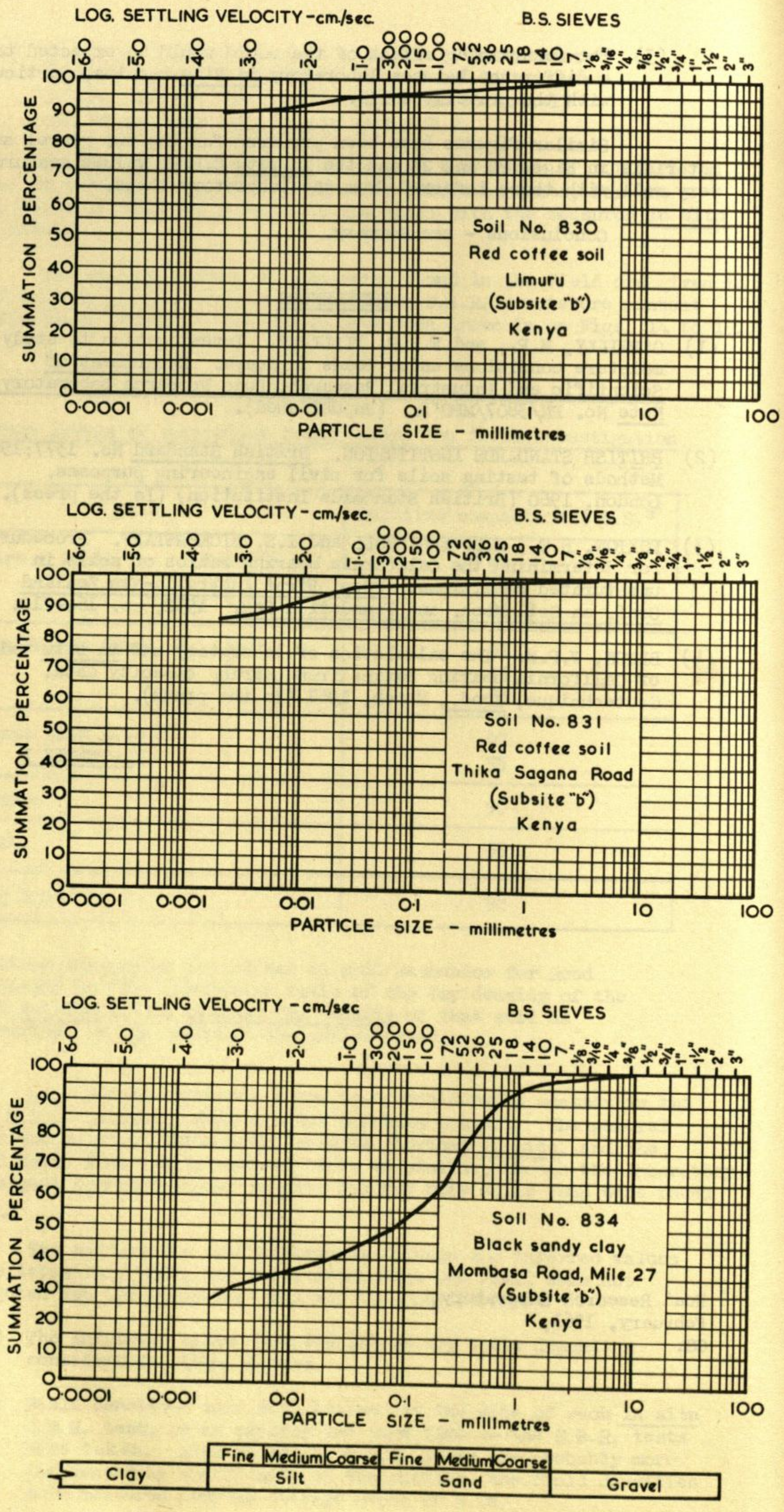

Fig.1 PARTICLE SIZE DISTRIBUTIONS – SOILS NOS. 830, 831, 834

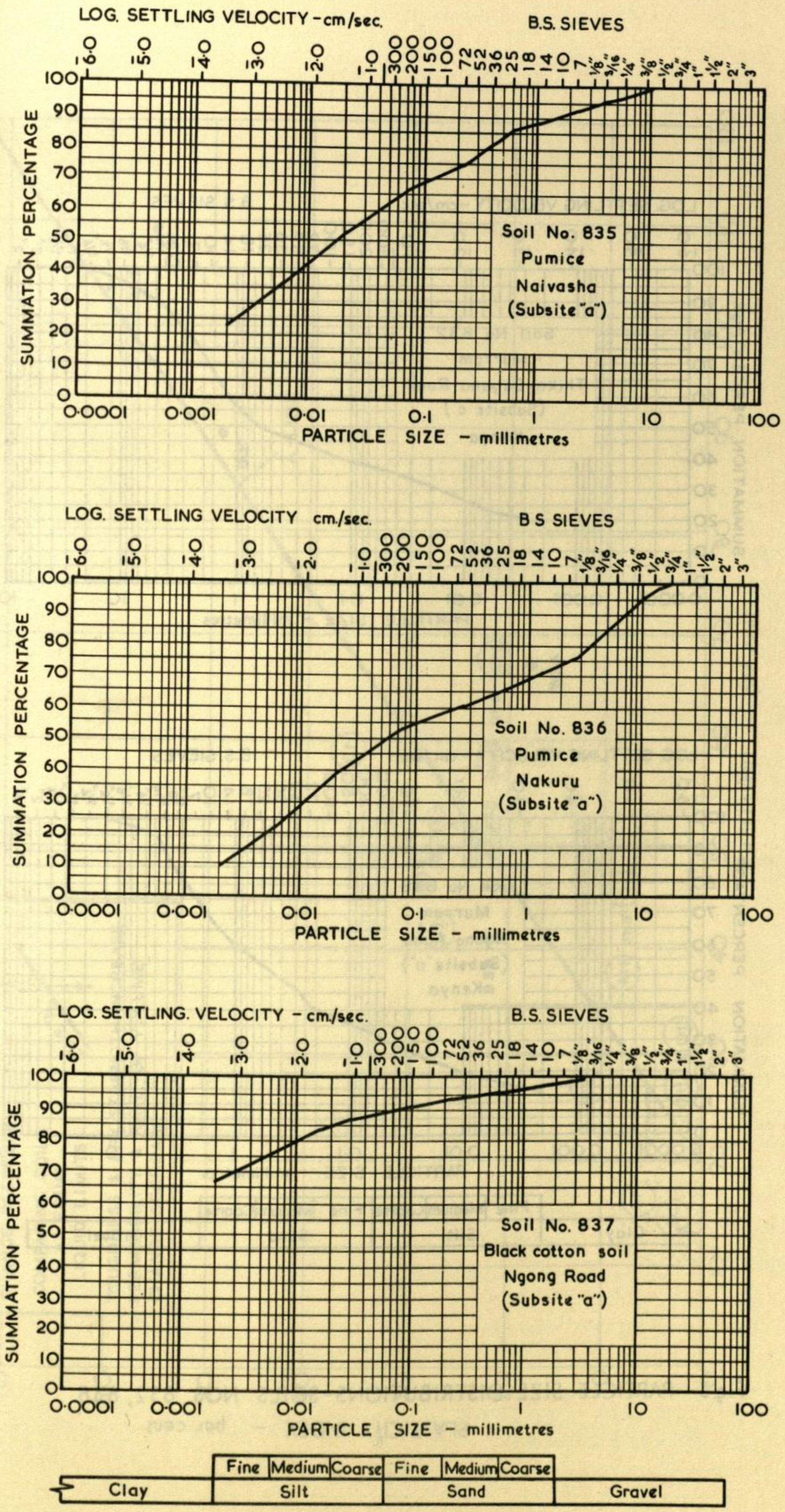

Fig. 2 PARTICLE SIZE DISTRIBUTIONS – SOILS NOS. 835, 836, 837

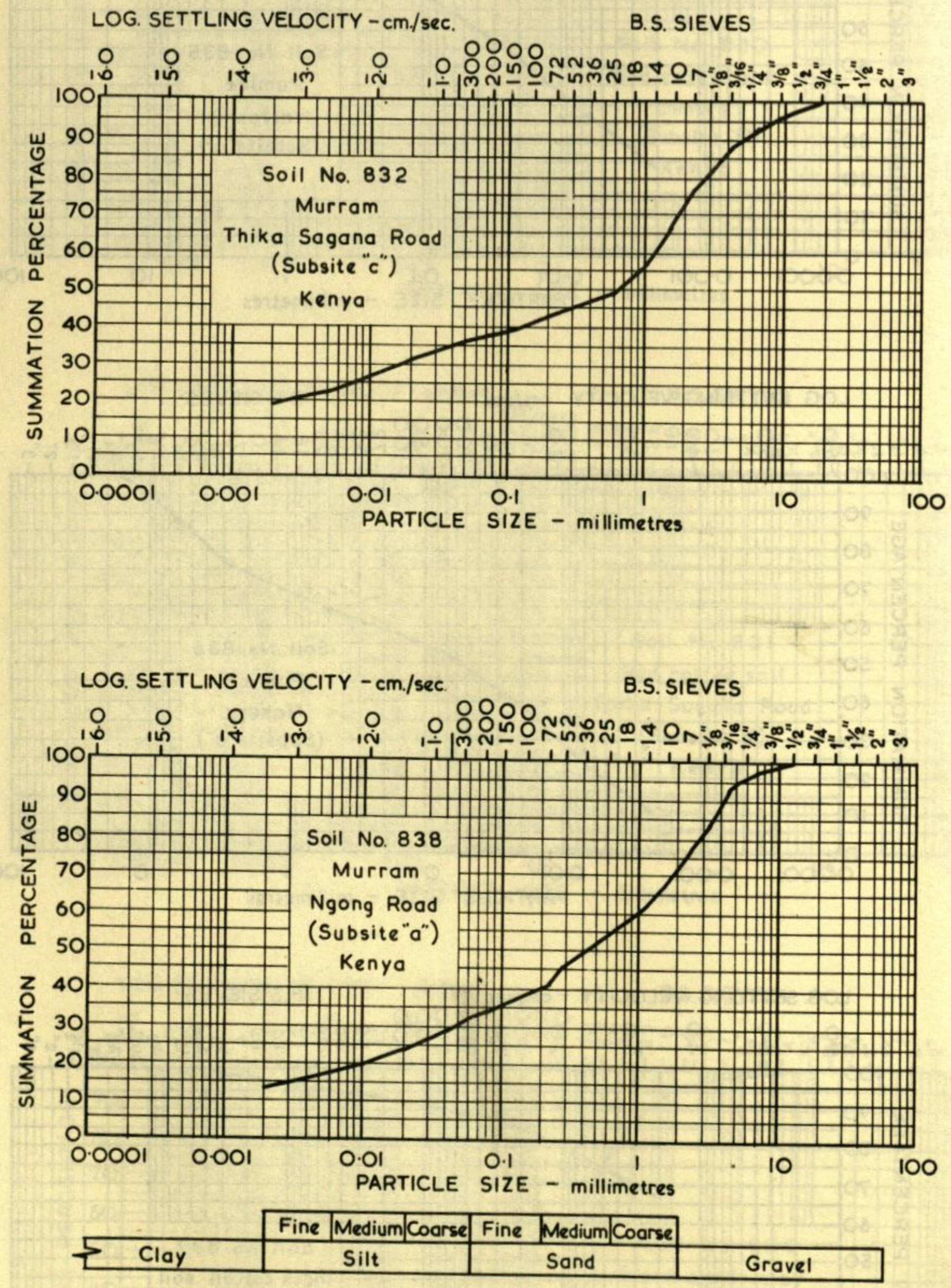

Fig. 3 PARTICLE SIZE DISTRIBUTIONS - SOILS NOS. 832, 838

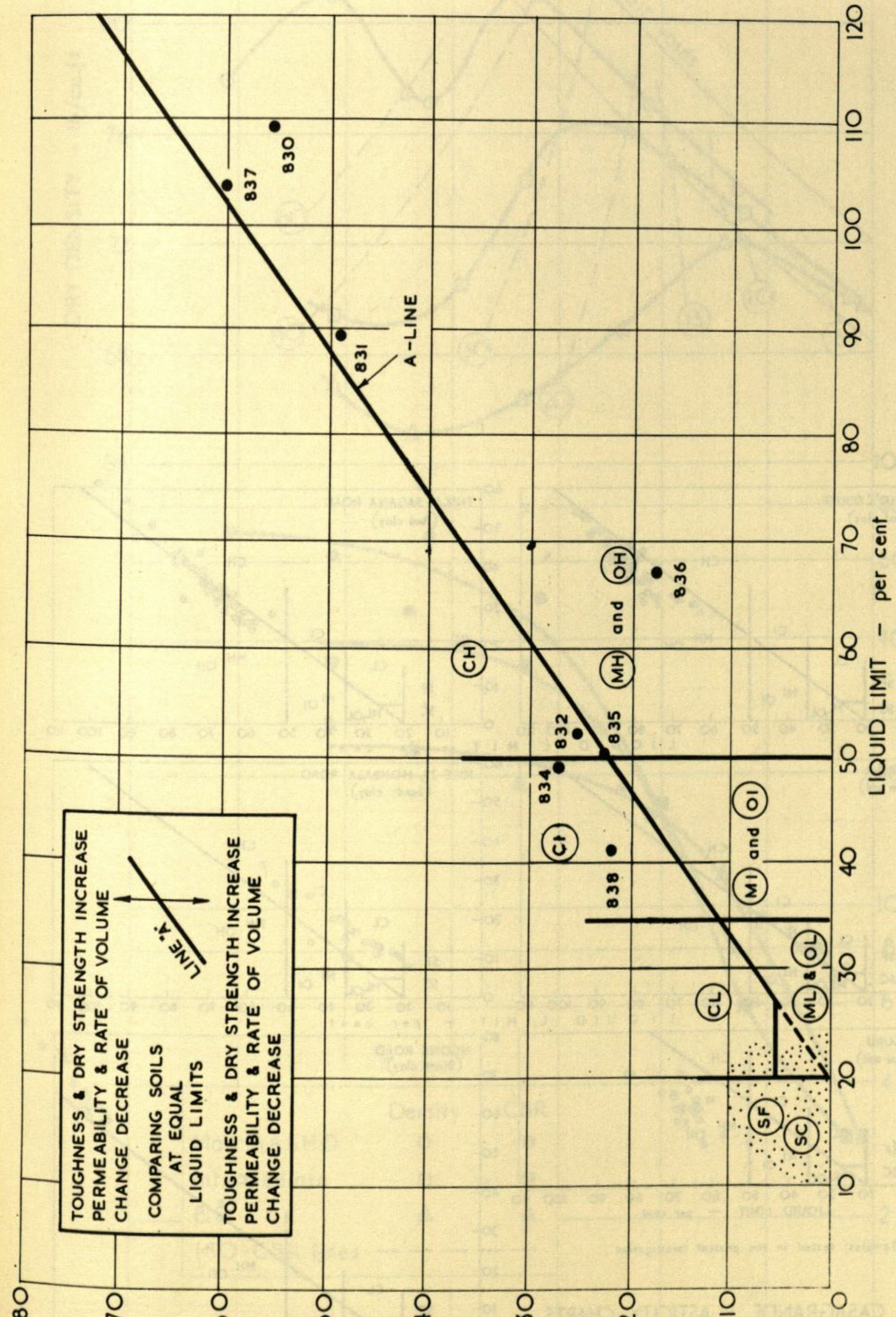

Fig. 4. THE CASAGRANDE SOIL CLASSIFICATION CHART FOR EIGHT KENYA SOILS Nos. 830, 831, 832, 834, 835, 836, 837, 838

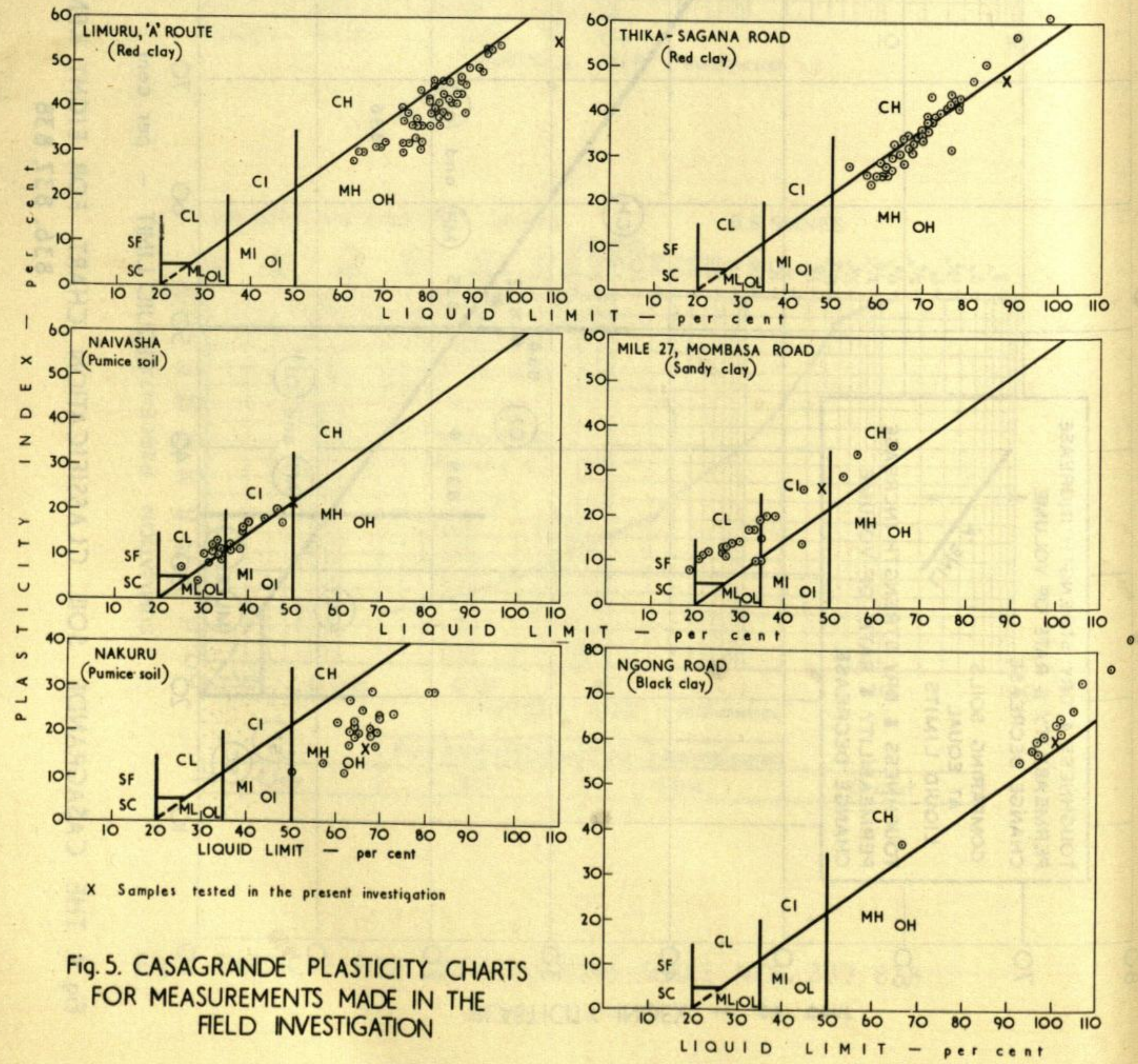

Fig. 5. CASAGRANDE PLASTICITY CHARTS FOR MEASUREMENTS MADE IN THE FIELD INVESTIGATION

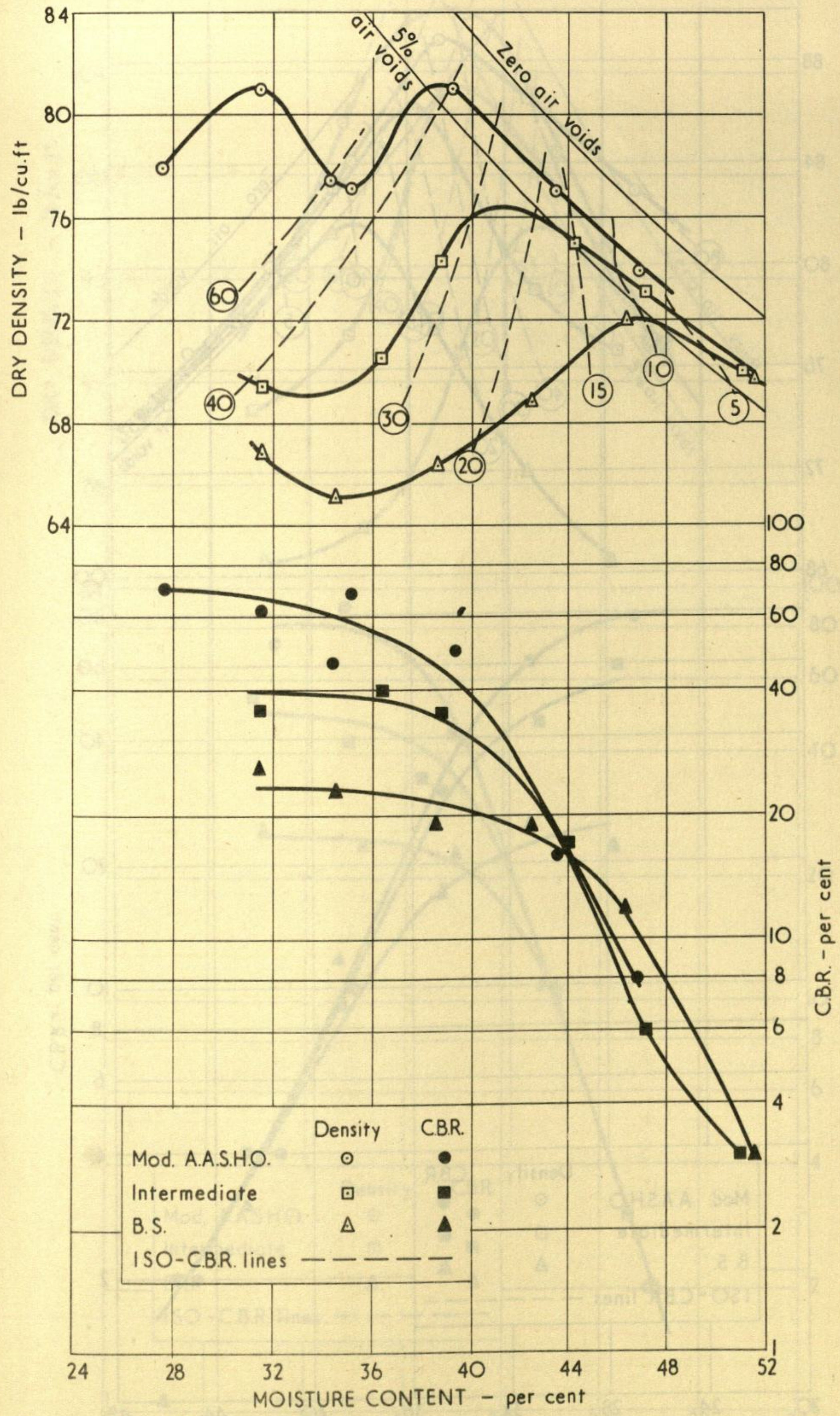

Fig. 6 COMPACTION AND C.B.R. DATA FOR RED CLAY FROM LIMURU 'A' ROUTE SUBSITE (b), KENYA. SOIL NO. 830

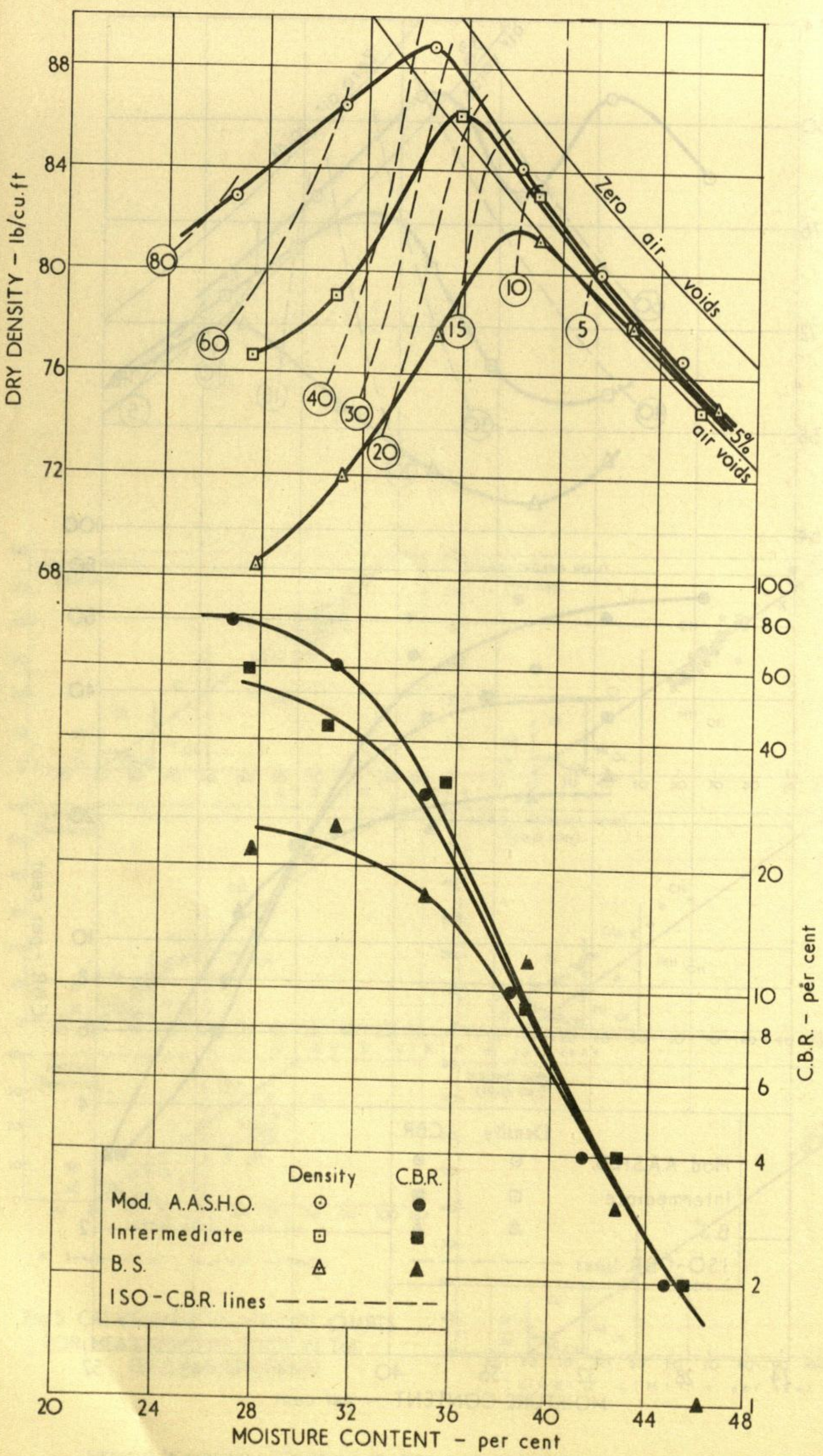

Fig. 7 COMPACTION AND C.B.R. DATA FOR RED CLAY FROM THIKA SAGANA ROAD SUBSITE (b), KENYA. SOIL NO. 831

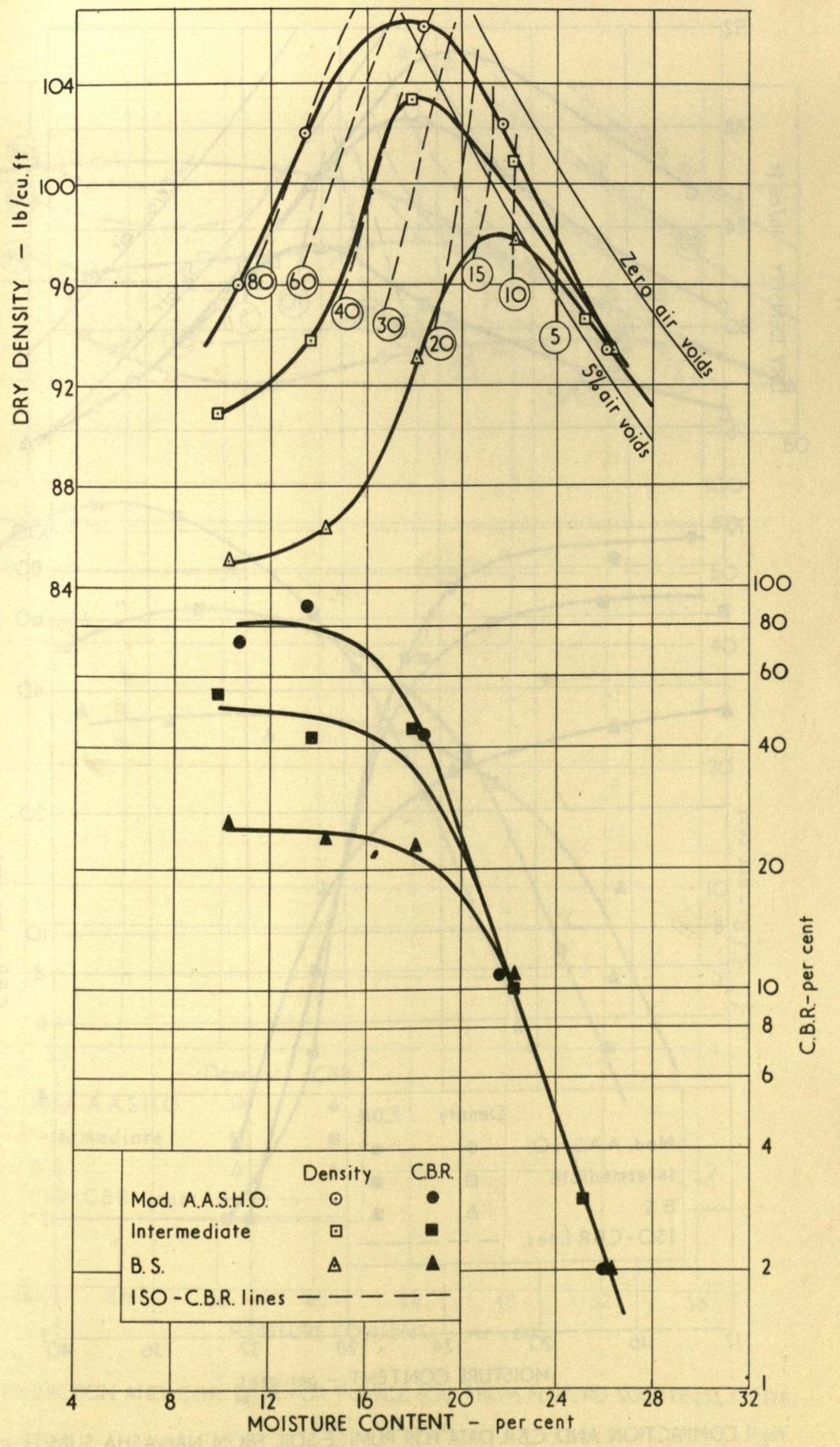

Fig. 8 COMPACTION AND C.B.R. DATA FOR BLACK SANDY CLAY FROM MOMBASA ROAD MILE 27, SUBSITE (b), KENYA. SOIL NO. 834

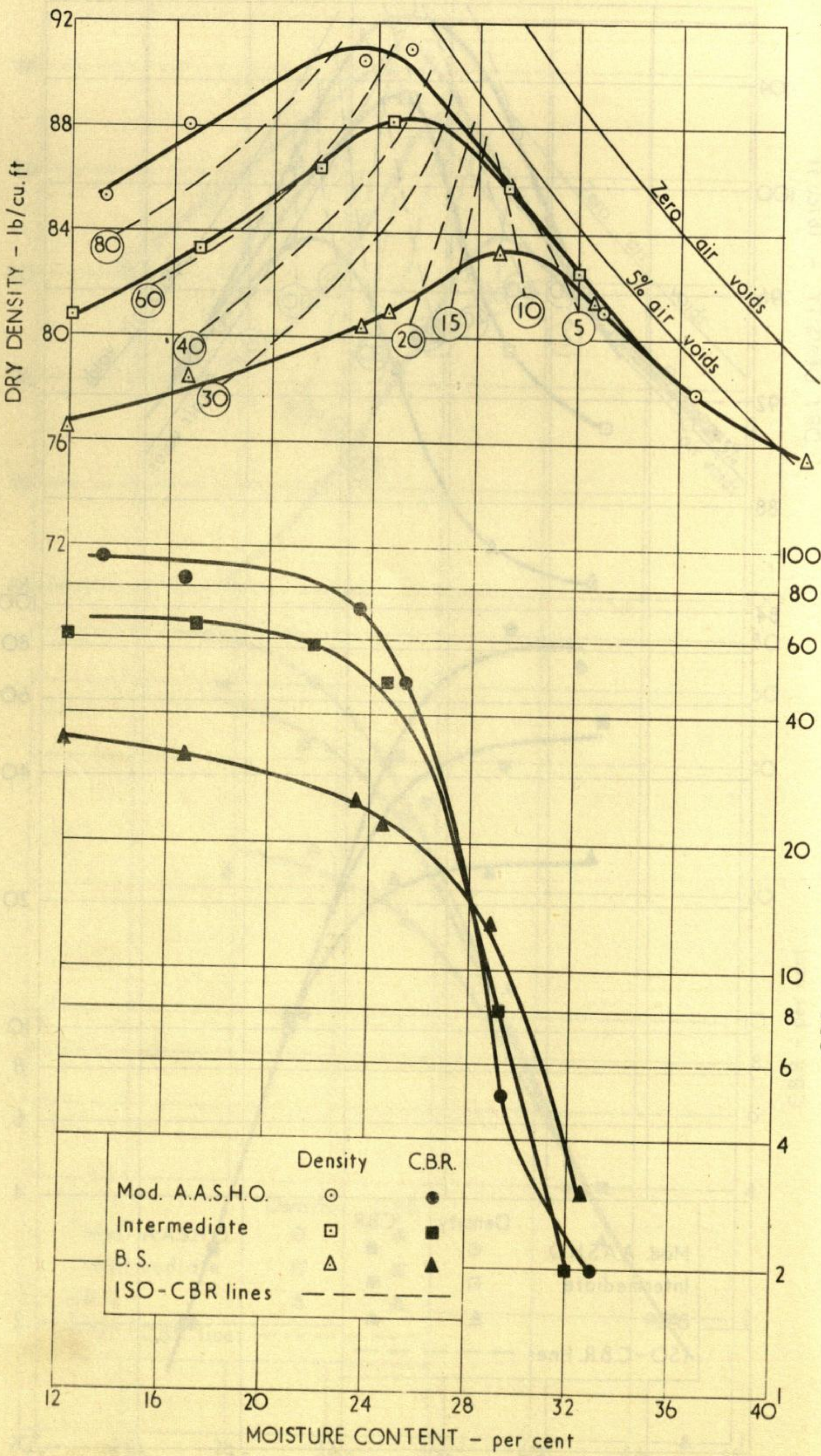

Fig. 9 COMPACTION AND C.B.R. DATA FOR PUMICE SOIL FROM NAIVASHA SUBSITE (a), KENYA. SOIL NO. 835

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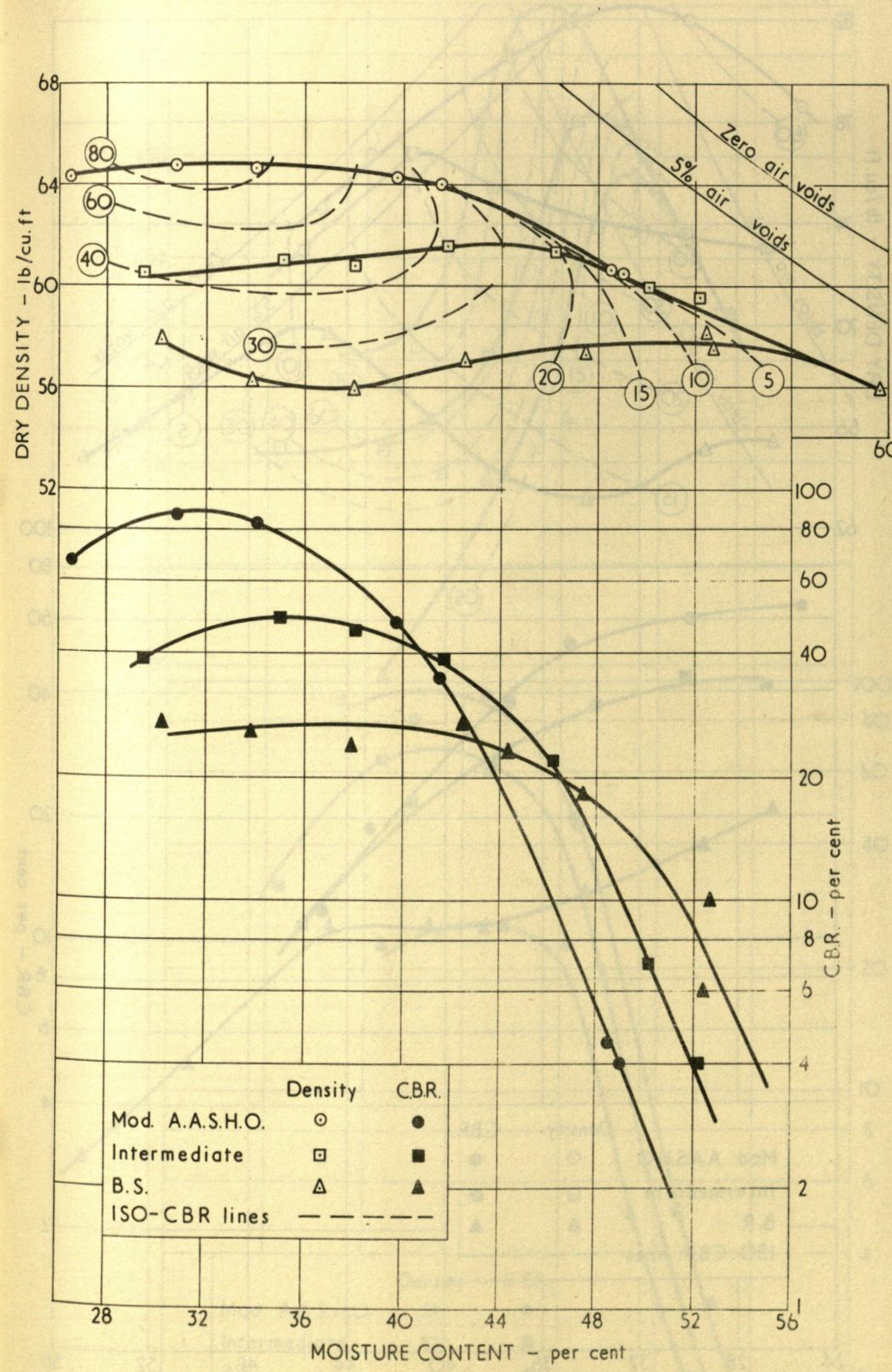

Fig. 10 COMPACTION AND C.B.R. DATA FOR PUMICE SOIL FROM NAKURU SUBSITE (a), KENYA. SOIL NO. 836

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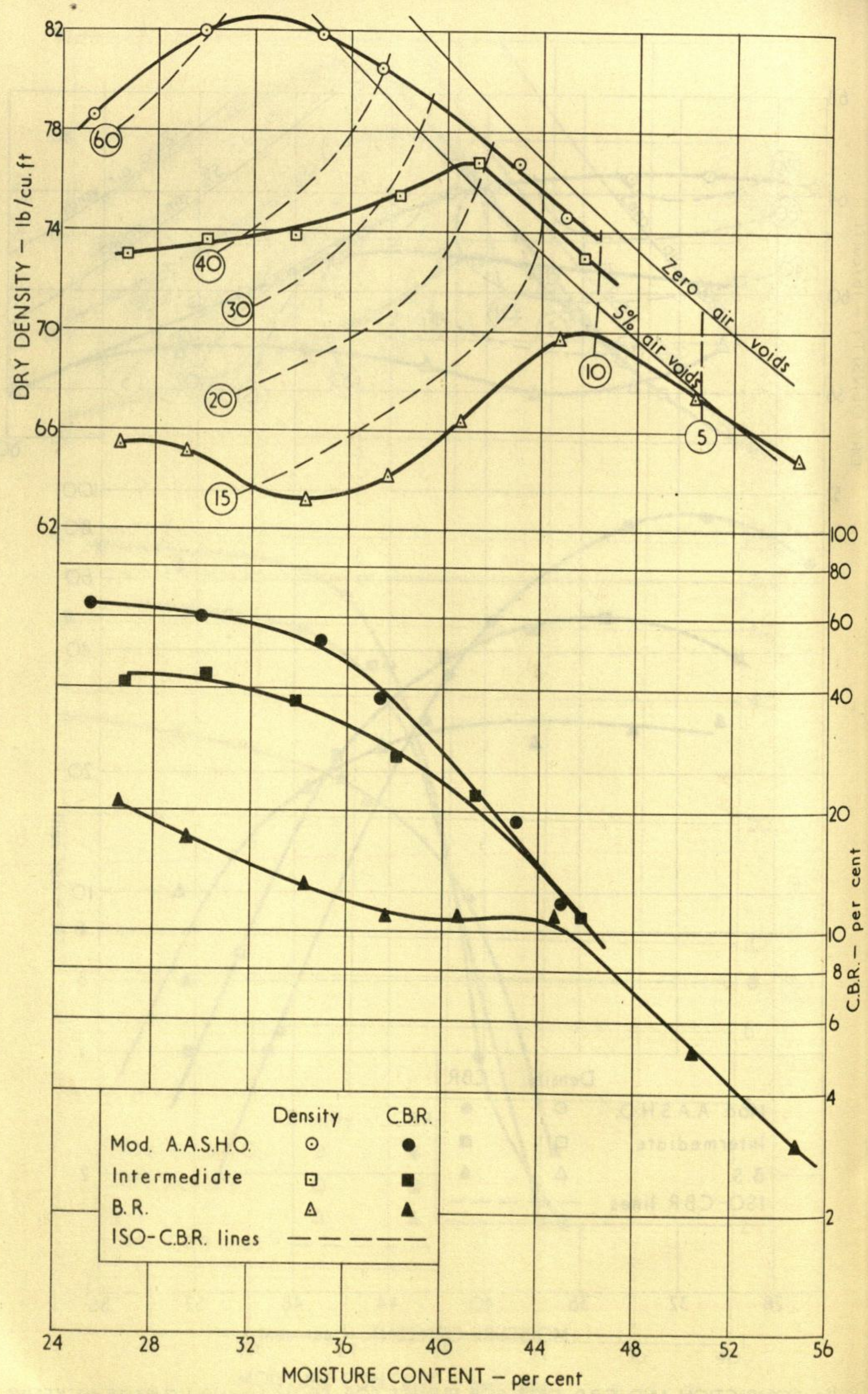

Fig. 11 COMPACTION AND C.B.R. DATA FOR BLACK CLAY FROM NGONG ROAD SUBSITE (a), KENYA. SOIL NO. 837

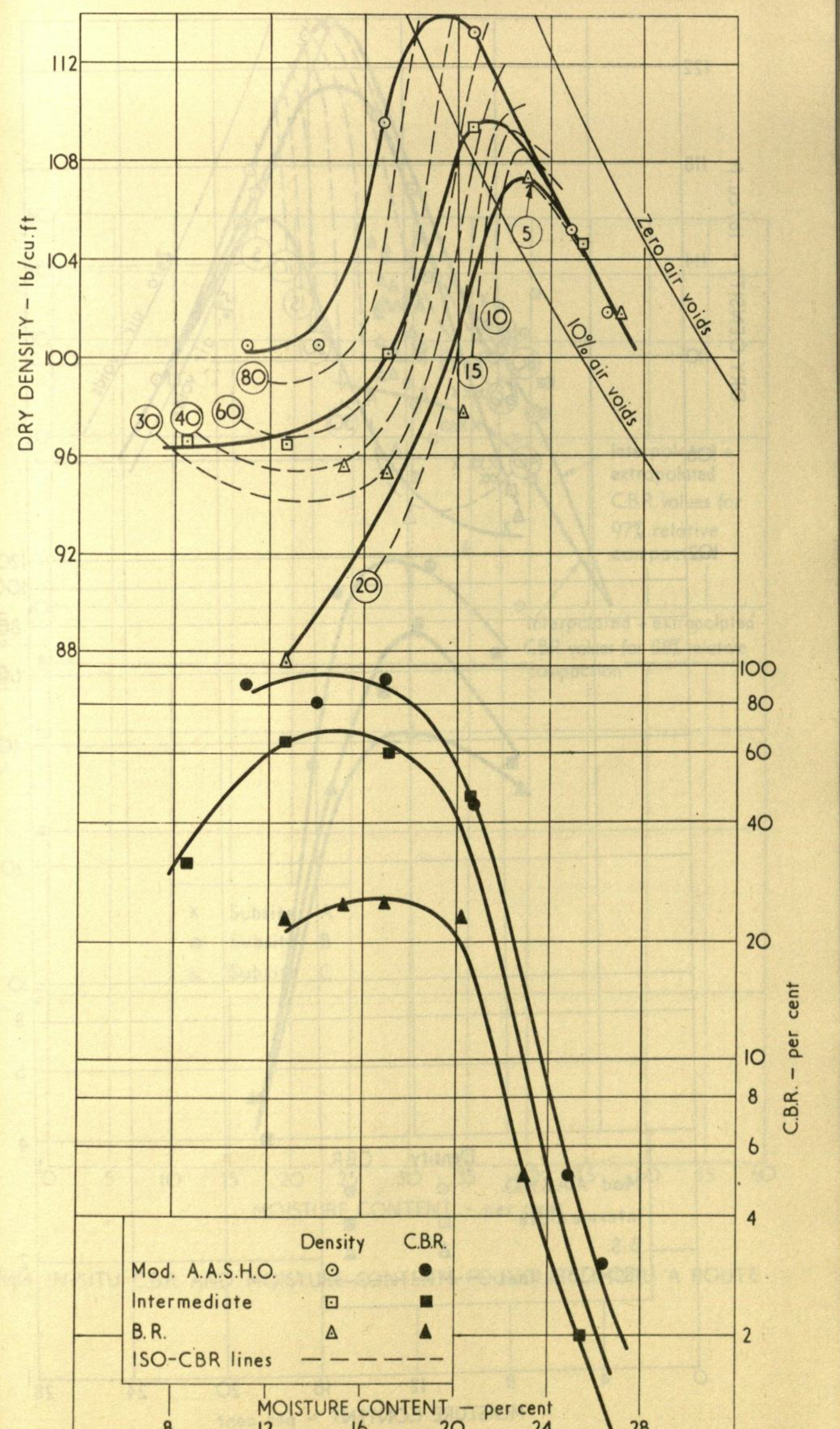

Fig. 12
COMPACTION AND C.B.R. DATA FOR NODULAR GRAVEL-SAND-CLAY FROM THIKA SAGANA ROAD SUBSITE (c), KENYA. SOIL NO. 832

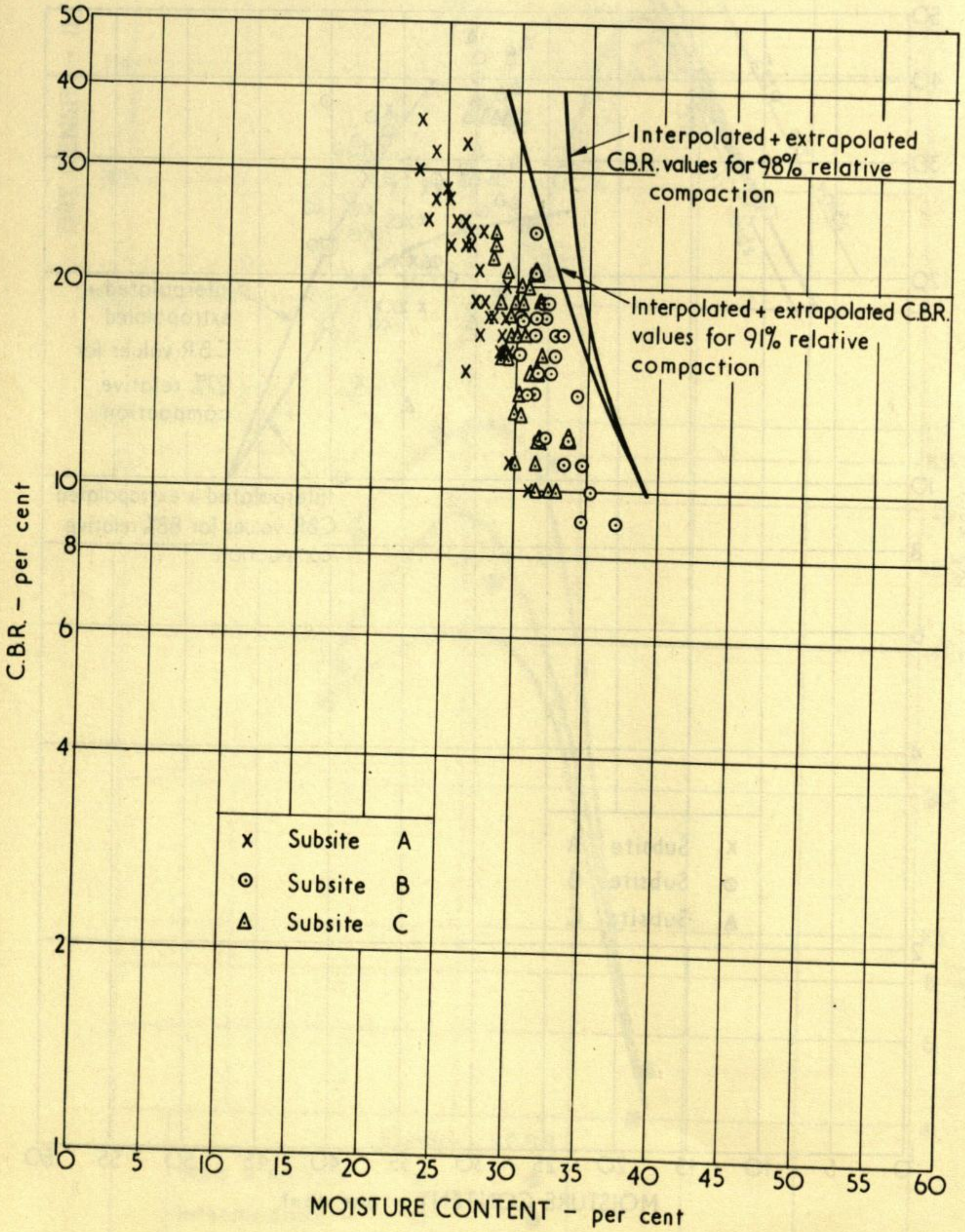

Fig 15 IN-SITU C.B.R. AND MOISTURE CONTENTS FOUND AT THIKA SAGANA ROAD

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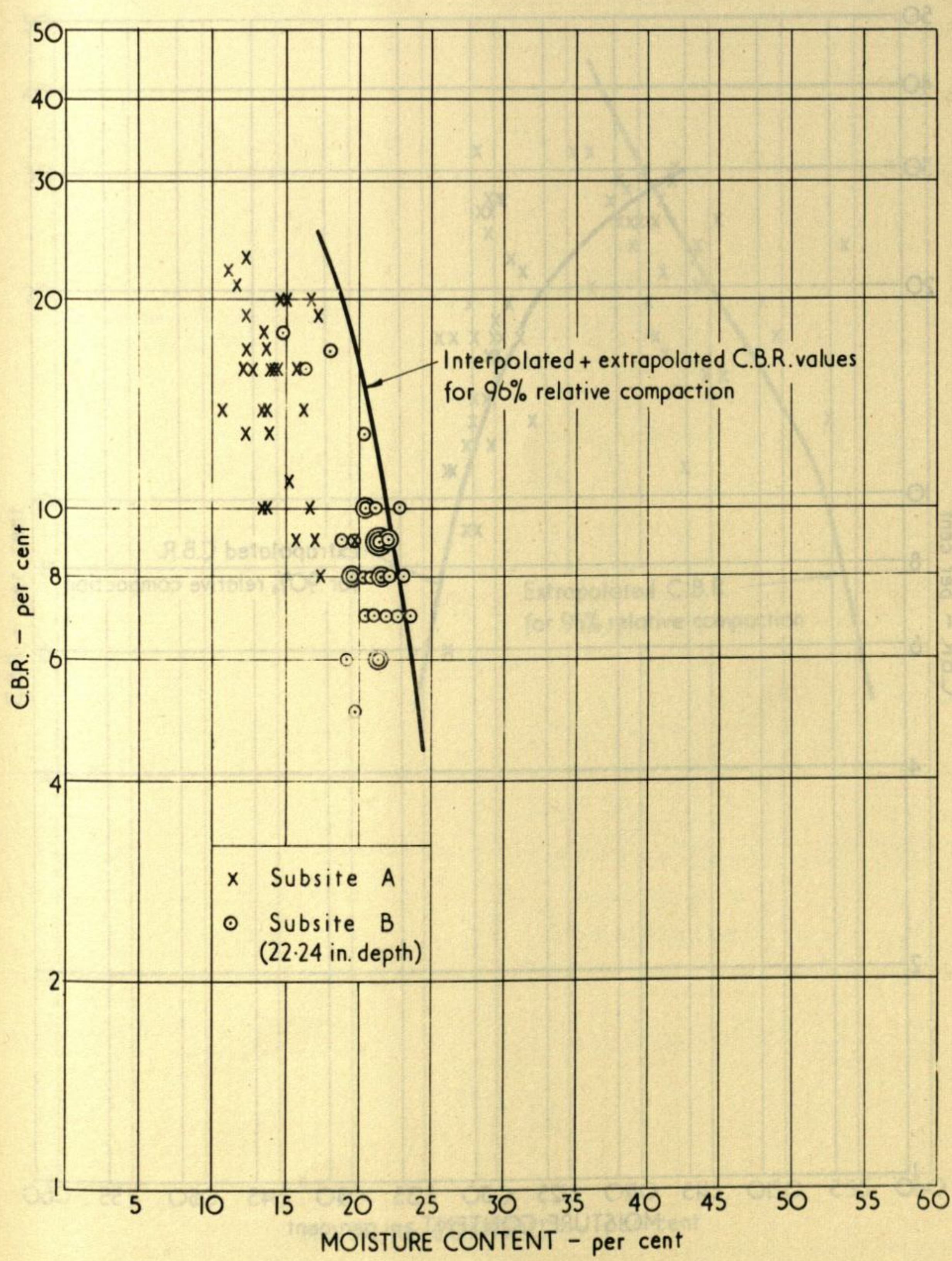

Fig. 16 IN-SITU C.B.R. AND MOISTURE CONTENTS FOUND AT MILE 27 MOMBASA ROAD

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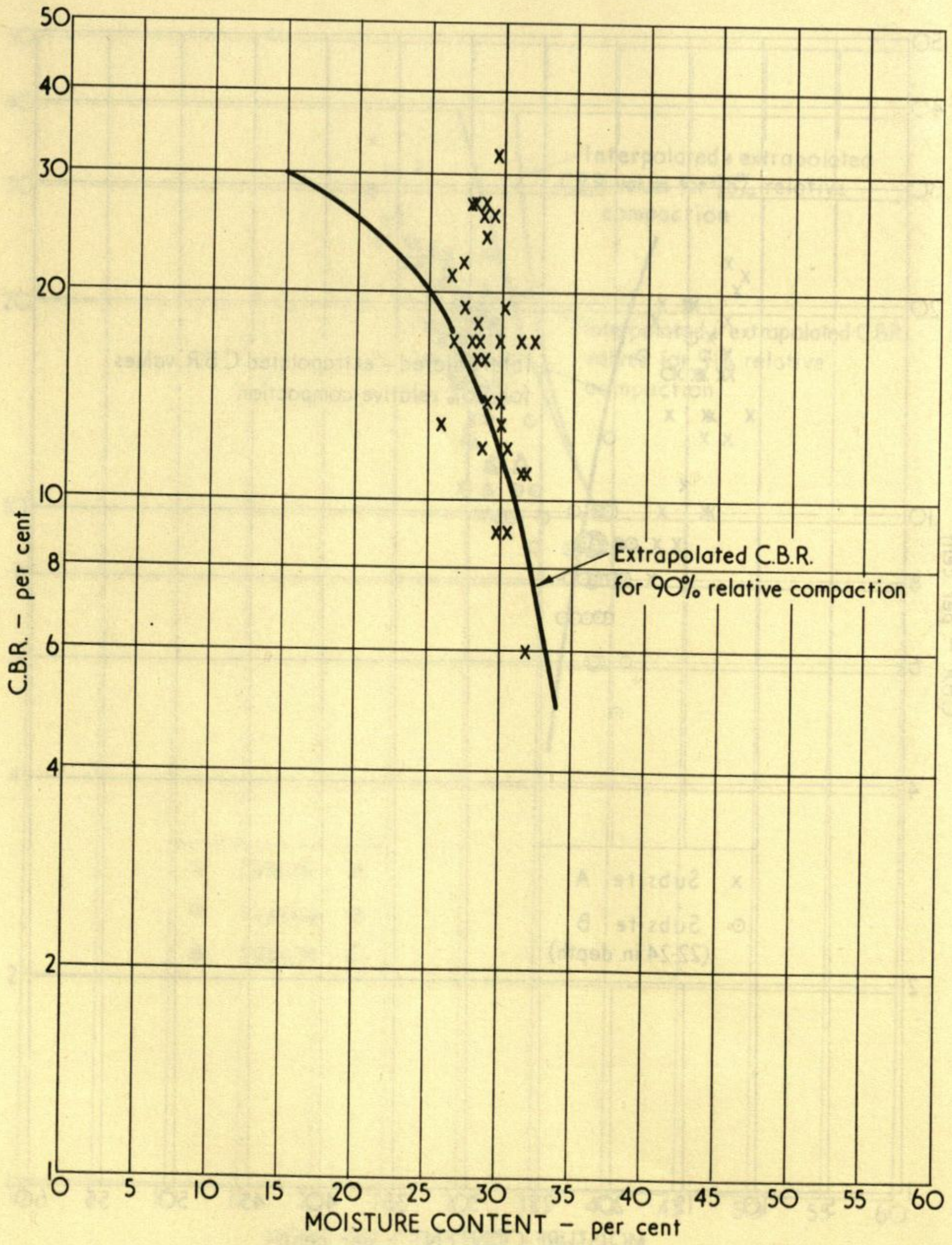

Fig.17 IN-SITU C.B.R. AND MOISTURE CONTENTS FOUND AT THE NAIVASHA SITE

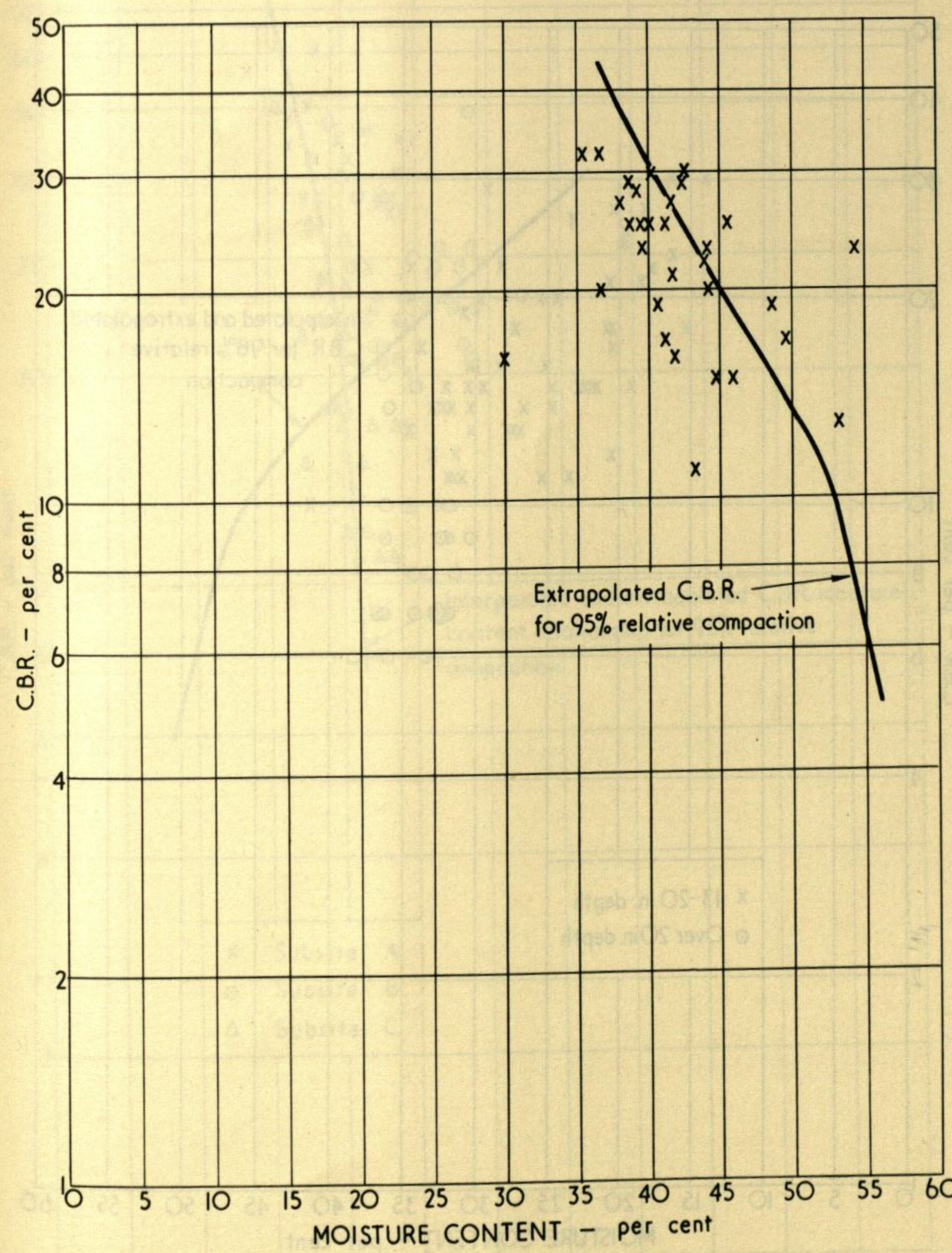

Fig.18 IN-SITU C.B.R. AND MOISTURE CONTENTS FOUND AT THE NAKURU SITE

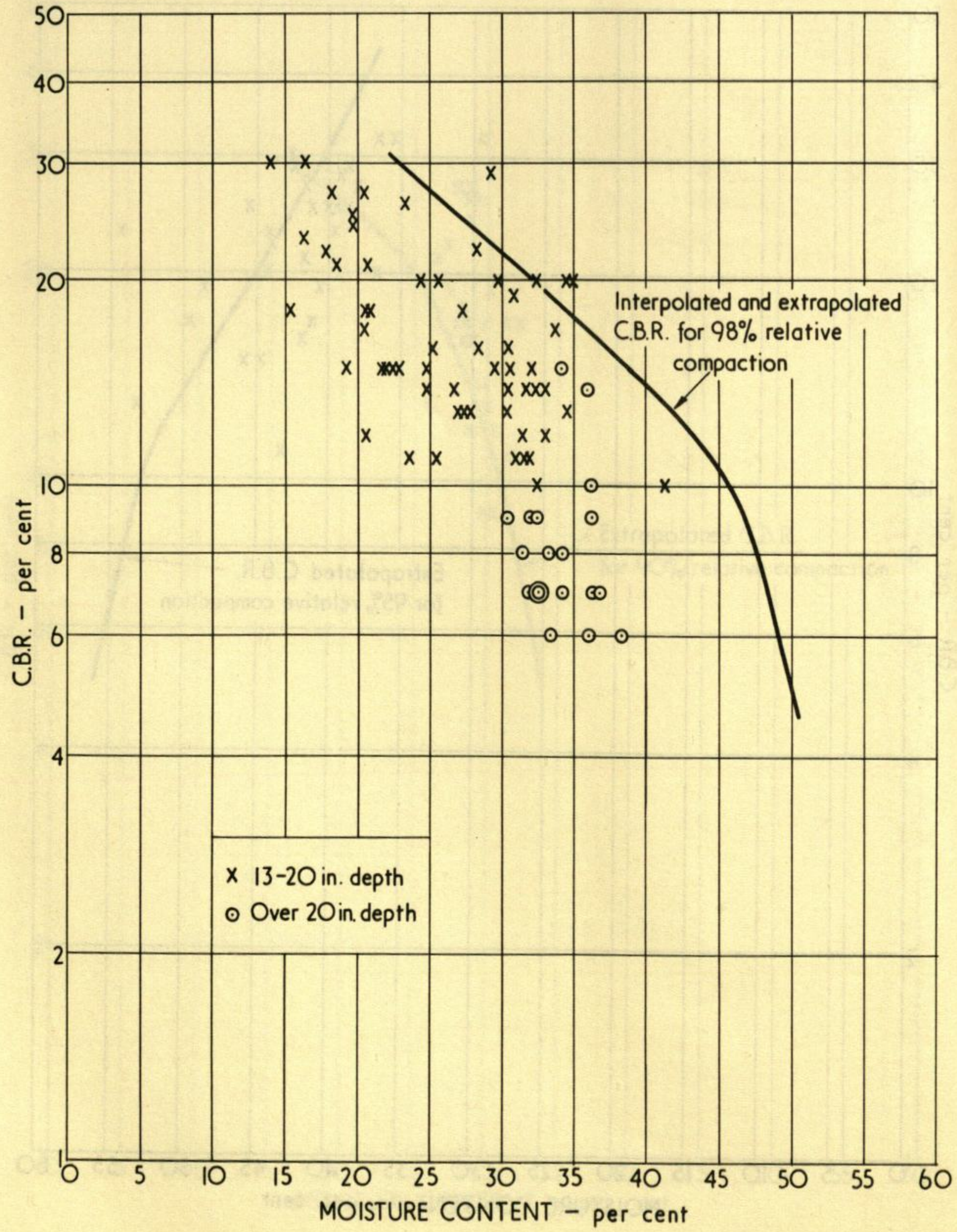

Fig. 19 IN-SITU C.B.R. AND MOISTURE CONTENTS FOUND AT THE NGONG ROAD SITE

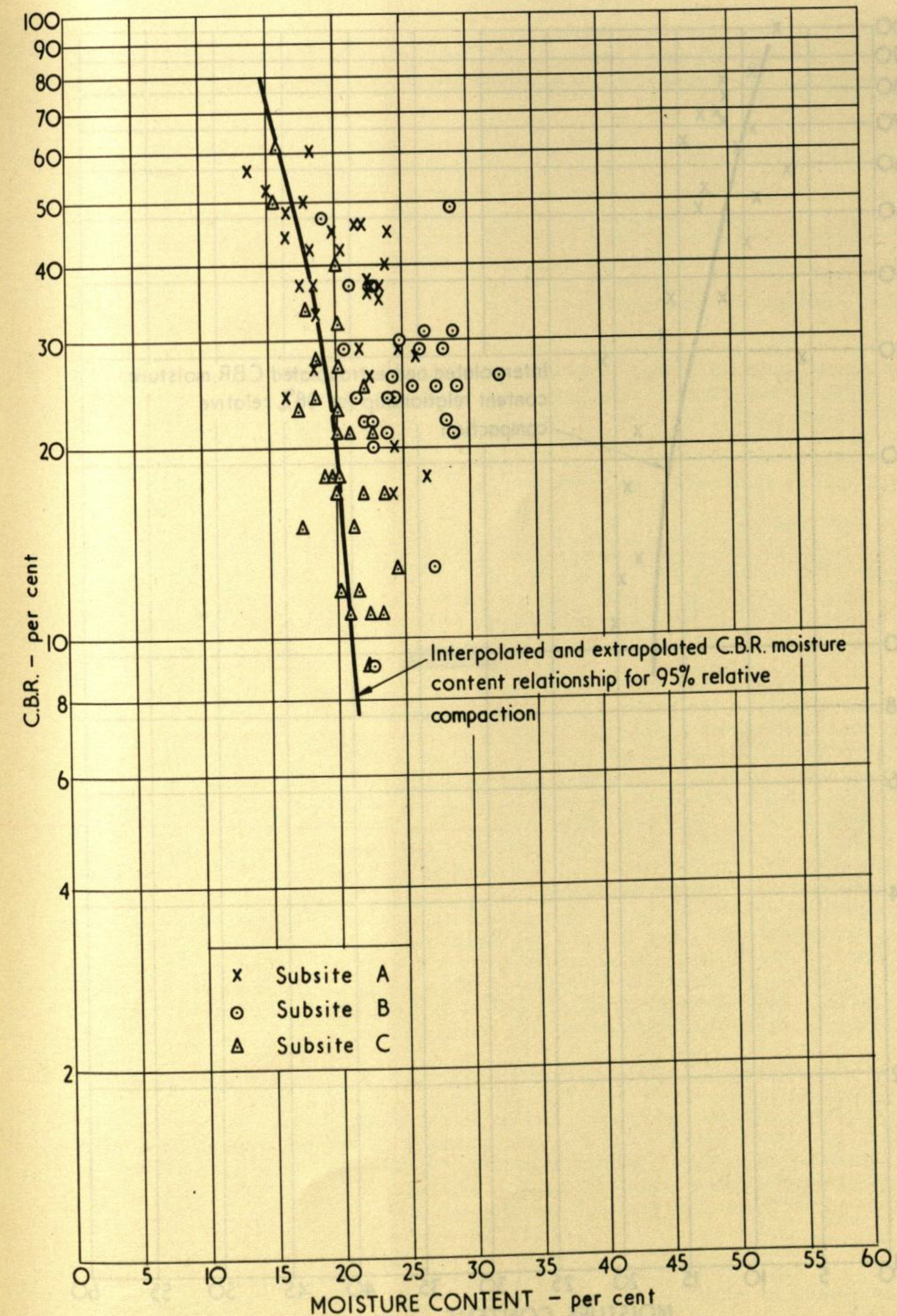

Fig. 20 IN-SITU C.B.R. AND MOISTURE CONTENTS FOR THE NODULAR GRAVEL-SAND-CLAY FROM THE THIKA SAGANA ROAD

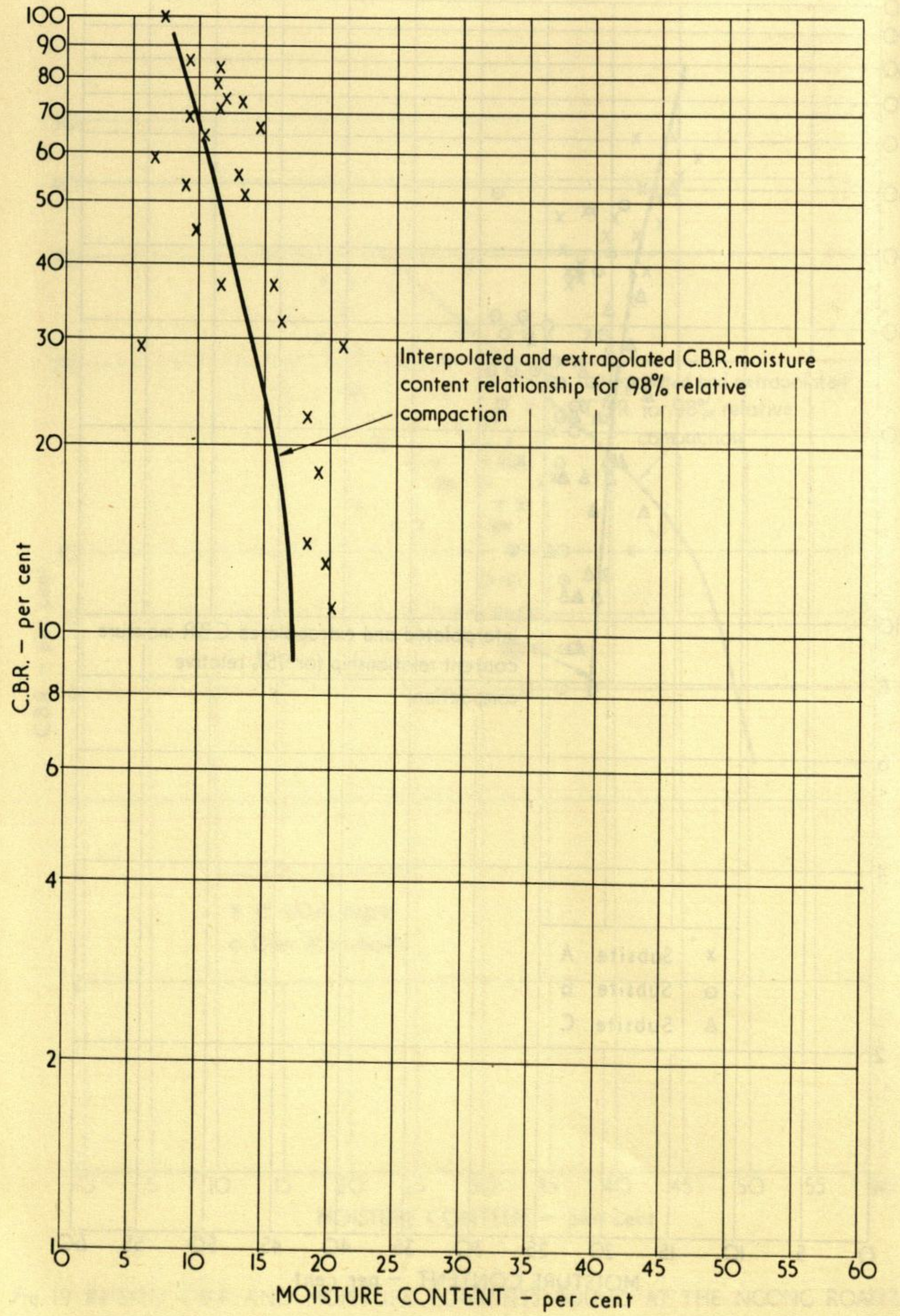

Fig. 21 IN-SITU C.B.R. AND MOISTURE CONTENTS FOR THE GRAVEL-SAND-CLAY FROM THE UPPER LAYER OF THE NGONG ROAD

APPENDIX

APPENDIX 1

During the investigation, some 30 to 40 C.B.R. tests were made on each of the soils at a range of moisture contents and densities. An examination has been made of the load penetration curves, and the following trends were observed.

(1) Corrections. With the clays in general, origin corrections were not required to the load penetration curves, the few exceptions occurring with the Thika-Sagana red clay at low moisture contents and low compactive efforts when they behaved more like granular materials. (Corrections were required in the case of tests on the bottoms of two samples of black clay at high moisture contents and compactive efforts: in both these cases there was evidence that shear had taken place in the base of the specimen when removing the base plate).

With granular soils, corrections were frequently necessary due to the disturbance in the surface layer when striking off surplus material, or a poorly compacted surface at the base of the specimen. In the case of the Nakuru pumice, corrections were frequently necessary, particularly for specimens at the higher moisture contents, and these are most likely associated with difficulties in seating the plunger on the spongy surface which these specimens frequently had.

(2) Difference in C.B.R. between 0.1 and 0.2 in penetration. The general trend of the load penetration curves for the clays showed a slight increase in C.B.R. from 0 to 0.1 in. penetration and thereafter a fall. In the case of the red clays, about a quarter of the samples tested had C.B.R's at 0.2 in. penetration equal or slightly greater than those at 0.1 in.

In the case of the granular soils (the gravel sand clays and the pumice soils), the majority of test specimens gave a C.B.R. value at 0.2 in. penetration, which was equal to or greater than that of 0.1 in. The increase between 0.1 and 0.2 in. penetration was greater for the pumice soils than for the gravel sand clays, and was more pronounced at moisture contents near to and above the optimum for the level of compaction used. With both these types of soils, there is a tendency for samples compacted on the wet side of the optimum to be "spongy" due to entrapped air. This tendency is most marked with the pumice soil where air is probably also compressed within the porous soil particles during compaction. The tendency for the C.B.R. value to rise between 0.1 and 0.2 in. penetration, may well be due to gradual release of air in the portion of the specimen immediately under the plunger. Further, in view of the fact that the majority of these rises occur in the tops of the specimens, they may also be associated with the recompaction of the layer disturbed during the striking off of excess material.

(3) Effect of increasing moisture content on the shape of the load penetration curve. In the case of the pumice and gravel-sand-clay soils, at moisture contents up to near the optimum for the method of compaction used, the curves tended to follow the standard curves and origin corrections were seldom necessary. At higher moisture contents, origin corrections were frequently necessary, and there was an increasing tendency for there to be an increase in C.B.R. between 0.1 and 0.2 in. penetration.

With the black clay and to a lesser degree with the black sandy clay, the fall-off in C.B.R. between 0.1 and 0.2 in. penetration became very marked at moisture contents above the optimum for the compactive effort used.

The moisture content appeared to have little effect on the shape of the curves for the red clays.

(4)

(4) Effect of compactive effort on the shape of the load penetration curve. When considered in relation to the optimum moisture content for the compactive effort used, the different compactive efforts did not appear to alter the general shape of the load penetration curves, except that increasing compactive effort generally resulted in increasing C.B.R.'s.

Table 1 gives a summary of the C.B.R. tests done on the tops and bottoms of the samples and shows where corrections were necessary, and whether the value at 0.1 in. penetration was less, equal to or greater than the value at 0.2 in. penetration. Typical shapes of the curves are given in Fig. 1.

/TABLE 1

TABLE 1

Summary of C.B.R. tests carried out, showing corrections required and comparison of C.B.R. values at 0.1 in. and 0.2 in. penetration

Soil	Limuru "A" Route. Red clay. Lab. Sample No. 830.									Thika-Sagana Road. Red clay Lab. Sample No. 831.									Mombasa Road. Mile 27. Black sandy clay. Lab. Sample No. 34.									Naivasha. Pumice soil Lab. Sample No. 835.								
Compactive effort	Moisture content %	Load/penetration curve data								Moisture content %	Load/penetration curve data								Moisture content %	Load/penetration curve data								Moisture content %	Load/penetration curve data							
		Origin correction		C.B.R. at 0.2 in. penetration in relation to 0.1 in. penetration							Origin correction		C.B.R. at 0.2 in. penetration in relation to 0.1 in. penetration							Origin correction		C.B.R. at 0.2 in. penetration in relation to 0.1 in. penetration							Origin correction		C.B.R. at 0.2 in. penetration in relation to 0.1 in. penetration					
				Rises		Equal		Falls					Rises		Equal		Falls					Rises		Equal		Falls					Rises		Equal		Falls	
		T	B	T	B	T	B	T	B		T	B	T	B	T	B	T	B		T	B	T	B	T	B	T	B		T	B	T	B	T	B	T	B
British Standard	31.4						✓	✓		27.6	✓	✓			✓			✓	10.2					✓	✓			11.9			✓					✓
	34.4							✓	✓	31.1							✓	✓	14.2							✓	✓	16.6							✓	✓
	38.5						✓	✓		34.8							✓	✓	18.0							✓	✓	23.4							✓	✓
	42.4							✓	✓	39.0							✓	✓	22.2							✓	✓	24.5							✓	✓
	46.3					✓			✓	42.8					✓			✓	26.3							✓	✓	28.8			✓			✓		
	51.6			✓	✓					46.2					✓	✓												32.6	✓				✓			
																												41.0					✓	✓		
Optimum moisture content %	47									38									21									29								
Intermediate	31.4				✓			✓		27.4	✓	✓					✓	✓	9.7			✓					✓	12.0	✓		✓					✓
	36.3							✓	✓	30.7					✓			✓	13.6					✓	✓			17.0					✓			✓
	38.7							✓	✓	35.5		✓					✓	✓	17.8									21.7			✓					✓
	44.0			✓					✓	38.9					✓			✓	22.1					✓			✓	24.6							✓	✓
	47.2					✓	✓			42.8							✓	✓	25.1							✓	✓	29.2	✓		✓	✓				
	51.0			✓	✓					45.5					✓	✓												32.0				✓	✓			
Optimum moisture content %	41									36									18									25								
Modified A.A.S.H.O.	27.6					✓			✓	26.7							✓	✓	10.6			✓			✓			13.3					✓	✓		
	31.5							✓	✓	31.0							✓	✓	13.4							✓	✓	16.5					✓			✓
	35.1							✓	✓	34.7							✓	✓	18.3							✓	✓	23.5	✓		✓					✓
	39.3							✓	✓	38.3							✓	✓	21.6							✓	✓	25.3	✓				✓			✓
	43.5					✓			✓	41.4							✓	✓	26.0							✓	✓	29.4				✓	✓			
	46.8					✓			✓	44.8							✓	✓										33.0					✓	✓	✓	
	34.3							✓	✓																			36.6								
Optimum moisture content %	39									34									17									24								

/TABLE 1 (Contd.)

TABLE 1 (Contd.)

…tests carried out, showing corrections required and comparison of C.B.R. values at 0.1 in. and 0.2 in penetration

…ong Road. Black clay. Lab. Sample No. 837. Load/penetration curve data: Origin correction B	C.B.R. at 0.2 in. penetration in relation to 0.1 in. penetration: Rises T	Rises B	Equal T	Equal B	Falls T	Falls B	Moisture content %	Thika-Sagana Road. Murram. Lab. Sample No. 832. Load/penetration curve data: Origin correction T	Origin correction B	C.B.R. at 0.2 in. penetration in relation to 0.1 in. penetration: Rises T	Rises B	Equal T	Equal B	Falls T	Falls B	Moisture content %	Ngong Road. Murram. Lab. Sample No. 838. Load/penetration curve data: Origin correction T	Origin correction B	C.B.R. at 0.2 in. penetration in relation to 0.1 in. penetration: Rises T	Rises B	Equal T	Equal B	Falls T	Falls B
					✓	✓	12.6	✓				✓	✓			7.2	✓	✓	✓	✓				
					✓	✓	15.1					✓	✓			11.9		✓			✓	✓		
				✓	✓		16.9							✓	✓	15.3							✓	✓
					✓	✓	20.2							✓	✓	18.8	✓		✓	✓				
		✓			✓		23.0			✓			✓			22.5								
					✓	✓	27.0					✓	✓											
					✓	✓																		
					✓	✓																		
							23									10								
					✓	✓	8.4	✓	✓	✓	✓					7.5	✓	✓	✓	✓				
					✓	✓	12.6	✓	✓			✓	✓			11.6	✓							✓
					✓	✓	17.0	✓	✓					✓	✓	13.0			✓					
					✓	✓	20.6	✓		✓					✓	18.2	✓	✓	✓	✓				
					✓	✓	25.4					✓	✓			21.8								
					✓	✓																		
					✓	✓																		
							21									15								
					✓	✓	11.0	✓		✓					✓	8.2	✓		✓	✓				
					✓	✓	14.0	✓				✓	✓			11.0	✓		✓			✓		
					✓	✓	16.8	✓		✓					✓	15.0	✓		✓		✓			
					✓	✓	20.7	✓						✓	✓	16.1	✓		✓			✓		
✓					✓	✓	24.9					✓	✓			18.5		✓			✓	✓		
✓					✓	✓	26.4							✓	✓	22.5								
							19									15								

Appendix 1.

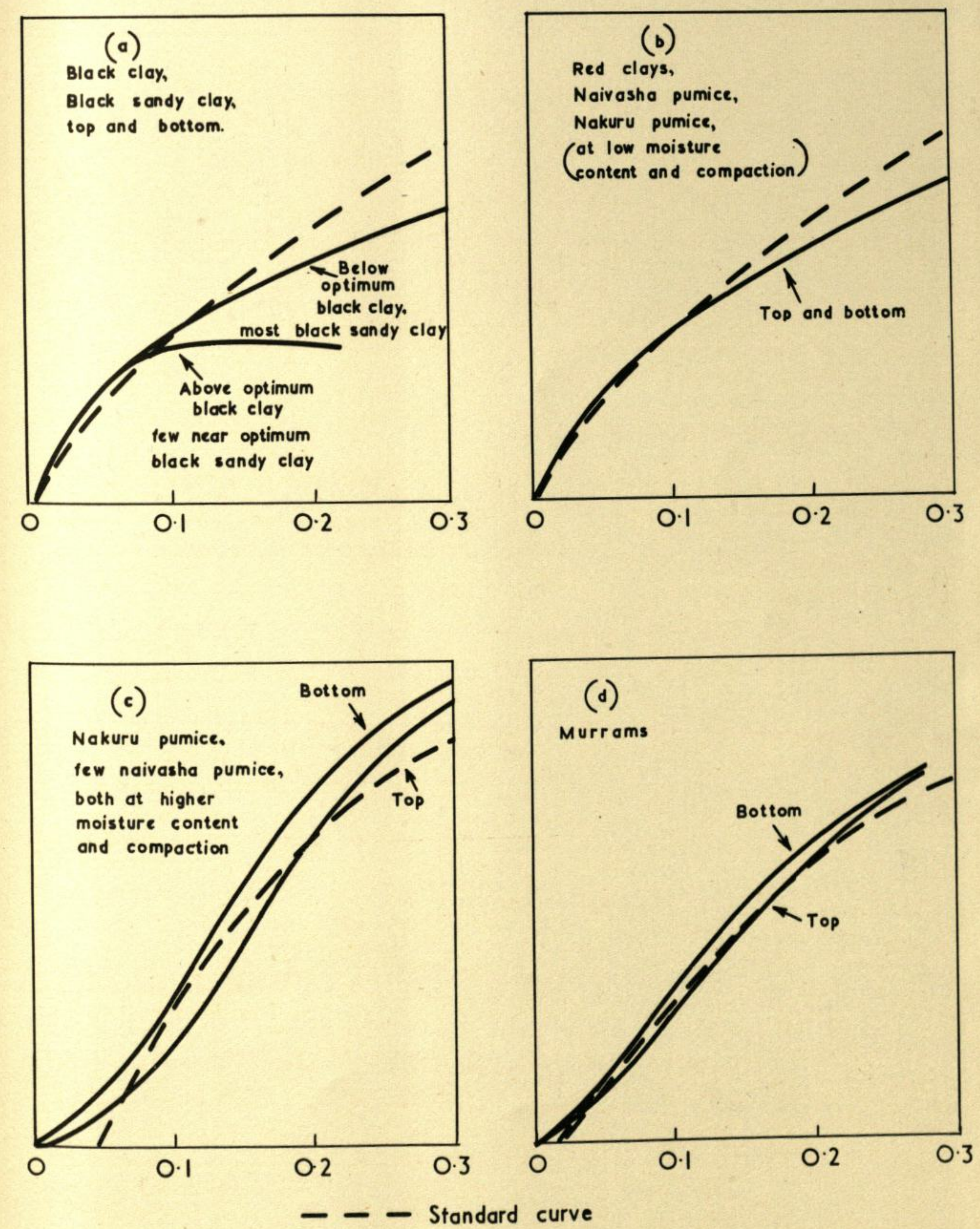

Fig. 1.

TYPICAL LOAD/ PENETRATION CURVE FORMS FOR EIGHT KENYA SOILS