Indian Geotechnical Journal, 18 (2), 1988

Strength Anisotropy of Plastic Soils

by

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Introduction

Anisotropy, with reference to its effect on undrained shear strength, has been known and well discussed. It has been acknowledged that in many stability problems it is a factor of such importance that it has to be taken into account, when selecting the shear strength values to be introduced in the analysis.

In general two different approaches have been employed by the investigators to study the strength anisotropy of soils. In the first approach, samples were taken at different orientations and tested on triaxial or direct shear test apparatus. In the second approach, vanes of different shapes were used in routine vane shear tests on undisturbed or remoulded soil samples.

In this investigation, the samples were tested at high moisture content (around their liquid limit) in lab. vane shear test. The consolidation by self weight of soil and by the weight of water present, have not been considered. Values of cohesion mobilized on horizontal and vertical planes and on planes making 30° and 45° angle from the vertical plane have been obtained by utilizing the equations given by Aas (1965), (Eqn.1) Flaate (1966) (Eqn.2) and Madhava and Roy (1970) (Equations 3 & 4).

$$T = \frac{\pi D^2 H}{2} C_v + \frac{\pi D^3}{6} C_h, \quad \ldots (1)$$

$$T = \frac{\pi D^2 H}{2} C_v + \frac{\pi D^3}{8} C_h \quad \ldots (2)$$

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(*This modified paper was received in March* 1988 *and is open for discussion till the end of June* 1988)

$$T = \frac{\pi D^2 H}{6 \cos \alpha} C_\alpha + \frac{\pi D^3}{12} C_h \qquad \dots (3)$$

$$T = \frac{\pi D^2 H}{8 \cos \alpha} C_\alpha + \frac{\pi D^3}{12} C_h \qquad \dots (4)$$

where T — Torque measured

D — Diameter of the vane

H — Heiaht of the vane

α — Angle with the vertical

C_α — Cohesion mobilized on any plane making an angle α with the vertical

C_v — Cohesion mobilized on vertical plane

C_h — Cohesion mobilized on horizontal plane

Experimental Details

The SVS 2 laboratory (motorised) vane shear apparatus has been used for the measurement of cohesion of unconsolidated soft soils. The rate of rotation was kept constant (0.05 rpm) in all the tests. Two vertical and two conical vanes have been used to get the desired strength values. Samples were prepared by filling soft soil in containers made of perspex. The size of the containers was such that it could be fitted tightly in the metallic container provided with the apparatus.

The shape and dimensions of the vanes are shown in Figure 1. The Atterberg limits of the soils tested are given in Table 1. The soil samples were prepared at moisture contents around their liquid limit. The moisture

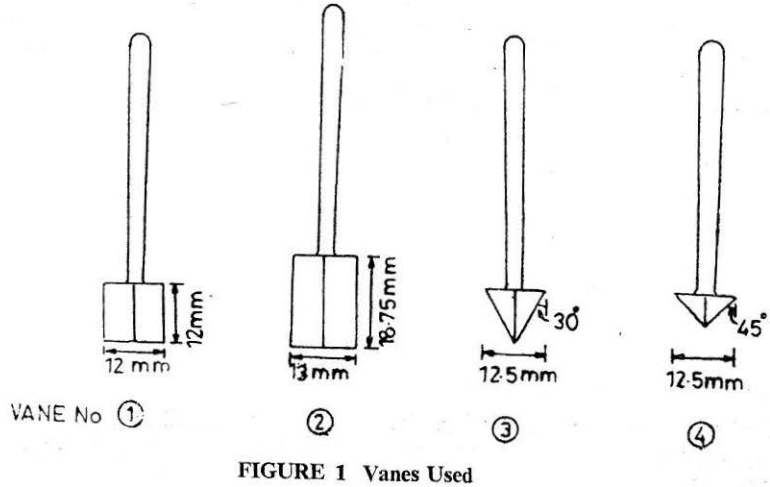

FIGURE 1 Vanes Used

contents of the soil samples as recorded at the time of testing are given in Table 2.

TABLE I

Atterberg Limits of the Soils Tested

Soil	L.L. (%)	P.L. (%)	P.I. (%)
A	48.00	23.85	24.15
B	69.00	27.20	41.80
C	120.25	37.50	82.75
D	149.00	40.00	109.00

TABLE 2

Moisture Contents of the Soil Samples

Soil	L.L. (%)	Moisutre contents (%)		
		I	II	III
A	48.00	38.42	47.55	58.01
B	69.00	63.03	71.75	77.11
C	120.25	110.30	120.30	134.90
D	149.00	133.50	149.80	165.10

Results and Discussion

Polar diagrams of shear strength values C_α

Values of C_α for various values of ($\alpha = 0°, 30°, 45°, 90°$) have been plotted on natural scale in figures 2 to 9. The values plotted are for remoulded soil samples, prepared at three moisture contents around their liquid limits and tested after 40,000 minutes of their preparation, when all the thixotropic regain had taken place in the remoulded soil samples. It is observed that the trend of variation in the values of 'C_α' obtained by equations based on (1) and (3) and (2) and (4) is of similar nature. Further, the values of 'C_α' are found to increase as α increases from 0° to 90°.

It is well known that anisotropy in clays is intimately connected with the structural arrangement of the soil particles. The soil structure depends upon the state of compaction, plasticity of soil, nature of pore fluid (i.e.

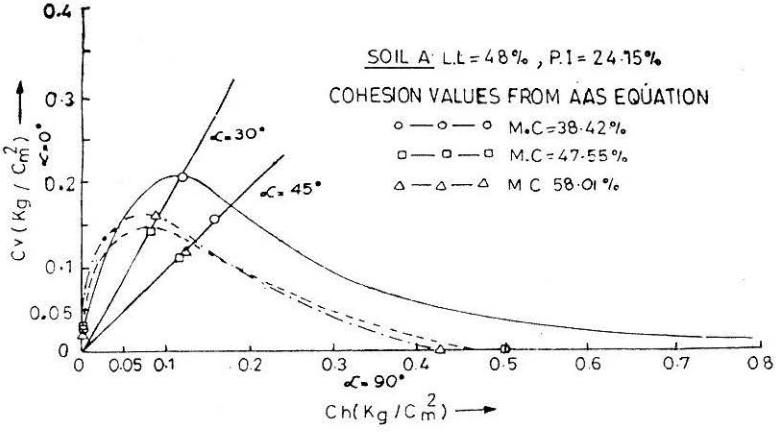

FIGURE 2 Variation of C_α with α

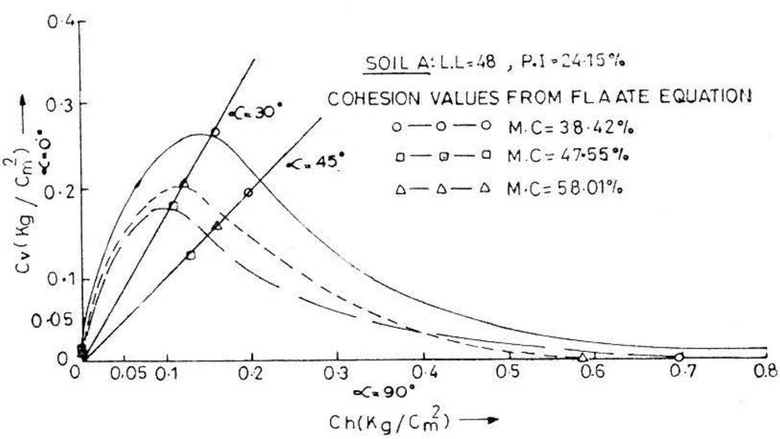

FIGURE 3 Variation of C_α with α

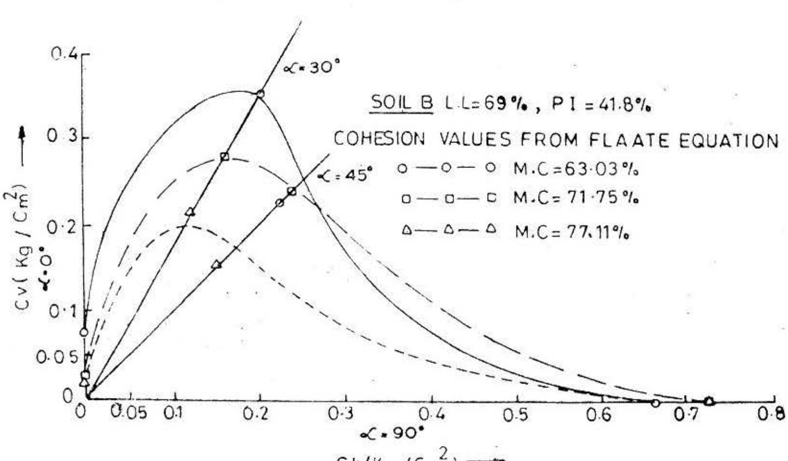

FIGURE 4 Variation of C_α with α

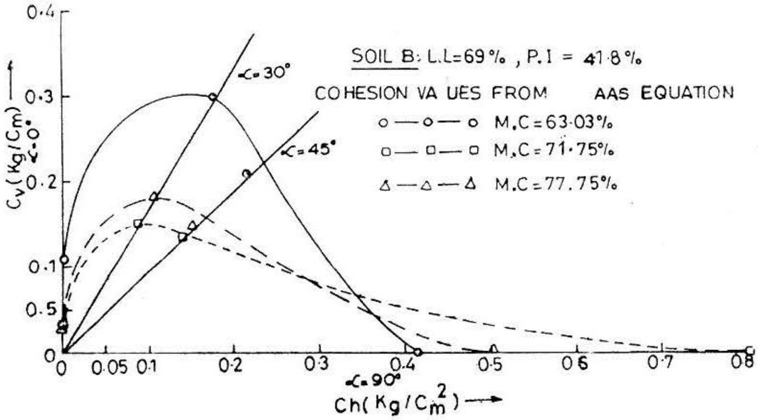

FIGURE 5 Variation of C_α with α

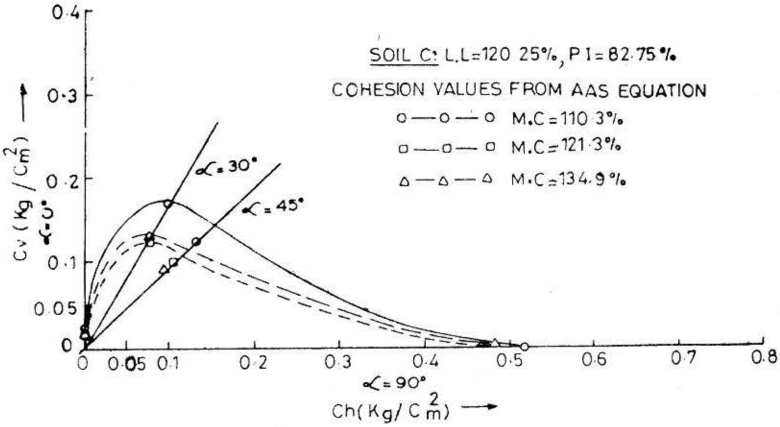

FIGURE 6 Variation pf C_α with α

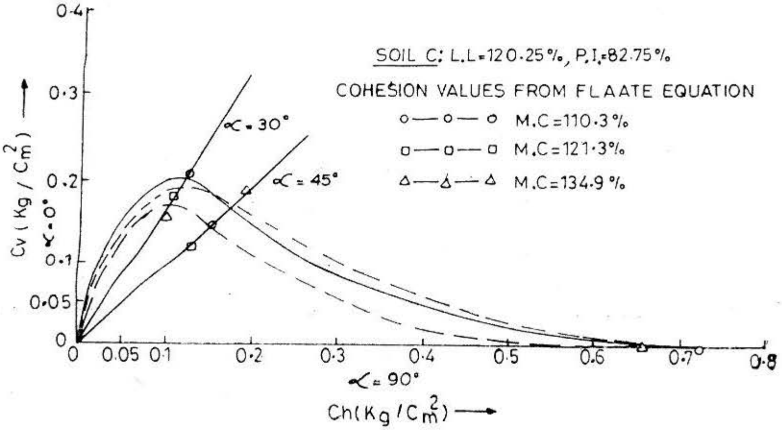

FIGURE 7 Variation of C_α with α

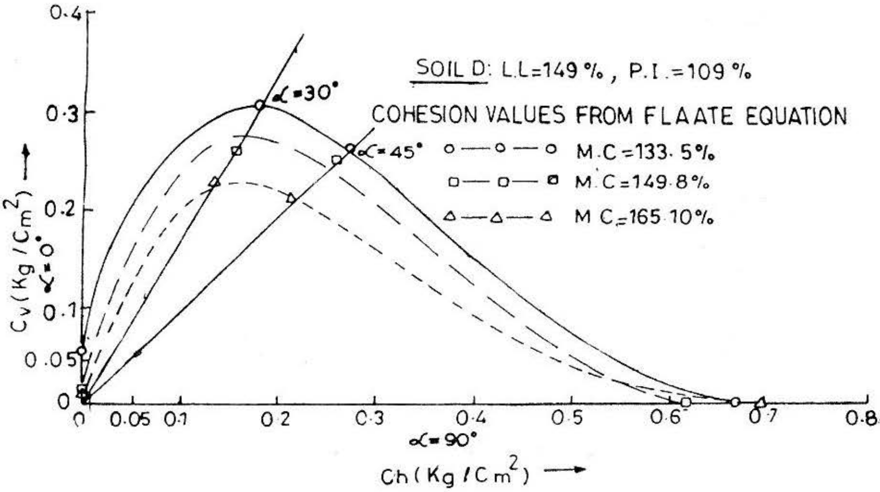

FIGURE 8 Variation of C_α with α

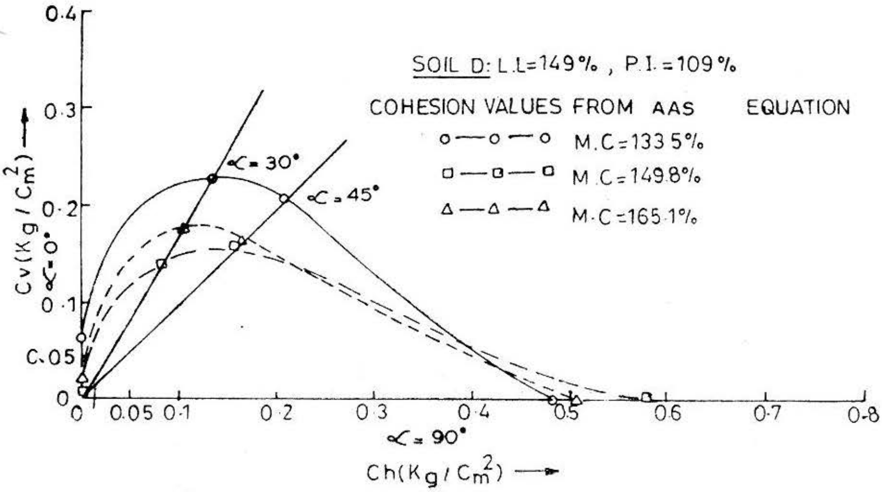

FIGURE 9 Variation of C_α With α

the type of ions present in it), nature of externally applied load, state of effective stress and the method of testing (rotation of particles depends on method of testing) etc. In the present study, the soils tested had plasticity index values varying from 24% to 109% and the tests were performed on remoulded soil samples, with no drainage allowed. A possible explanation of the variation of C_α with α as observed in the present investigation can be given as follows.

Two cases of soil structure are dispersed and floculated. The dispersed structure in an imaginary, ideal case can be of two types, A(I) and A(II) as shown in Figure—10. It is obvious from figures that in case A(I),

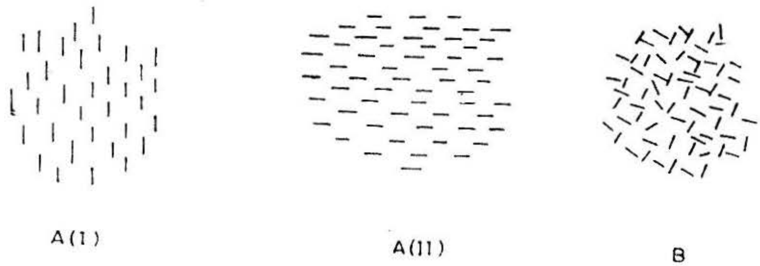

FIGURE 10 Soil Structure Model

$C_h > C_v$ and in case A(II), $C_v > C_h$. These are two extreme cases of anisotropy. In an ideal floculated structure, the orientation of soil particles is perfectly random (case **'B'** in figure—10) and hence C_h will be approximately equal to C_v and the soil would be isotropic.

The natural soils in general are anisotropic. The values $C_h > C_v$ for a soil indicates the orientation of the particles is somewhere between A(I) and 'B', while $C_v > C_h$ indicates that the orientation of particles is somewhere between A(II) and 'B'. In the present investigation, C_h is generally greater than C_v. This shows that under the present method of sample preparation and testing, the orientation of particles was somewhere between A(I) and 'B'.

Results of similar nature were obtained by Aas (1965, 1967) who tested N.C. silty quick clays (L.L. = 25%, P.I. = 6%), N.C. silty sensitive clays (L.L. = 32%; P.I. = 14% and 8%) respectively, and O.C. quick clays (L.L. = 45%, P.I. = 17 %). He obtained C_h/C_v ratio of the order of 1.1 to 2.0.

Strength anisotropy (C_h/C_v) Vs. Moisture content

Strength anisotropy (C_h/C_v), obtained on the basis of equations 1 and 2, have been plotted against moisture content, figures —11 to 14.

It is observed, that C_h/C_v increases with moisture content beyond liquid limit. At moisture contents less than liquid limit, the ratio C_h/C_v will decrease or increase depending upon the initial orientation of particles as discussed earlier (Figure 10).

Conclusions

Based on the studies conducted following conclusions are arrived at :

(1) The value of C_α (α = 0°, 30°, 45° and 90°) increases as α increases from 0° to 90°.

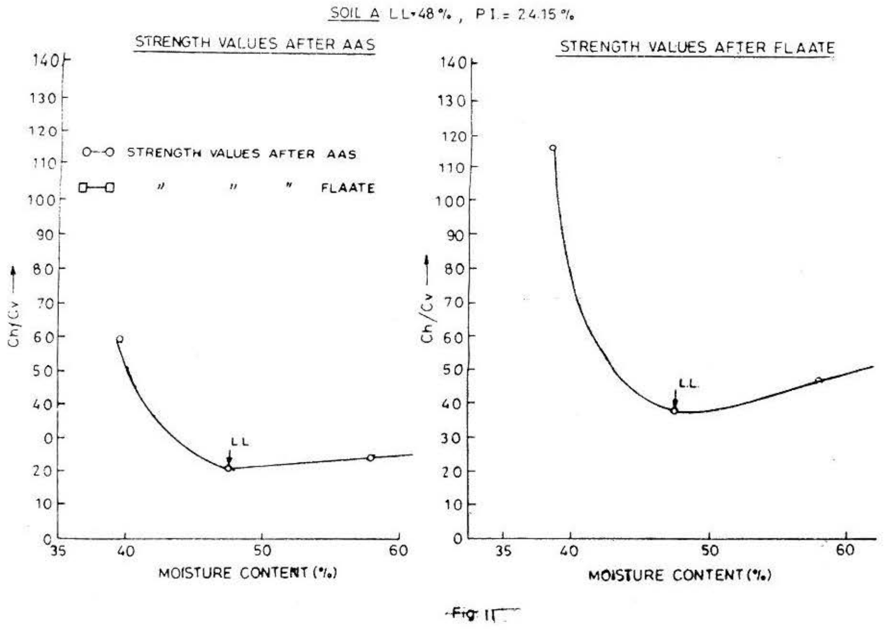

FIGURE 11 Variation of C_h/C_v with Moisture Content

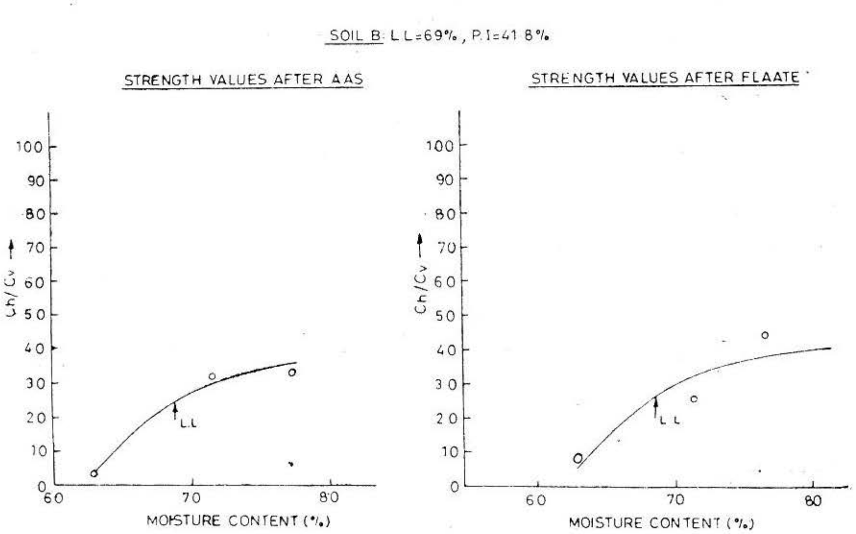

FIGURE 12 Variation of C_h/C_v with Moisture Content

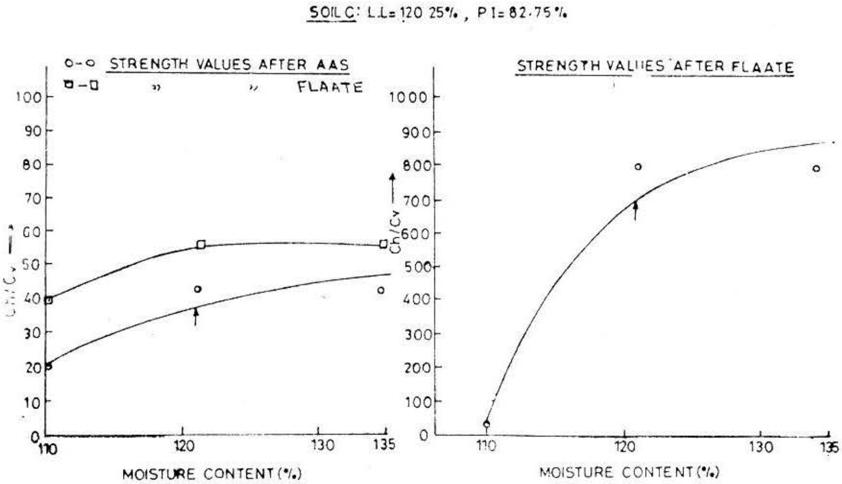

FIGURE 13 Variation of C_h/C_v with Moisture Content

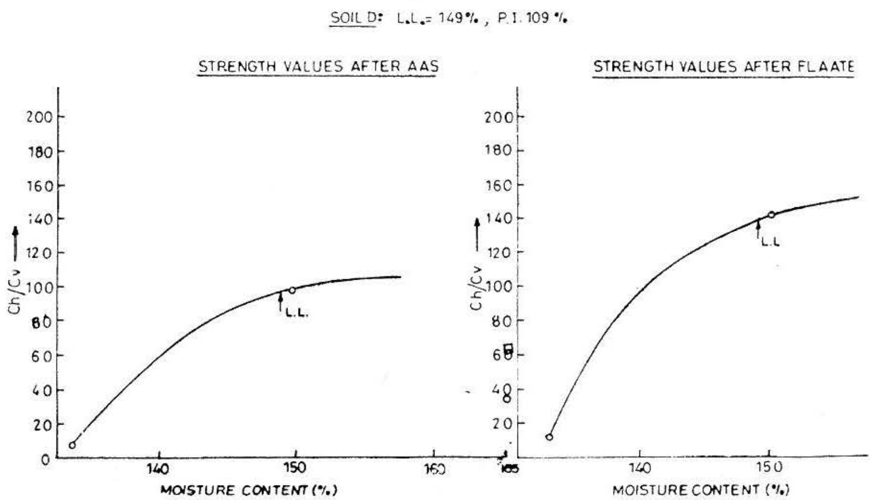

FIGURE 14 Variation of C_h/C_v with Moisture Content

(2) Inspite of the difference in assumptions in the derivation of equations by Aas (196-) and by Flaate (1966), the trend of variation of C_α with α is similar as represented by similar shape of polar diagrams.

(3) For remoulded and unconsolidated plastic soils, tested at moisture contents close to their liquid limit, 'C_h' is always found to be greater than 'C_v'.

(4) Strength anisotropy (C_h/C_v) increases for moisture contents beyond L.L. For moisture contents less than L.L., the C_h/C_v ratio will decrease or increase depending upon the initial orientation of the particles.

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