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ISO 9001:2000 No Sijil :0500132

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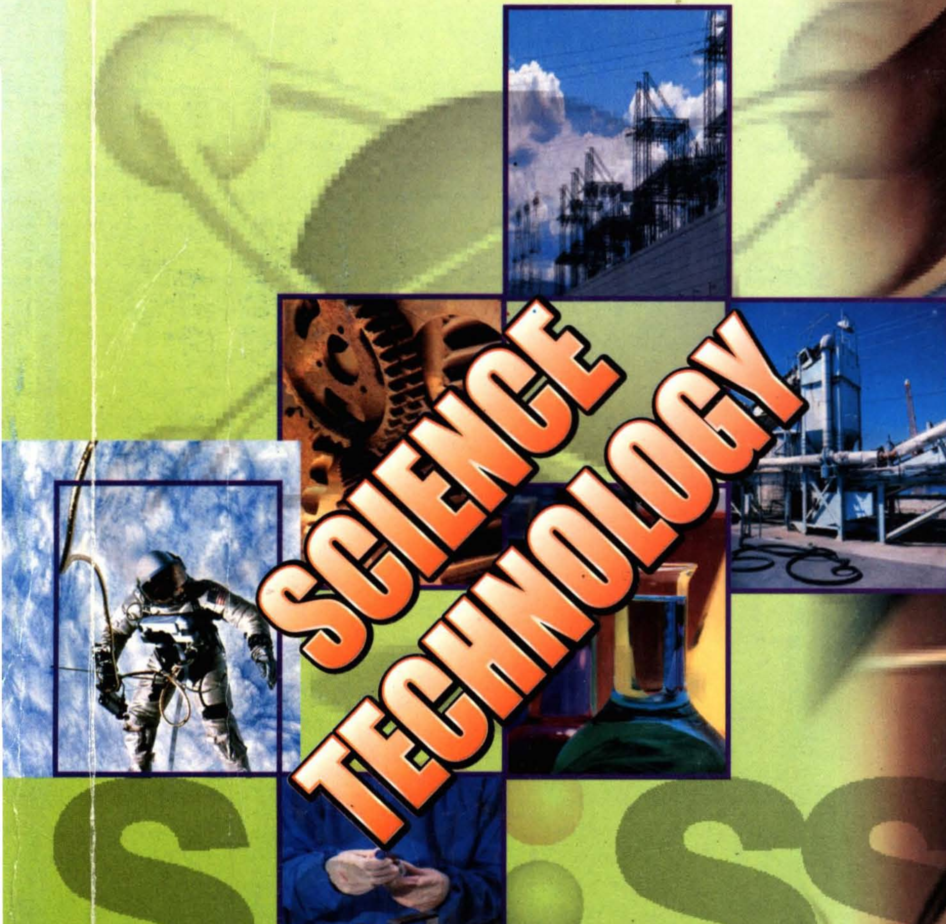

30-31 May 2006

Swiss Garden Resort & Spa

Kuantan, Pahang

Study on the Performance of the Ordinary Portland Cement as Soil Stabilizing Agent for Silty Soils

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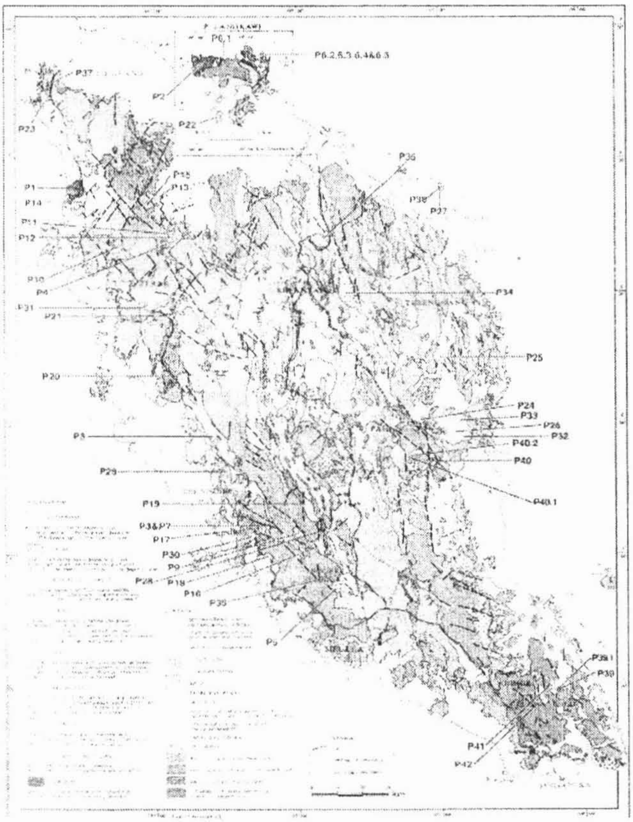
ABSTRACT

The infrastructure development in Malaysia has grown impressively and construction projects are carried out almost everywhere although at the not very suitable sites, which sometimes consist of problematic fine soils. According to Mutallib (1991), there are about 65% of soil in Malaysia consisting of fine soil such as clay, silt, peat and organic soil, where 8% (2.6 million hectares) is covered with peat and organic soil. Thus, the researchers and engineers' job in stabilizing and improving the quality of soft soil is vital to ensure the safety and economic of the design and construction projects. There are many methods available for improving soil quality and one of them is by mixing stabilizer agents with the soils, which may be natural soil, industrial by products or waste material, and cementations and other chemicals. The study focuses on the effectiveness and performances of the ordinary Portland cement (OPC) as a soil stabilization agent on the fine soil. Stabilization is done for combination of soil-cement mixtures with cement content at 1, 5 and 10% by weight of dry soil and with curing periods of 0, 1 and 7 days. The basis for comparing the various proportions of stabilizer is the value of California Bearing Ratio. The result shows the strength characteristics of stabilized soil in terms of CBR exhibited a significant increase compared to the untreated samples. The addition of 1%, 5% and 10% of OPC provides stronger material for road sub-base and base course. The highest improvement for cement stabilization is 1420% which is obtained by the addition of 10% cement using 7 days curing time compared to the untreated soils. In terms of CBR value, the performance is 102.3 % where the highest value obtained is 13.5kN compared to the standard CBR value, which is 13.2kN. The result shows that there was a significant increase in strength in terms of CBR value for stabilized soil compared to the untreated samples.

Keywords: *Soft soil, cement stabilization, California Bearing Ratio*

Introduction

Problematic soils are known for their high compressibility and low shear strength. Access to these superficial deposits is usually very difficult as the water table will be at, near or above the ground surface. Undoubtedly, these contribute to the tendency of avoiding constructing and building on these soils, or when this is unavoidable, to simply remove, replace or displace them, which in some instances may lead to the uneconomical design and construction conditions. Malaysia is one example of a country that faces this kind of problem. About 65 percent of soil in Malaysia consists of soft soil such as clay, silt, peat soil and organic as shown in Figure 1 (Mutallib et. al 1991)



Legend

Marine and continental deposit: clay, silt, sand and peat

Inter-bedded sandstone, siltstone and shale

Phyllite, slate and shale with subordinate sandstone

Shale, sandstone, conglom-

Fig. 1: Location of type area of on land Palaezonic rock formations of Peninsular Malaysia
(Map reproduced with the permission of the Director-Generals and Geosciences Department Malaysia)

Traditionally the aims of improving soils as foundation or construction materials have been one or more of the following (Babu 1994):

- Increased strength, reduced erodability.
- Reduced distortion under stress (increased stress-strain modulus).
- Reduce compressibility (volume decreased due to reduction in air voids or water content under load).
- Controlled shrinking and swelling (improve volume stability)
- Controlled permeability, reduced water pressures, redirect see page.
- Prevent detrimental physical or chemical changes due to environmental conditions (freezing/thawing, wetting/drying).
- Reduced susceptibility to liquefaction.
- Reduced natural variability of borrow materials or foundation soils.

The main objective of chemical stabilization on soils is to maintain the favourable characteristics of the soil from the aspects of the given engineering parameters, regardless of the moisture in its environment. It is also intended to modify the interactions between water and soil by surface reactions in such a manner as to make the behaviour of the soil with respect to water effects most favourable for the given purpose (Ali & Tatt 2000).

In the construction and maintenance of transportation facilities, geomaterials such as soil and rock must be stabilized through chemical and mechanical processes. Chemical stabilization includes the use of chemicals and emulsions as compaction aids to soils, as binders and water repellents (Das 2000).

Experiment

Materials

Soils classification tests were performed based on British Standards 1377:1990. Sieving-sedimentation analysis with wet sieving and followed up with a determination of fine particles by the hydrometer procedure as explained by Head

(1992). The parameters that are related with basic physical and engineering characteristic of fine soil which is specific gravity, Atterberg limit, optimum moisture content, particles size distribution, permeability and shear strength were obtained from the laboratory test. Results of soil physical properties and classification are summarized as in Table 1 below:

Table 1: Soil Physical and Engineering Properties

Soil Property	*Values of Properties*
Specific Gravity, (Mg/m^3)	2.69
Plastic Limit, (%)	28.99
Liquid Limit, (%)	33.00
Plasticity Index, (%)	4.00
Permeability, (cm/s)	8.38×10^{-5}
Optimum Moisture Content, (%)	16.43
Maximum Dry Density, (Mg/m^3)	1.74
Unified Soil Classification System (USCS)	ML
Particle Size Distribution (hydrometer test)	MLS

California Bearing Ratio (CBR)

The main test in this study is the California Bearing Ratio (CBR) testing. The CBR test acts as an attempt to quantify the behavioural characteristics of a soil trying to resist deformation when subject to locally applied force such as a wheel load. It forms the basis for the pre-eminent empirical pavement design methodology. The test results have been correlated with flexible pavement thickness requirements for highways and air fields. In order to assess the improvement the bearing capacity of fine soil, cement stabilizer has been added to the fine soil.

Mix Design

The Ordinary Portland Cement (OPC) is used as cement stabilization in this study. Regardless of the type used, the Portland cement acts both as a cementing agent and a modifier. In fine-grained soils, the silt phase may also contribute to the stabilization process through reaction of the free lime from the cement. In this manner, the cement acts as a modifier by reducing the plasticity and expansion properties of the soil (Gary 2002).

A wide range of soils types may be stabilized using Portland cement (refer Table 2). It is generally more effective and economical to use it with granular soils due to the ease of pulverization and mixing and the smaller quantities of cements required. Fine-grained soils of low to medium plasticity can also be stabilized, but not as effectively as coarse-grained soils. If Plasticity Index (PI) exceeds about 30, cement becomes difficult to mix with the soil. However, according to the table 1, soil sample used still meet the criteria and considered suitable to be stabilized using Portland cement.

Table 2: Cement Requirements for Various Soils (Gary 2002)

Unified Soil Classification	Usual Range in Cement Requirement Percent by Volume	Percent by Weight
GW, GP, GM, SW, SP, SM	5-7	3-5
GM, GP, SM, SP	7-9	5-8
GM, GC, SM, SC	7-10	5-9
SP	8-12	7-11
CL, ML	8-12	7-12
ML, MH, CH	8-12	8-13
CL, CH	10-14	9-15
OH, MH, CH	10-14	10-16

The three different percentages of cements stabilizers are chosen to evaluate the optimum performance of the stabilizers to the fine soil and to see the pattern of their improvement. There are three different curing time effects which are immediate, 1 day and 7 days:

a) 1% of weights of cement mix with 5kg of dry weight fine soil.
b) 5% of weights of cement mix with 5kg of dry weight fine soil.
c) 10% of weights of cement mix with 5kg of dry weight fine soil.

Results and Discussions

The CBR value is estimated at penetrations of 2.5mm and 5.0mm. Then the test results obtained are compared to the standard CBR value, which are 13.2 kN and 20 kN at 2.5mm and 5.0mm penetration respectively. The higher of the two values is taken as a CBR value for the material.

Table 3 shows the CBR results for cement treated soils at 2.5mm and 5.0mm penetration. These values are compared against the standard force-penetration relationship for a soil with a 100% CBR. According to the Table 3, the CBR results show the strength of cements treated soils was increased compared to the untreated soils. The CBR results are increasing gradually proportional to the increment of percentage of cements and curing times.

The CBR values for the original soils are 0.7 kN and 1.25 kN at 2.5mm and 5.0mm penetration respectively. Then, for the addition of 1% of cement, the highest increment is 4.25 kN at 5.0mm penetration with 7 days curing time. The CBR value increased about 3.0 kN compared to the untreated soils. While for the addition of 5% of cement, the highest value is 5.45 kN and also at 5.0 penetration with 7 days curing time. This increment is about three times more than the untreated soil. Then the highest improvement of the CBR value in the cement stabilization is 14 times more than the original soil which is 19 kN for addition 10% of chemicals at 5.0mm penetration and 7 days curing time. This value is almost equal to the standard CBR load which is 20 kN at 5.0 mm penetration.

Table 3: CBR values of cement treated Soil compare to Standard CBR Load

	CBR values (kN) with Curing Time						Standard CBR Load at 100%(kN)	
	0 day		1 day		7 days			
Penetration (mm) / Cement (%)	2.5	5.0	2.5	5.0	2.5	5.0	2.5	5.0
0%	0.7	1.25	0.7	1.25	0.7	1.25	13.2	20
1%	1.7	2.6	3.0	3.8	3.5	4.25		
5%	1.98	3.2	5.0	5.25	5.1	5.45		
10%	3.2	4.75	10.0	12.5	13.5	19.0		

The CBR results for cement treated soil given in percentages are shown in Table 4. These values are compared against the standard force-penetration relationship for a soil with a 100% CBR. The standard CBR value is 13.2 kN and 20 kN at 2.5mm and 5.0mm penetration respectively.

Table 4: The % of CBR Values of Cement Treated Soil

	CBR Values (%) with Curing Time					
	0 day		1 day		7 days	
Penetration (mm) / Cement (%)	2.5	5.0	2.5	5.0	2.5	5.0
0%	5.30	6.25	5.30	6.25	5.30	6.25
1%	12.88	13.00	22.73	19.00	26.52	21.25
5%	18.18	14.00	34.10	33.00	38.64	27.25
10%	24.24	23.75	75.76	62.50	102.27	95.00

Based on the results in Table 4, a graph of force versus penetration is plotted and a smooth curve is drawn through the relevant points as shown in Figure 2, 3 and 4. The highest improvement of stabilized soil is 102.27% and obtained by an addition of 10% chemical and 7 days curing as indicated in Table 4 and Figure 2. It is about 96.97% improvement compared to the original soil.

Meanwhile, the strength improved for about 12.88% at 2.5mm penetration for the addition of 1% cement with 0 day curing time which is the lowest of the improvement in the cement treated soils.

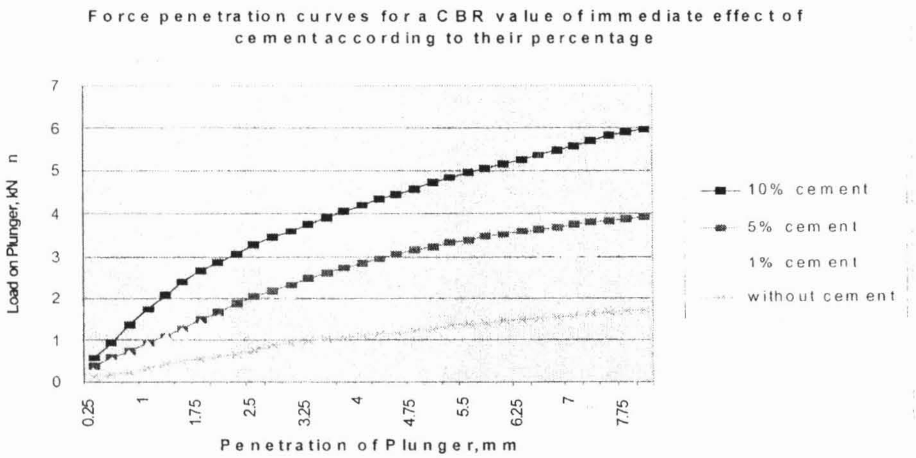


Fig 2: Force Penetration Curves for a CBR Value of Immediate Effect of Cement according to their Percentage

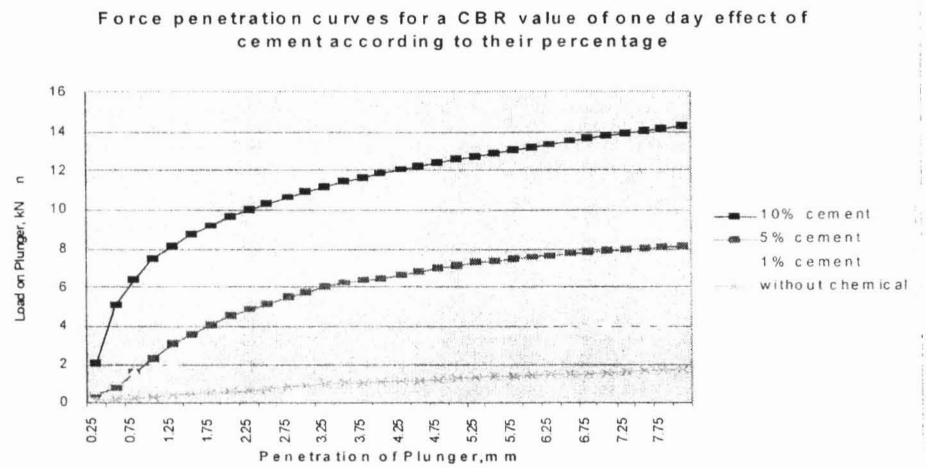


Fig. 3: Force Penetration Curves for a CBR Value of One Day Effect of Cement according to their Percentage

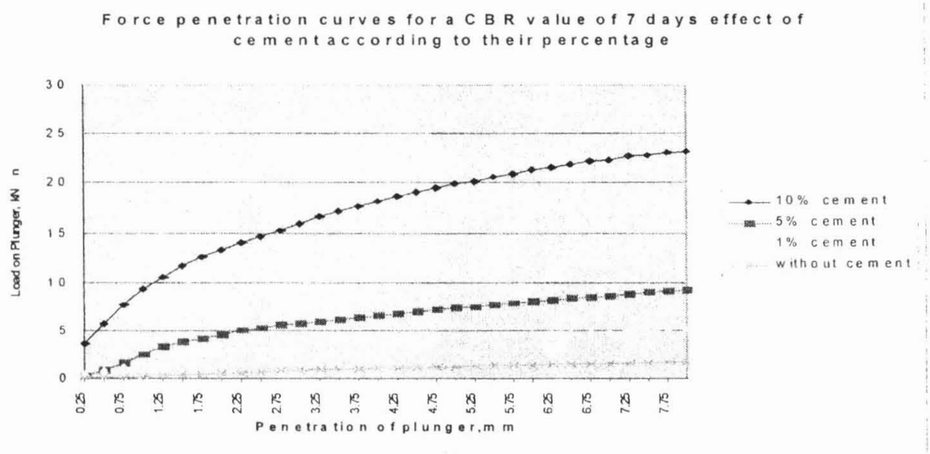


Fig. 4: Force Penetration Curves for a CBR Value of 7 Days Effect of Cement according to their Percentage

According to Figure 2, 3 and 4, the CBR value is increased gradually proportionate to the number of penetration. For the three different curing times, the non- treated soil with no curing time given the lowest value of CBR while the highest value of CBR was obtained by addition of 10% cement and 7 days curing time.

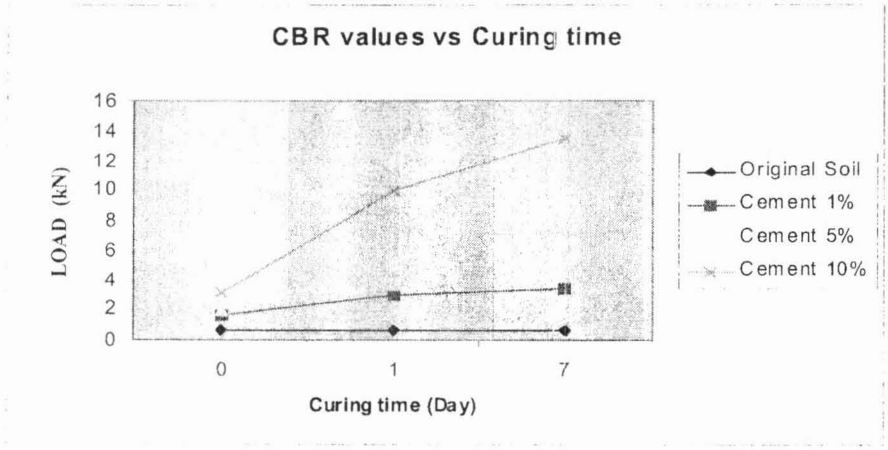


Fig. 5: Graph CBR Values versus Curing Time for 2.5mm Penetration

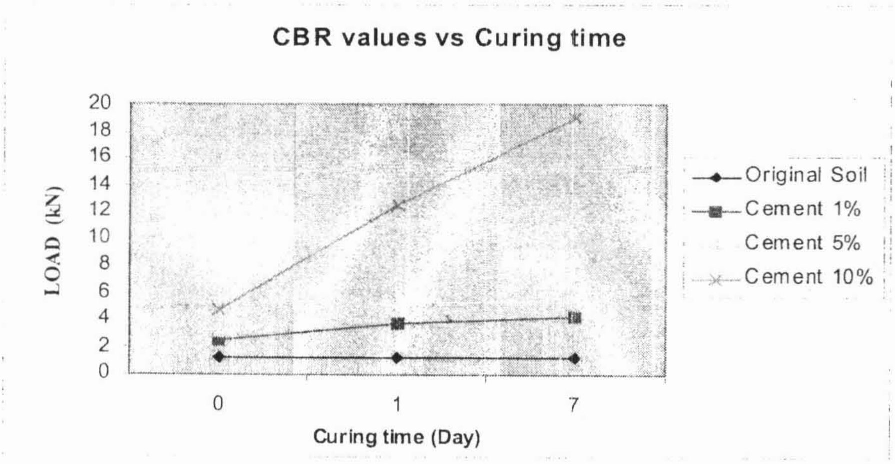


Fig. 6: Graph CBR Values versus Curing Time for 5.0mm Penetration

The strength gain with time of treated fine soil at different cement content is presented in Figures 5 and 6. The results show that the strength of all cement treated sample increases with time. All the CBR values of treated soil are higher than the natural soil (without cement), higher cement percentage and longer curing time in the soil mixture results higher CBR values as illustrated in Figures 5 and 6.

Conclusion

The strength of stabilized soil as indicated by the CBR values increases when the content of cements and the curing time increased. All the CBR treated values are higher than the natural soil, higher cement percentage and longer curing time in the soil mixture results higher CBR values.

The pavement thickness determination is tone example to show the effectiveness the of soil stabilization. Figure 7 shows the design of sub-base and capping thickness for correlating the CBR value and the pavement thickness.

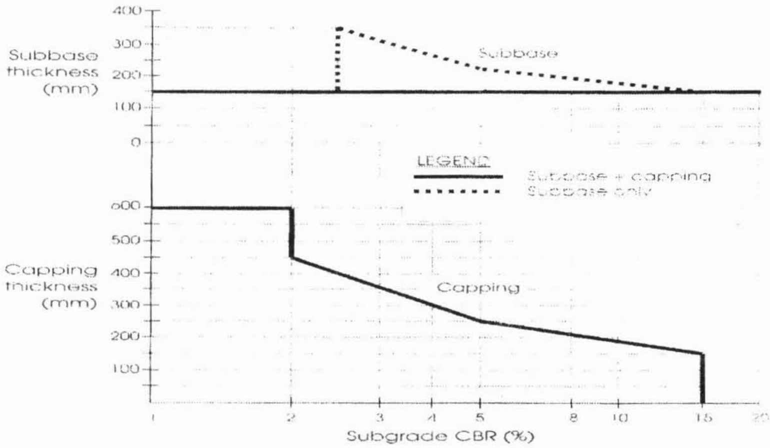


Fig. 7: Design of Sub-base and Capping Thickness (Rogers, M., 2003)

According to Figures 5 and 6, the addition 10% of chemicals and cements has given the best improvement compared to original soil. The higher curing time gives the higher value of CBR values for both treated of soils. The addition 10% of chemicals with 7 days curing time shows the CBR value is almost equal to the maximum value of CBR. So, no sub-base required for addition 10% of chemical with 7 days curing time.

The use of cement stabilization method, therefore, will reduce construction cost of pavement respectively. Savings are achieved through a combination of the following factors such as reduction in the thicknesses of base course or sub-base layers and elimination or minimizing the need to remove and replace the otherwise unsuitable sub-grade materials.

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