Treatment of Crushed Stone with Quaternary Ammonium Chloride

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ABRIDGMENT

•THE EFFECT of a quaternary ammonium salt on the stability of a base course material treated with varying percentages of the salt and exposed to the action of water was determined by investigating its shearing strength.

The quaternary ammonium salt used was dioctadeyl dimethyl ammonium chloride.

The granular base course material used was a crushed rock obtained from a quarry located in Taylor County, Iowa, classified as A-1-a. This material, although meeting the AASHO specifications for base courses, was very susceptible to the action of water, as indicated by its soaked CBR value of 33 at standard AASHO density.

Preliminary investigations were conducted to establish the maximum dry densities and optimum moisture contents. Curing studies were also conducted by air-drying the specimens to establish the residual moisture contents at which the soaked specimens would give the maximum immersed CBR.

The specimens for determination of shearing strength were molded by vibrational compaction to near Standard Proctor density at the optimum moisture contents. The specimens were confined in rubber membranes, and then were cured by air-drying. They were soaked vertically in water which worked into the soil from the bottom up for about 48 hr, and were tested by the unconsolidated-undrained triaxial shear test. The Mohr envelopes and their 95 percent confidence limits were evaluated using the least squares method developed by Balmer (1). The results are summarized in Table 1.

TABLE 1

EFFECT OF QUATERNARY AMMONIUM SALT ON APPARENT COHESION AND APPARENT ANGLE OF SHEARING RESISTANCE OF GRANULAR BASE COURSE MATERIAL[a]

Arquad 2HT Content (%)	Apparent Cohesion (psi)	Angle of Shearing Resistance (deg)
0	11.5 ± 6.5	16.5 ± 5
0.01	4 ± 2	23.1 ± 2.6
0.03	7.5 ± 1.5	22.7 ± 1.2
0.05	6 ± 2	24.3 ± 1.3

[a]Evaluated using total principal stresses determined by undrained, quick triaxial tests.

The apparent cohesion and apparent angle of shearing resistance (based on total stresses) are unlike the true apparent cohesion and angle of shearing resistance (based on effective stress), neither independent variables of the shearing resistance nor basic properties of a soil; they depend extensively on the pore pressure (neutral stress) developed within the stressed soil-water system. The determination of true apparent cohesion and angle of shearing resistance and their use require careful examination of

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neutral stresses which, in certain cases such as road base courses, may be unpredictable, undeterminable, and inconsistent due to the heterogeneous nature of the material and the variable nature of such field conditions as loading and seepage patterns. The apparent cohesion and apparent angle of shearing resistance, however, under prevailing conditions determine the shearing resistance of the material (soil-water system) according to Coulomb's empirical law of shearing resistance. For example, prevailing conditions for a material protected against the ingress of water do not allow the development of significant and fluctuating pore pressure, resulting in high and stable values of apparent cohesion and/or apparent angle of shearing resistance. In other words, these paramenters indicate the stability attained by a treatment. For these reasons and because of its simplicity the undrained quick test was used.

Waterproofing additives, by controlling the impregnation of the material by water, reduce and stabilize pore pressure development and thus eliminate high magnitudes and fluctuations of developed neutral stresses, and result in high shearing resistance and stability.

The addition of the quaternary ammonium salt to the granular base material caused a significant reduction in the fluctuations of both apparent cohesion and apparent angle of shearing resistance (Table 1). A possible explanation of the mechanism of waterproofing action of the quaternary ammonium salt on water susceptible granular material is that a granular material is made up of aggregate-size structural units with large pores between these units. The structural units are particles of gravel, sand, and silt cemented together by clay. When the material is untreated, water penetrates into the large pores and into the structural units, which may cause segregation of fines and may increase the pore pressure with the structual units. The water in large pores is assumed to have little effect on the neutral stresses affecting the shear strength of a granular material but the water within the pores of structural units does. Due to heterogeneity of the granular material augmented by the action of water (segregation of fines causing a sort of plug against the entrance of water) moisture adsorption and the pore pressures within these structural units of untreated material may vary, causing significant fluctuations in shearing strengths of different samples or of different parts of the base of a road. These fluctuations are evidenced by high values of 95 percent confidence limits.

When the material is treated the aggregation is increased due to coagulant action of the quaternary ammonium salts, leading to reduced segregation during compaction (better homogeneity), and the structural units are waterproofed against the penetration of water. Water then enters only the large pores. The pore pressure within the structural units is limited to a stable equilibrium value that is far less than the maximum pore pressure developed in soaked-untreated material.

The following conclusions are based on the data obtained.

Quaternary ammonium salts are effective additives for improving the shear strength of a water susceptible granular material under adverse moisture conditions. Without treatment the shear strength of the material varies greatly. The average shear strength of the untreated material is significantly lower than that of treated materials. There is little variation in the shear strength of treated material under extreme moisture conditions, eliminating the uncertainties otherwise inescapable and risky for design purpose.

REFERENCE

1. Balmer. ASTM, Proc., Vol. 52, pp. 1260-1271, 1952.