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Importance of Controlling the Degree of Saturation in Soil Compaction

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Abstract

In the typical conventional fill compaction, the dry density ρ_d and the water content w are controlled in relation to $(\rho_d)_{max}$ and w_{opt} determined by laboratory compaction tests using a representative sample at a certain compaction energy level CEL. Although CEL and actual soil type affect significantly the values of $(\rho_d)_{max}$ and w_{opt}, they change inevitably in a given earthwork project while CEL in the field may not match the value used in the laboratory compaction tests. Compaction control based on the stiffness of compacted soil in the field has such a drawback that the stiffness drops upon wetting more largely as the degree of saturation, S_r, of compacted soil becomes lower than the optimum degree of saturation $(S_r)_{opt}$ defined as S_r when $(\rho_d)_{max}$ is obtained for a given CEL. In comparison, the value of $(S_r)_{opt}$ and the $\rho_d/(\rho_d)_{max}$ vs. S_r - $(S_r)_{opt}$ relation of compacted soil are rather insensitive to variations in CEL and soil type, while the strength and stiffness of unsoaked and soaked compacted soil is controlled by ρ_d and "S_r at the end of compaction". It is proposed to control not only w and ρ_d but also S_r so that S_r becomes $(S_r)_{opt}$ and ρ_d becomes large enough to ensue soil properties required in design.

Keywords: Degree of compaction, Degree of saturation, Dry density, Soil compaction, Water content

1 Introduction

In the typical conventional soil compaction procedure by end product specification, the dry density ρ_d and the water content w of compacted soil are controlled relative to the maximum dry density $(\rho_d)_{max}$ and the optimum water content w_{opt}, respectively, obtained by laboratory compaction tests performed on a representative sample at a certain compaction energy level (CEL), such as those of curve B-B shown in Fig. 1a (n.b., the test results described in Fig. 1a are explained in the next section). However, $(\rho_d)_{max}$ increases and w_{opt} decreases with an increase in CEL. In Fig. 1a, the compaction curve moves toward upper left with an increase in CEL associated with an increase in the number of passing (N) of a compaction machine in the full-scale compaction tests. The CEL in the top 10 cm-thick soil layer in the 30 cm-thick lift already exceeds Standard Proctor (1.0Ec) when N= 4, while the value when N= 16 is

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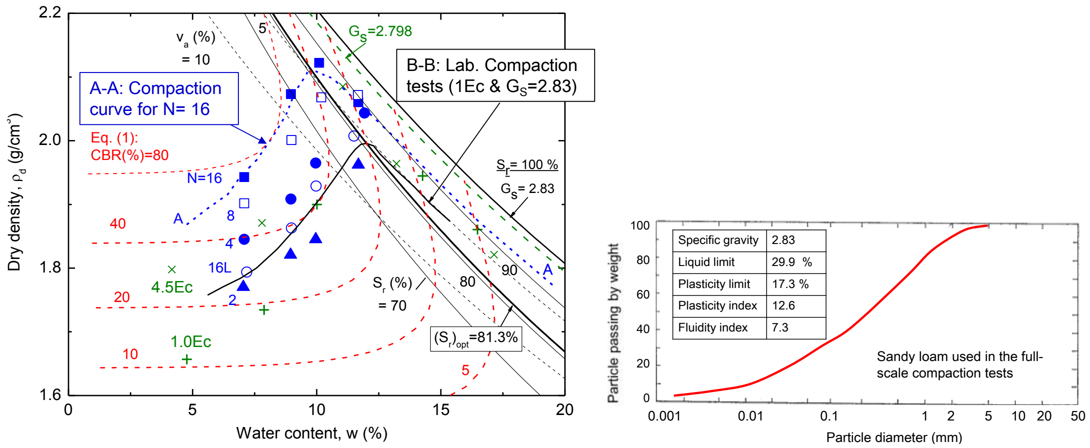
much higher than Modified Proctor (4.5Ec). Besides, when N= 16, the ρ_d values in the bottom 10 cm-thick soil layer (denoted as 16L) are much lower than those in the upper soil layer (denoted as N= 16), showing a fast decrease in CEL with depth. These facts indicate that, even at a nominally fixed CEL, actual CEL inevitably varies randomly associated with variations in actual N and actual lift and systematically with depth in each lift.



a) b)

Figure 1: a) Compaction characteristics with contours of unsoaked CBR from full-scale and laboratory compaction tests; and b) grading curve of sandy loam (after the data reported by Nemoto & Sasaki, 1994).

In this respect, Ishii et al. (1987) showed that CEL when compacting a 35 cm-thick soil layer by 16 passings of a flat surface 10 ton-vibratory steel roller, representative of typical modern fill compaction works, is approximately equivalent to 4.5Ec. In this case, the in-situ w_{opt} is much lower than "w_{opt} by laboratory compaction for 1.0Ec", while the in-situ $(\rho_d)_{max}$ becomes much higher than the value for 1.0Ec. Compaction at $w >$ "w_{opt} for 1.0Ec" is often recommended in practice aiming at avoiding large collapse and a large decrease in the strength/stiffness upon wetting and/or obtaining the minimum saturated coefficient of hydraulic conductivity, k, for seepage-control soil structures. However, w higher than "w_{opt} for 1.0Ec" may become considerably higher than "in-situ w_{opt}", which may result in inefficient compaction and even over-compaction and/or a k value larger than the minimum.

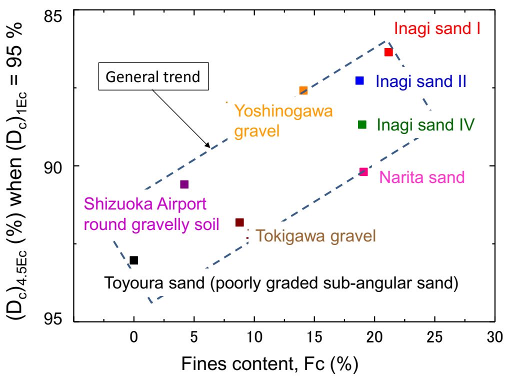


Figure 2: "D_c for 4.5Ec when D_c based on for 1.0Ec is equal to 95 %" vs. fines content relation of sandy & gravelly soils reported in Tatsuoka et al. (2015).