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An application of performance-based design concept to design of compacted ground

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ABSTRACT: In order to estimate the risks of structural design, mechanical behaviour of the structures should be predicted by rational methods with accuracy. However, in the case of compacted ground, it is difficult to estimate the mechanical behaviour because it is usually in an unsaturated state. Therefore empirical methods have been used in practice. Although the validity of such methods has been confirmed, the relationship between compaction control standard and the mechanical behaviour has not been examined sufficiently. In this paper the authors discuss these relations and evaluation methods by using water content and dry density that are usually used in practice.

1 INTRODUCTION

Recently, performance-based design concept has been introduced to structural design codes in Japan. In order to design structures in consideration of the performance or reliability, it is necessary to evaluate reliability of design methods in addition to uncertainty of design values.

This paper discusses the design methods of compacted ground. Compaction control by density is usually used in earthwork, and it is appropriate method qualitatively because strength and stiffness of compacted ground increase with dry density. However, the design value of compacted ground is often determined empirically and the relationship between the mechanical behaviour of compacted ground and compaction control standard is not clarified sufficiently. This is due to the difficulty of the evaluation of mechanical behaviour of unsaturated soils. In this paper, the authors discuss the evaluation method of compression curves by using water content and dry density that are usually used in practice.

2 COMPRESSION CURVES OF COMPACTED SOILS

Figure 1 shows the compression curves of a compacted silt (Honda et al. 2006). For cases in which the confining pressure is the same, unsaturated specimens maintain a higher void ratio than saturated specimens. This is because the yield stress increases with suction. If the stress exceeds the yield stress, plastic compression occurs and the compression curve for the unsaturated specimen approaches the curve for the saturated specimen with the progress of the plastic deformation, since the water content changes little. Ultimately, the compression curve for the unsaturated specimen reaches that for the saturated specimen. The void ratio at the point of saturation is estimated by the product of the specific volume and the water content.

Figure 2 shows the conceptual compression curves of compacted soils. On the basis of this figure, compression curves in unsaturated state and saturated state are formulated by equations (1) and (2), respectively. By substituting equation (1) for equation (2), equation (3) is derived. This equation is also derived by the constitutive model that the authors have proposed (Honda et al. 2005, 2007).

Equation (3) can be used to predict the compression curves in unsaturated state by two types of compression index λ, λ_u and water content w. Moreover it can also be used to evaluate the yield

stress by the initial void ratio which is derived by the compaction control standard or observed data in the field. Because void ratio e is calculated by equation (5), which is derived by equation(4), with dry density γ_d and specific gravity Gs.

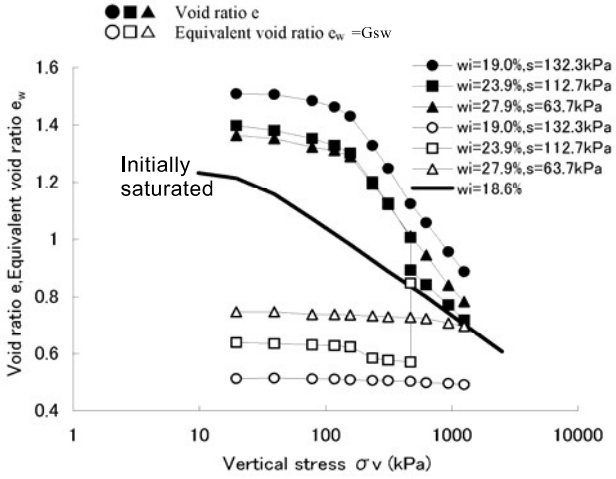


Fig. 1 Compression curves of silt (Honda et al.2006)

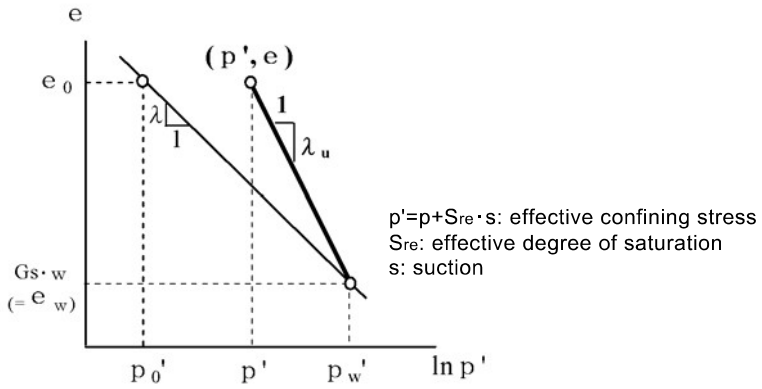


Fig. 2 Conceptual compression curves

$$e = e_w - \lambda_u \ln(p'/p_w') \tag{1}$$

$$e = e_0 - \lambda \ln(p'/p_0') \tag{2}$$

$$e = (\lambda_u/\lambda)e_p - ((\lambda_u/\lambda)-1)G_s w \tag{3}$$

where $e_p = e_0 - \lambda \ln(p'/p_0')$

$$\gamma_d = \frac{Gs}{1+e}\gamma_w \tag{4}$$

$$e = Gs \cdot \gamma_w / \gamma_d - 1 \tag{5}$$

3 EVALUATION OF COMPRESSION INDEX IN UNSATURATED STATE

Equation (3) shows the relationship between water content and void ratio in the case when parameter e_p, or effective confining pressure p', is constant. And we can consider it the equation of compaction curve on the dry side of the optimum when the compaction load is p'

Figure 3 shows the conceptual compaction curve which is drawn by equation (3), and represented by void ratio. In this figure, the relationship between water content and void ratio is represented by linear function with slope $((\lambda_u/\lambda)-1)G_s$.

Figure 4 shows the compaction curves and compression curves (Honda et al. 2007). The compression index in unsaturated state λ_u is calculated by the slope of compaction curves. The calculated value agrees with the slope of compression curve well.

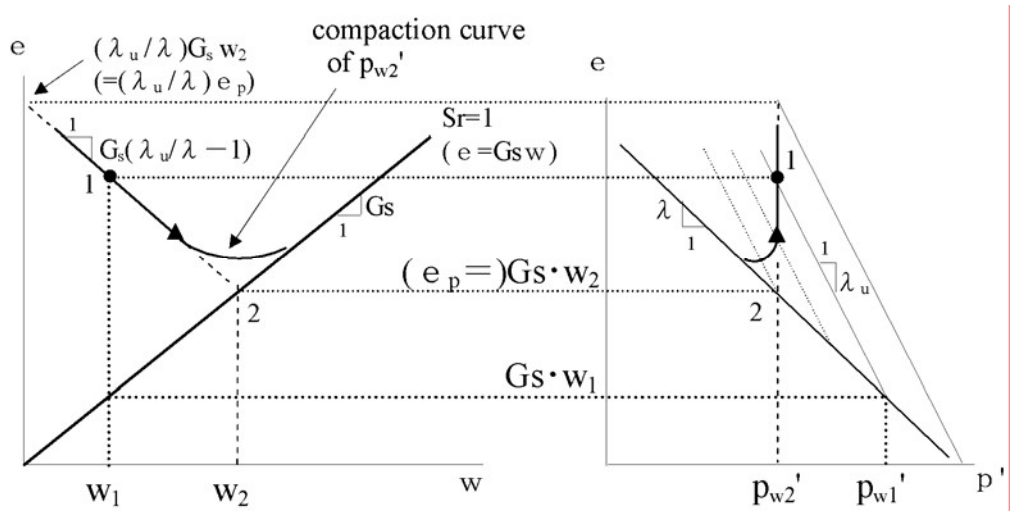
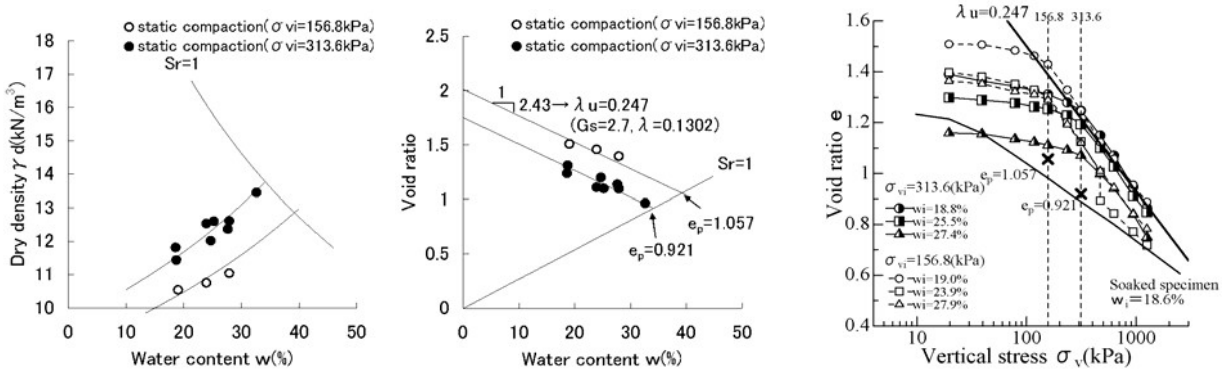


Fig. 3 Relationship between compaction curves and compression curves (Honda et al.(2007))



(a) Compaction curves (dry density) (b) Compaction curves (void ratios) (c) Compression curves

Fig. 4 Relationship between compaction curves and compression curves (Honda et al. 2007)

4 FINAL REMARKS

The evaluation method of the compression characteristics for compacted soils is studied in this paper. In order to estimate the risks of the design and earthwork, mechanical behaviour of the compacted ground should be predicted by rational methods with accuracy.

Although the validity of the theoretical framework is confirmed by oedmeter test results, it should be examined by various types of soils.

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