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Small Strain Behaviour of a Compacted Subgrade Soil

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Abstract
The small strain behaviour is a key indicator for assessing the performance of compacted fills. The initial compaction conditions i.e. water content and applied energy, govern compaction effectiveness and, thus, the structure and matric suction of compacted subgrade soil. This paper presents an experimental study of the small strain behaviour of a typical compacted subgrade soil, i.e. silty sand, prepared with different compaction conditions. Specimens were prepared for different compaction states to mimic the typical acceptance criteria of end-product specifications. The small strain modulus (G_0) was evaluated using Bender elements, while the post-compaction matric suction was measured using the filter paper method and a tensiometer. The experimental data indicates a strong modulus dependency on water content or suction across the compaction plane but suggests G_0 is better described as a function of the degree of saturation (S_r). The laboratory results are also examined in light of common end-product specifications, which show that it may be beneficial to compact the soil slightly dry of optimum moisture content from the modulus point of view.

Keywords: Small strain stiffness, compacted soil, end-product specifications

1 Introduction

Compaction has been adopted in most construction works such as road and railway embankments, dams, landfills, airfields, foundations, and hydraulic barriers. During construction and placement of fills, the compaction characteristics are evaluated based on a minimum deviation interval from selected laboratory key parameters (i.e. maximum dry unit weight, or MDD and optimum moisture content, or OMC). Although controlling the quality of compaction with those criteria, including different methods such as sand cone, rubber balloon, and nuclear gauge, has been well established,

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problems related to poor compaction still occur (i.e. differential settlements, increase in pavement roughness). This is mainly associated with the insufficient compaction control verification at the time of placement of the fills. These methods cover a limited area, typically less than less than 1 % of the actual compacted area, that lead to insufficient compaction locations being missed. This in turn deems necessary the execution of costly and time consuming post-construction maintenance operations during the service life of the infrastructure. In addition, the conventional rollers (i.e. with static and vibratory drums) may not deliver uniform field compaction throughout the site due to differences in the hydration time and lift thickness. These variations can have substantial effects on the stress-strain behaviour of the compacted soil (e.g. Heitor et al., 2012, Indraratna et al. (2014). Recently, intelligent compaction control (ICC) technologies have emerged to address this problem. Various manufacturers equipped the roller drums with an accelerometer based measuring systems, which are able to monitor the soil response (i.e. its stiffness or modulus) at the time of compaction through a continuous feedback system. This allows the compaction quality to be better controlled and thus the fills are compacted more uniformly. The wide application of ICC technology in the compaction of fills seems very promising; however, the effects of dry unit weight, moisture content, suction, and the imparted energy level on the soil modulus are not understood very well, particularly for fine grained soils. Undoubtedly these parameters have a strong influence on the soil modulus, particularly the suction and degree of saturation.

The results from previous research studies indicate that the small strain modulus is dependent on the level of stress, the as-compacted water content and changes in post-compaction suction (Claria and Rinaldi, 2004; Sawangsuriya et al., 2008; Heitor at al., 2015a). Indeed, Mancuso et al. (2002) investigated the effect of suction on the small strain shear modulus in the low suction range and found that the shear modulus increased with suction, however, a noted inflexion was observed at the air entry value (AEV) and two distinct ranges were defined, a bulk water regulated zone and a menisci water regulated zone. Before AEV the shear modulus increases linearly with suction, thereafter its increase is predominantly non-linear. Similar observations were also reported for a range of different soils by Marinho et al. (1996); Vinale et al. (2001), Inci et al. (2003), and Sawangsuriya et al. (2008), Rujikiatkamjorn et al. (2012); Indraratna et al. (2012) and Heitor et al. (2015b). Mancuso et al. (2002) and more recently Heitor et al. (2013) also revealed that the small strain shear modulus is influenced by the soil fabric derived from the compaction process. This is associated with the inherent microstructure and porosity differences of specimens prepared at OMC and wet of OMC that are fundamentally different from those prepared at dry of OMC, which exhibit a matrix and aggregations dominated microstructure, respectively (Heitor et al., 2013). Furthermore, the data presented in Mancuso et al. (2002) seems to suggest that the small strain shear modulus is more sensitive to changes in suction when the soil water retention curve (SWRC) is within the macroporosity range, remaining nearly constant once the residual water content is exceed (also interpreted as the beginning of microporosity range).

While the behavior of soil modulus is relatively well understood for different levels of suction and or moisture content, there are limited studies that have reported the modulus behavior across the compaction plane and associated sensitivity to variations in dry unit weight and moisture content. This is very relevant in view of more extensive implementation of ICC in construction projects, particularly because the adoption of this technology calls for a fundamental change in project delivery and compaction control practices.

In this paper the small strain behaviour of a typical compacted subgrade soil, i.e. silty sand across the compaction plane, is examined. Specimens were prepared for different compaction states to mimic the typical end-product specifications acceptance criteria and the corresponding small strain modulus (G_0) and suction were evaluated. The behavior of this compacted material upon wetting and drying, which critical for evaluating in service performance, is not included in this paper, but a detailed discussion is given in Heitor et al. (2015).

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