# Effect of the soil's suction history on the small strain behavior

Ana Heitor[1*], Buddhima Indraratna[2] and Cholachat Rujikiatkamjorn[3]
*[1] Lecturer, [2] Research director and Distinguished Professor, [3] Associate Professor*
*Centre for Geomechanics and Railway Engineering, Faculty of Engineering, Univ. of Wollongong, Wollongong City, NSW 2522, Australia*
aheitor@uow.edu.au, indra@uow.edu.au, cholacha@uow.edu.au

## 1 Introduction

While the cyclic loading performance of the underlying transport formations (subgrade) is traditionally assessed for fully-saturated conditions, most load bearing strata in rail infrastructure remain unsaturated. Past research studies (e.g. Gens, 2010, Alonso et al., 2010, Heitor et al., 2013, Indraratna et al., 2014 and Heitor et al., 2015) showed that the behaviour of such materials is governed by the initial compacted state, i.e. role of matric suction in relation to the degree of saturation. Furthermore, during their service life, most earth structures experience changes in hydraulic behaviour owing to climatic changes. While the results of previous research studies indicate that the effect of changes in suction on the dynamic response is significant, only limited research has been engaged in the assessment of the effect of post-compacted changes in suction induced by periods of intensive precipitation (i.e. wetting) and drought (i.e. drying). The seasonal fluctuations of moisture reflected in the soil's suction history have an important impact on the geomechanical performance of compacted soil.

## 2 Soil's suction history

The effect of suction history on $G_0$ (Ng et al., 2012 and Heitor et al., 2015) can be quantified considering:

(a) hydraulic cycles,
(b) the current suction ratio or CSR and
(c) recent suction history.

The CSR (Eq.1) is defined as the maximum historical suction ($s_{max}$) of a soil experienced divided by the current suction($s_{current}$). The recent suction history refers to the influence of the penultimate suction path on soil behaviour along the current stress path. The hydraulic cycles refers to the number of times the soil has achieved a certain suction level upon drying and wetting.

$$CSR = \frac{s_{\max}}{s_{current}} \tag{1}$$

where suction, s = $(u_a - u_w)$, $u_a$ is the pore air pressure and $u_w$ is the pore water pressure. This paper aims to offers novel insights into effect of suction history on the small strain behaviour in cycles of wetting and drying, particularly in terms of CSR and hydraulic cycles.

## 3 Small strain stiffness results

The variation of $G_0$ with increasing (drying) and decreasing (wetting) suction is depicted in Figure 1a. The most striking aspect is that $G_0$ exhibits higher values when following the wetting paths. This might not correspond to the expected intuitive behaviour at first glance, but it can be associated with the soil-water exchange in soil pores. The amount of water in the soil, as reflected by the degree of saturation ($S_r$), represents the cumulative number of air-water menisci affecting inter-particle connections for a given suction level. Thus, despite having the same suction, upon drying and wetting, the different amounts of water in the soil lead to different mechanical behaviour. In addition, this behaviour can also be linked to the hysteretic response observed in the SWRC (i.e. the ink-bottle

[*] Corresponding author (YGP)

effect) and associated fabric during drying and wetting processes (e.g. Cuisinier and Laloui, 2004, Monroy et al., 2010). Figure 1a also shows that hysteretic response in drying and wetting processes is different for values of $s_{max}$ (i.e. the largest suction the specimen have been exposed to) and also differs for subsequent drying-wetting cycles. For instance, the hysteresis amplitude for $s_{max}$ of 150kPa is 28MPa whereas for $s_{max}$ of 300kPa is 56 MPa and at a suction 25kPa, the $G_0$ differed by 25.4 MPa, between the first and second cycles. This seems to indicate that when compacted specimens experience multiple cycles of drying and wetting to the same suction level the soil skeleton is strengthened which may be attributed to some extent to hydraulic ageing. The $G_0$ values are plotted against the CSR values computed for the wetting paths. To better illustrate the influence of the suction stress history at different current suction ratios on $G_0$, the data normalised by the current stress state (p') suggested by Heitor et al. (2015) is shown in Figure 1b.

$$p' = \left[ (p - u_a) + (u_a - u_w) S_r \right] \quad (2)$$

Figure 1b shows that the normalised $G_0$ increased with the CSR and the modulus response is strongly dependent on the current stress state (*p'*), as the normalised modulus values are smaller for larger $s_{max}$.

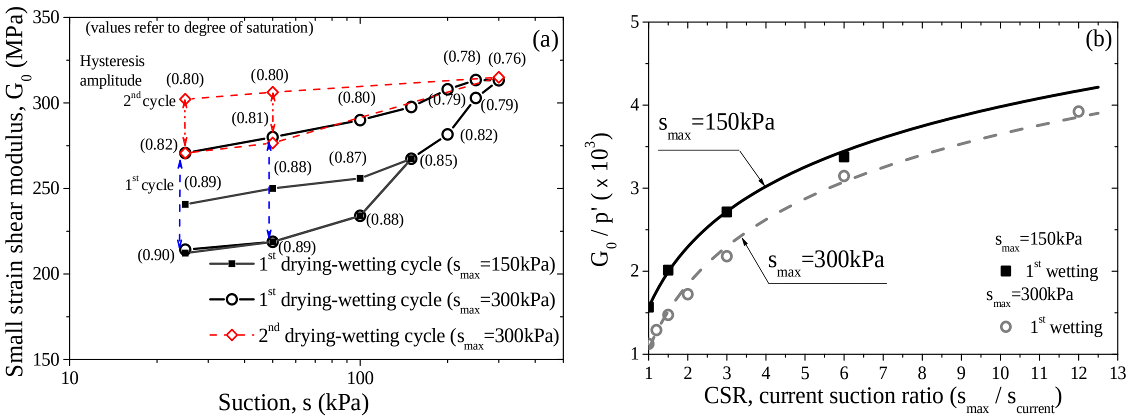


**Figure 1:** Variation of (a) $G_0$ with suction and (b) normalized $G_0$ with CSR during wetting and drying for specimens compacted at energy level of 529.5kJ/m3 and different $s_{max}$ values (modified after Heitor et al., 2015).

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