Abstract

Following a critical review of the conceptual and laboratory studies on expansive soil behaviour, it is shown that the current understanding of unsaturated expansive soil behaviour is not consistent. In the main, the approach used is based on the concept of soil water potential. Notwithstanding its success, the suction concept is suited for water movement in soils, and not the mechanics of the soil response. On this background, a new concept of visualising the swelling phenomenon is formulated. The concept is herein called the ***induction concept***. It facilitates the characterisation of soil potentials (adsorptive forces) from a mechanistic point of view. The concept forms the basis of characterising the soil potentials in terms of effective stress. In this regard, an effective stress hypotheis is proposed and later on validated. The accompanying change in soil structure is adequately catered for via compatible physical soil models. One such physical soil model is developed herein for the first time. It is called the ***Swelling Boundary Surface (SBS) model***. The SBS physical soil model is compatible with the changes of the soil potentials during soil swelling. It is applicable to different wetting conditions, direction of water flow and degrees of soil confinement.

An appropriate laboratory test programme was designed to study the fundamental response of an unsaturated expansive soil to flow of water. Accordingly, the laboratory test results analysed and reported herein set out to rationalise the induction concept and to validate the effective stress hypotheses. This leads to the characterisation of the expansive soil behaviour in terms of the effective stress. The study is limited to the stress-strain-water content relationships and does not explicitly incorporate time effects.

The resistance concept (Janbu, 1963, 1998) is the method adopted for analysing the test results. One of the merits of the resistance concept is that it is not dependent on the condition of the soil, e.g. initial water content or degree of saturation. Pure numbers are obtained from the test data, which are specific to the soil type. They constitute the essential soil parameters required in any geotechnical analysis. The simplicity and rationality inherent in the resistance concept, which is already used in geotechnical engineering, is particularly suited to analysis of unsaturated expansive soil behaviour.

The analyses show that the change in the internal effective stress governs the soil behaviour. Principally, the internal effective stress at the shrinkage limit is characteristic to the soil and it underlies the intrinsic soil property. It is herein called ***pretension stress***, while the intrinsic soil property is herein called ***pretension rate***. The pretension rate can be normalised against atmopsheric pressure and thus expressed as pure number called ***pretension number***. The significance of eodometer compression and the preconsolidation pressure of the soil to the intrinsic soil property is demonstrated.

The rationalisation of the induction concept has far reaching consequences. It affords the development of appropriate unsaturated expansive soil models in effective stress terms. Significantly, it provides a first opportunity to harmonise the mechanical behaviour of unsaturated and saturated soils in terms of effective stress. The rationalisation of the previously dubbed 'empirical' consistency limits in terms of effective stress opens the possibility of adopting them in characterising and modelling soil behaviour. Lastly, the resistance concept was successfully used to characterise both the swelling and shrinking behaviour of an expansive soil.

Declaration

I hereby certify that, except when specific reference to other investigation is made, the work described in this thesis is the result of the investigation by the candidate.

K. Mawire
(candidate)

Date:

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Notations

1) Latin letters

A	soil attraction
D	coefficient of diffusivity (diffusion coefficient)
DP	disintegration point
e	void ratio
EL	elastic limit
e_o	initial void ratio
f	free energy of any system
G_s	specific gravity
k	pretension number
K	pretension rate
LCE	low compactive effort
LL	liquid limit
m	modulus number
M	Oedometer (tangent) modulus
m_h	stress number for hydrotransient (swelling) pressure
m_b	mobilisation number
m_s	stress number
M_o	initial stress modulus
M_b	mobilisation, swelling or unloading modulus
M_r	reloading modulus
m_r	reloading number
NC	normally consolidated
OC	overconsolidated
P	hydrotransient or swelling pressure
p	soil suction
P_H	horizontal swelling pressure
PI	plasticity index
PL	plastic limit
P_o	reference pressure = atmospheric pressure
P_V	vertical swelling pressure
R	Time resistance
s	soil number
S	soil resistance (flexibility modulus)
SL	linear shrinkage limit
SP	pressure saturation point
S_r	degree of saturation
t	time
U	water (penetrant) uptake at saturation point (infinite time)
U_a	pore air pressure
U_a-U_w	soil suction
U_t	water (penetrant) uptake at time t
U_w	pore water pressure
w	water content
w/c	water content
W_o	initial water content
Y	swelling modulus

Y_o	initial swelling modulus
y	swelling number
YP	yield point
1D	one-dimensional

2) Greek letters

δ	heave
ε	swelling strain
ε_a	axial swelling strain
γ	bulk density
γ_d	dry density
σ'	effective stress
σ_c	(effective) preconsolidation pressure
σ'_{cm}	mobilised preconsolidation pressure
σ'_i	intergranular effective stress
σ'_o	initial effective stress
σ'_s	pre-swelling stress
σ'_T	pre-tension stress
σ'_v	vertical effective stress
σ'_w	mobilised effective stress
σ_i	internal (effective) stress
ψ	soil suction

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