Calculation of Landfill Waste Settlement

Summary:

Landfill waste settlement of the solid phase is one dimensional in the LDAT waste degradation and transport model. It takes place vertically within a particular Stack of LDAT elements. The Stack settlement is consistent with the Powrie and Beaven relationship between the landfill waste effective stress in an element, and the waste dry density in that element.

The solid phase waste dry density in each element changes with time due to dissolution of the solids into the landfill leachate and bio-chemical degradation. These changes are calculated by the LDAT calculation engine, and then vertical transfers of solids are made between elements to align the waste dry density with the current landfill waste effective stress using the Powrie and Beaven relationship.

The landfill waste settlement at any time is estimated by dividing the total inert mass of solids taken from the upper boundary stock at that time, by the horizontal cross-section area of the Stack, and by the current value of the landfill waste dry density of the solids in the upper waste element.

Calculation of Landfill Waste Settlement

The method of calculating the settlement in the solid phase is illustrated in Figure 1. It is assumed that settlement only takes place vertically in a Stack of elements, that there is no creep, and that the Stack settles independently from neighbouring Stacks.

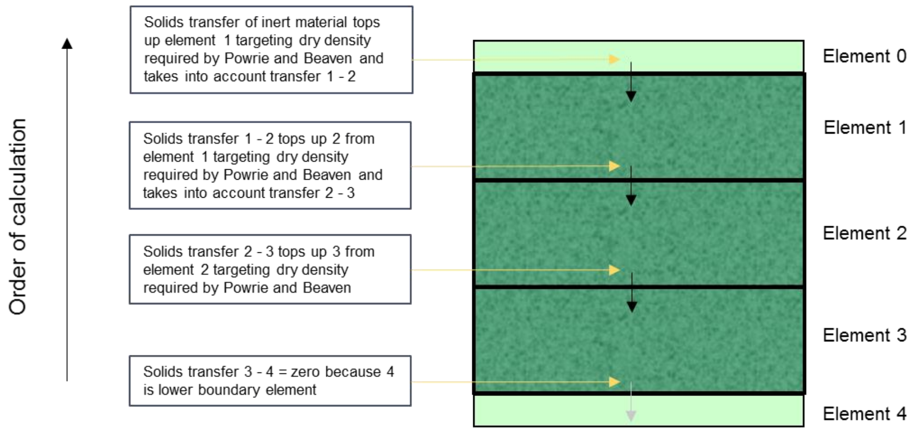


Figure 1 Settlement calculation for a three active element Stack

The calculation proceeds element by element, starting from the lower Active Element and proceeds upwards to the upper Boundary Element.

For each element there will be a change in solids as the result of dissolution and bacteria growth/death. Apart from the lower Active Element there will be a top up transfer through the lower boundary, which at the time of making the calculation will be a known quantity. Taking these two changes into account sufficient material is then transferred from the Active Element above (or in the case of the Upper Active Element – from the Upper Boundary Element) to provide the element with a dry density that is consistent with the currently applied effective stress in accordance with the Powrie and Beaven relationship.

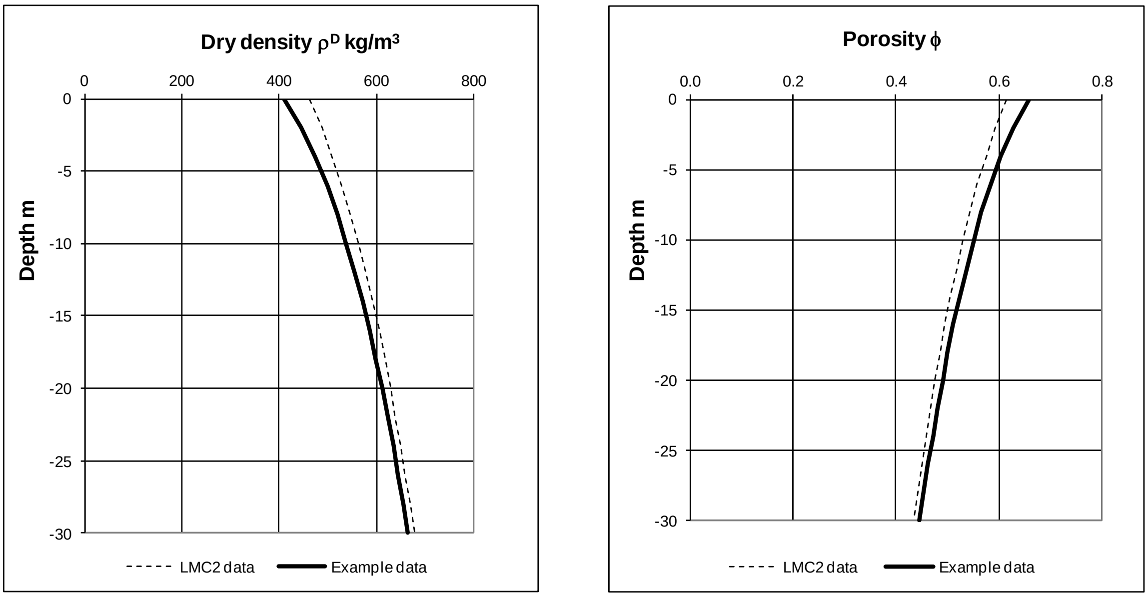
At any point in time the total mass of inert material, $m^{I}_{boundary}$, passed into the Stack from its Upper Boundary will be known, as will the dry-density in the upper Active Element, ρ^{D}_{upper}. If the element horizontal cross-section area is A, then the depth of settlement can be calculated as,

$$d_{settlement} = \frac{m^{I}_{boundary}}{\rho^{D}_{upper} A}$$

LDAT uses the (Powrie and Beaven 1999) relationship for dry density ρ^{D}_{e}, equation 1. See also Figure 1.

$$\rho^{D}_{e} = \rho_{REF}\left(\frac{\sigma'_{e}}{\sigma'_{REF}}\right)^{\lambda} \qquad (1)$$

Porosity ϕ_e is derived from this since $\phi_e = 1 - \frac{\rho^{D}_{e}}{\rho^{S}}$, where ρ^{S} is the solid phase material density.



Parameter		Notation	Units	LMC2 data	Example data
Dry density	Reference dry density	ρ_{REF}	kg/m^3	388	388
	Reference effective stress	σ'_{REF}	kPa	40	40
	Power law index	λ		0.248	0.248
	Overburden	σ_0	kPa	80	50
Porosity	Material density	ρ^{S}	kg/m^3	1200	1200

Figure 2 Dry density and porosity profiles

Powrie, W. and Beaven, R.P. (1999) Hydraulic properties of household waste and implications for landfills. Proceedings of the Institution of Civil Engineers, Geotechnical Engineering, 1999, 137, Oct., pp 235-247.