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Mechanisms of settlement in municipal solid waste landfills

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MSW components

Waste component characteristics [a]

Material group		Shape	Compressibility	Degradability
Organic	Paper/cardboard	2D	High	Medium
	Food waste	3D	High	High
	Garden waste	2D,3D	Medium	Medium
	Leather, textiles	1D,2D	Medium	Medium
Inorganic	Plastics and rubber	1D,2D	High	Low
	Metals, glass	3D	Low	Non
	Minerals	0D	Low	Non
Others [b]		0D	Low	Low

Note: [a] The list is based on categories commonly used in the literature;
[b] Indistinguishable components which are commonly very small and may be stuck together.

Principal mechanisms of settlement

- Rearrangement of the solid matrix by *sliding, reorientation or distortion of waste particles*.
- *Compression of the pore fluid*.
- *Compression or crushing of waste particles.*
- *Breakage of particles*, or *softening of particle contacts*.
- *Degradation,* due to biological decomposition and physico-chemical processes.
- Conventional mechanical *creep* (i.e., continuing settlement at constant effective stress).
- *Ravelling* (i.e. the gradual migration of finer particles into the larger voids).

The three distinct phases of settlement against time (i.e., immediate, primary and secondary settlements) incorporate parts of above mechanisms, respectively.

Particle compressibility

- The potential compressibility of particles is one of the key factors distinguishing MSW from most soils. In general, particles can reduce in volume (compress or crush) as a result of a compression of the solid phase or of gas trapped within the solid phase:

$$\Delta V_{\mathrm{ps}} = f_1(\Delta\sigma, \Delta u_{\mathrm{w}}, \Delta u_{\mathrm{g}})$$

$$\Delta V_{\mathrm{pg}} = f_2(\Delta\sigma, \Delta u_{\mathrm{w}}, \Delta u_{\mathrm{g}})$$

- Currently, there is still a lack of **particle level** study on the volume change behavior of wastes, and the effective stress law is generally applied.

Immediate compression

- It may be characterised by means of a total stress constrained modulus:

$$E_{0,i} = \delta\sigma_v / \delta\varepsilon_v$$

- It may well occur as waste is being deposited and so may pass un-noticed: in cases where immediate compression has been monitored, reported values of $E_{0,i}$ range between 0.2 MPa and 6 MPa, with lower stiffnesses generally associated with low density, and increasing water and organic contents.

Primary compression

- It may be characterised directly by the modified primary compression index:

$$C_c' = \varepsilon_v / (\log_{10}\sigma'_v)$$

- It avoids the need to define and quantify the relevant void ratio. Data from the literature indicate a range of C_c' of generally 0.20 to 0.47 for wastes having a significant organic component.

Secondary compression due to creep

- It may be characterised by an equation of the form:

$$\varepsilon_c = \alpha_c \ln(t/t_m)$$

- It is not always clear whether in the literature the effects of creep have been adequately separated from those of degradation, and some discrepancy may arise from differences in the value of the reference time t_m. Setting at least the second of these aside, reported values of creep parameter α_c range from 0.3% to 4.9% for loose, fresh waste. There is no real evidence of any dependence of the creep parameter on stress, but there may well be a density effect, with denser wastes being less susceptible to creep.

Secondary compression due to degradation

- It may be characterised by an equation of the form:

$$\varepsilon_{b} = \varepsilon_{bt}\,[1\text{-}\exp(\text{-}k_{b}(t\text{-}t_{b}))]$$

- The amount of degradation-induced settlement will depend on the proportion of degradable material present, while the rate of degradation will depend on the way in which the landfill is managed and operated. Values reported in the literature for laboratory tests on fresh MSW in which the effects of creep and degradation-induced settlement have been separated generally range from 11% to 22% for ε_{bt}, and 9.5×10^{-4} to 1.1×10^{-2} day^{-1} for k_{b}.

Hydro-biochemical-mechanical coupled models

- Such models are versatile and show great promise, although obtaining the required parameters is more challenging.