Predictive Model of Landfill Settlement with COMSOL Multiphysics® Employing (THMB) Coupled Processes

M. S. Mousavi[1], J. Eun[2]
1. Ph.D. Student, Civil and Environmental Engineering, University of Nebraska-Lincoln, Omaha, NE, USA
2. Assistant Professor, Civil and Environmental Engineering, University of Nebraska-Lincoln, Omaha, NE, USA

INTRODUCTION: Municipal Solid Waste (MSW) landfills experience significant settlement throughout the lifetime of the site. The settlement is determined by waste properties, placement timing, total height and multiple thermal, hydraulic, mechanical and biochemical processes. Considering the variety of environmental properties and heterogeneity of landfills, any settlement model must take temperature and saturation into account in addition to mechanical properties of MSW.

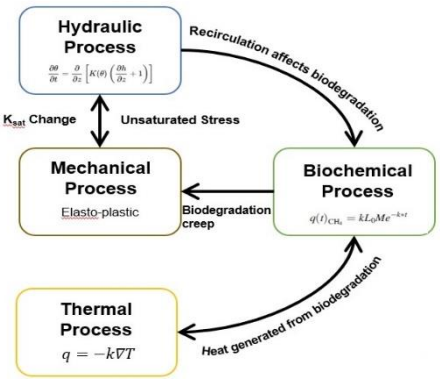

Figure 1. Coupled Processes in MSW Landfills

COMPUTATIONAL METHODS: Instant settlement of MSW landfills is defined by Modified Cam-Clay model due to the elastoplastic behavior of MSW. Long-term settlement is comprised of a mechanical creep and biodegradation creep model. Biodegradation creep has been modified to consider temperature and saturation variations in final biodegradation creep strain. The long-term time-dependent models are manually added to the modified cam-clay total deformation equation. The modified cam-clay model is triplicated and ran for three modes of settlement to result in final settlement.

$$\varepsilon_T = \frac{\lambda}{1+e}.\ln\left(\frac{p'}{p_0'}\right) + \left(\frac{\lambda-\kappa}{1+e}\right).\ln\left(\frac{M^2+\eta^2}{M^2}\right) + b.\sigma'\left(1-e^{-ct'}\right) + \varepsilon_{dg}.\left(1-e^{-k_{st}.t^*}\right)$$

$$k_{st} = \frac{T.S.n.\exp(-\{pH-7\}^2\ln\left(\frac{4}{3}\right))}{16.44\times(1+\exp(\frac{T}{4}-18))}$$

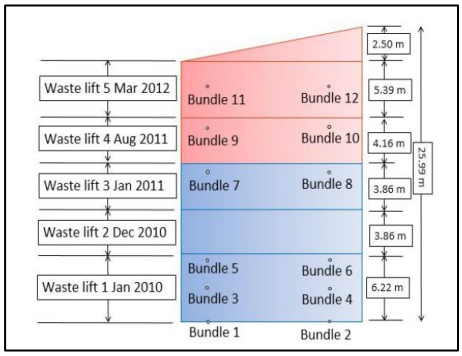

Figure 2. MSW Landfill layer setup (Van Geel and Murray 2015)

RESULTS: Settlements were estimated based on reported field parameters. Vertical settlement of each layer was simulated separately based on loads, temperature, saturation and mechanical properties of each layer.

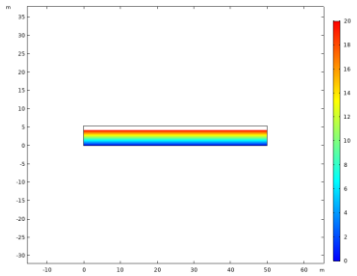

Figure 3. Settlement of each landfill layer

Variable	Value	Units
Density	930	Kg/m3
Compression index	0.016	1
b	0.00119	kPa^{-1}
c	0.0208	day^{-1}
ε_{dg}	0.112	1

Table 1. Field parameters used for coupled model

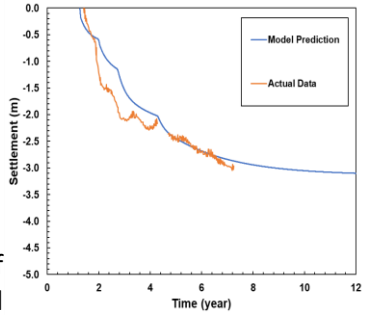

Figure 4. Bundle 7 settlement prediction vs actual measurement

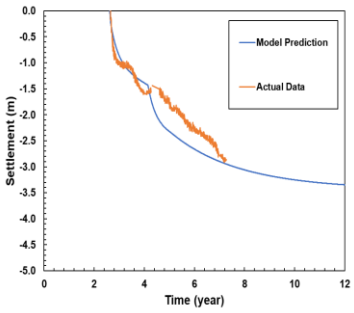

Figure 5. Bundle 11 settlement prediction vs actual measurement

CONCLUSIONS: The results show that modify cam-clay model incorporating mechanical and biodegradation creep yields accurate settlement prediction when temperature and saturation varieties in landfills are integrated into the biodegradation model. Also, the equation modification and custom options in COMSOL allow a convenient implementation of coupled models into the program which give reliable results. This model can be used for landfill designers and managers to estimate possible settlement of their landfill to prevent failures to the covers, liners, biogas collection and leachate collection and recirculation systems.

Laboratory experiments are being conducted at University of Nebraska-Lincoln to further enhance the accuracy of the proposed model to account for a variety of temperature and saturation conditions in landfills.

REFERENCES:

1. Babu, G. S., Reddy, K. R., & Chouksey, S. K., Constitutive model for municipal solid waste incorporating mechanical creep and biodegradation-induced compression., Waste Management, 30, 11-22 (2010)
2. Van Geel, P. J., & Murray, K. E., Simulating settlement during waste placement at a landfill with waste lifts placed under frozen conditions, Waste Management, 46, 352-361, (2010)