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Development of a Coupled Thermal-Mechanical-Biological Model to Simulate Impacts of Temperature on Waste Stabilization at a Landfill in Quebec, Canada

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Abstract : A coupled Thermal-Mechanical-Biological (TMB) model was developed for the analysis of impacts of temperatures on waste stabilization at a Municipal Solid Waste (MSW) landfill in Quebec, Canada using COMSOL Multiphysics, a finite element-based software. For waste placed in landfills in Northern climates during winter months, it can take months or even years before the waste approaches ideal temperatures for biodegradation to occur. Therefore, the proposed model links biodegradation induced strain in MSW to waste temperatures and corresponding heat generation rates as a result of anaerobic degradation. This provides a link between the thermal-biological and mechanical behavior of MSW. The thermal properties of MSW are further linked to density which is tracked and updated in the mechanical component of the model, providing a mechanical-thermal link. The settlement of MSW is modelled based on the concept of viscoelasticity. The specific viscoelastic model used is a single Kelvin – Voight viscoelastic body in which the finite element response is controlled by the elastic material parameters – Young's Modulus and Poisson's ratio. The numerical model was validated with 10 years of temperature and settlement data collected from a landfill in Ste. Sophie, Quebec. The coupled TMB modelling framework, which simulates placement of waste lifts as they are placed progressively in the landfill, allows for optimization of several thermal and mechanical parameters throughout the depth of the waste profile and helps in better understanding of temperature dependence of MSW stabilization. The model is able to illustrate how waste placed in the winter months can delay biodegradation-induced settlement and generation of landfill gas. A delay in waste stabilization will impact the utilization of the approved airspace prior to the placement of a final cover and impact post-closure maintenance. The model provides a valuable tool to assess different waste placement strategies in order to increase airspace utilization within landfills operating under different climates, in addition to understanding conditions for increased gas generation for recovery as a green and renewable energy source.

Keywords : coupled model, finite element modeling, landfill, municipal solid waste, waste stabilization
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