Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 112 (2017) 481 – 488

Energy Procedia

Sustainable Solutions for Energy and Environment, EENVIRO 2016, 26-28October 2016, Bucharest, Romania

Instability phenomena in municipal waste landfill. Numerical modeling in saturated and unsaturated conditions

Loretta Batali*, Andreea Carastoian, Horatiu Popa, Gheorghe Pantel

Technical University of Civil Engineering Bucharest, Bd. Lacul Tei 124, Bucharest, Romania

Abstract

Instability phenomena in waste landfills are not rare and the consequences are more severe than ones for typical landslide, having also environmental impact. Old waste dumps are often located in dried (or partially dried) valleys, natural gulches or ravines, therefore waste is often placed on sloped ground. Their mechanical characteristics are often very poor and, due to lack of drainage systems, are in saturated state. Therefore, instability can appear at every stage of the operation, during the closure or post-closing. The paper presents some aspects related to specific instability phenomena in waste landfills and dumps and to stability analysis in saturated and unsaturated state using numerical methods. As well, it presents a case study of an old dumpsite in Romania where a landslide occurred during the closing works and for which a consolidation solution was proposed, based on drainage and mechanical consolidation. Numerical modeling has been used for simulating the effect of the drainage and for evaluating the gain in stability, considering the unsaturated final state of the drained waste.

Peer-review under responsibility of the organizing committee of the international conference on Sustainable Solutions for Energy and Environment 2016

Keywords: municipal landfill; landslide; numerical modelling; unsaturated analysis; drainage system

1. Introduction

Romania has many non-conform municipal landfills, meaning waste dumps with no protection measures against pollution of groundwater, soil or air. All have to be closed according to European and national legislation in force.

As they are savage dumps, with no design or operation rules, the waste is most of the time in a loose state, saturated with leachate, thus having very poor mechanical characteristics.

* *Corresponding author Tel: +4-074-504-0975*
E-mail address: Loretta@utcb.ro

Peer-review under responsibility of the organizing committee of the international conference on Sustainable Solutions for Energy and Environment 2016
doi:10.1016/j.egypro.2017.03.1123

As well, the common practice is to dump the waste in natural declivities, such as dried valleys or valleys with temporary flow, old carriers etc.

Therefore, the resulted waste dump has a slope following the natural subgrade. The combination between this type of morphology and poor mechanical characteristics, together with presence of leachate (which is not drained) can often lead to instability phenomena (landslides). Besides the instability itself, this involves also environmental problems as leachate exfiltrations, fermentation gas exhaustion etc.

The paper presents general aspects regarding stability problems of old landfills, including aspects related to saturated and unsaturated stability analysis. It also presents a case study of an old municipal landfill of Romania, which has been closed and during the installation of the cover system a landslide has been formed and observed. The geotechnical and hydrogeological investigations showed that the instability is linked to the presence of a leachate body within the waste, due to the fact the waste was blocking the natural flow channels of the site. A consolidation solution was proposed, comprising vertical and horizontal drainage network and a mechanical consolidation work. Numerical modeling has been performed in order to assess the effect of the drainage on the leachate level and on the stability of the landfill. The stability analysis was performed in the initial saturated state and also taking into consideration the unsaturated area appearing at the waste surface after drainage. For this second situation the analysis that has been performed using numerical modeling is not an usual one, as the unsaturated state is rarely taken into consideration. However, in situations where major water drawdown is foreseen such an analysis can provide more realistic results.

The paper presents in detail the numerical modeling aspects, analyzes the results and discusses about the proposed consolidation solution. Also a comparison with conventional stability analysis results is presented.

2. Instability phenomena in municipal waste landfills

2.1. Generalities

Landfills comprise many types of slopes: natural ones, belonging to the initial site and man-made ones, as those for dikes, landfilling cells, closing system or even those within waste during the operational phase.

Prior to regulatory requirements for lining waste, landfills stability was considered as an operation problem of minor concern, the slipped waste being simply repositioned [1]. Once various types of lining, drainage or protection systems have been introduced, they could have been damaged by the waste movements and therefore more attention was paid for the stability issues.

2.2. Specific of stability analyses for landfills

For old landfills, as the one analyzed in this paper, one of the main problems is related to lack of drainage, therefore the leachate level is usually high. As most of old landfills were savage dumps, most of the times they are developed in dried or variable-flow valleys, thus involving slopes. The waste is not compacted or the compaction is very poor, therefore the waste is found in loose state, with very low mechanical characteristics.

The physical and mechanical characteristics of waste are not known, being very heterogeneous and difficult to predict, this being also a specific aspect of landfill stability analyses.

2.3. General consideration about stability analyses

There are several possibilities for performing a slope analysis, among which:

- limit equilibrium methods (LEM); in the last years, following the evolutions in the unsaturated soil mechanics, were introduced specific constitutive laws for unsaturated soils;
- numerical methods using displacement-based finite element method (FEM), using various constitutive models, enabling to calculate the progressive failure and safety using "phi-c reduction" or "shear stress reduction" techniques.

The finite element method is a precise numerical analysis method which satisfies the force equilibrium, compatibility condition, constitutive equation and boundary condition at each point of a slope. It simulates the actual