Construction Challenges in Landfilled Areas

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Abstract: ***The main aim of this article is to share awareness about some of the challenges faced by contractors during construction of buildings above landfills and to present a brief case study of an Electric substation project built above Landfill.***

Keywords: landfill, substation, structural, environmental, sustainable, challenges, differential settlement, bearing capacity, leachate, risk mitigation, electric, pile, debris

1. Introduction

Sustainable development is one of the most important aims of today's society and waste represents one of the hurdles that needs to be countered. From a sustainable building standpoint, former landfills are ideal sites for new development because they recycle land that has already been used. There is an increasing demand for developable space in Urban areas, hence it is anticipated that construction development on top of and adjacent to old landfills will become more common in the next decade. Development of old landfills includes both hard and soft uses. Hard uses include building, roadway and infrastructure development and Soft uses include golf courses, parks etc

Landfill Composition Types:

Table 1

Inert waste	Municipal solid waste (MSW)	Hazardous waste
Includes construction waste, demolition debris, some types of contaminated soil, whole and shredded tires and asbestos etc.	Comprises of household and commercial refuse. It includes paper, cardboard, glass, metal, plastics, textiles, green waste, food waste, whole and shredded tires and other putrescible organic waste. MSW is the most common type of waste and MSW landfills are the most common type of landfills.	Includes some types of contaminated soil, chemical process waste, refinery waste and other by - products of commercial /industrial processes. Hazardous waste landfills are perhaps the least common type of landfill subject to redevelopment because of environmental, health and safety concerns.

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Behavior of waste is complex and difficult to characterize which makes construction on old landfills a more challenging task. Furthermore, many old landfills do not have engineered containment systems and appropriate closure measures may not have been implemented. In addition, little is known about their content. Construction on closed landfill sites therefore requires careful planning and design to account for the characteristics of the waste as well as health and safety issues.

Table 2: Two Types of Construction Challenges Faced by Contractors in Land Filled Areas

S. No.	Structural Challenges	Environmental Challenges
1	Geotechnical properties of Landfill sites	Risk of soil & water contamination by leachate
2	Shear Strength of land fill soil	Landfill gas migration
3	Assessing the bearing capacity of landfills	Risk of fire & explosion
4	Inherent Instability of the ground	Air Quality andhealth risks
5	Differential settlement	
6	Foundation Design	

2. Structural Challenges

Geotechnical properties of Landfill sites - Quantification of Geotechnical properties of landfill can be very difficult as such materials are very heterogeneous, which may also include a large proportion of degradable components that change their properties with time. Similarly, the soil mechanics methods of analysis developed for traditional soils may not be wholly applicable to very heterogeneous and degradable materials, which undergo large deformations before failure. The parameters required for geotechnical design vary with the waste type, composition, depth, method of compaction and the rate of decomposition amongst others. The rate of compression is further influenced by several factors including the effects of time, temperature and other environmental conditions. In addition, the geotechnical properties of the refuse changes with time. It is difficult to derive reasonable geotechnical parameters from variable refuse fill materials.

Shear Strength of land fill soil - There are concerns that the Mohr - Coulomb theory may not adequately account for refuse materials which undergo large deformations without failure. Secondly, the incompatibility of strains that produce shear failure in soil and those that would produce shear failure in refuse suggests that stability analysisof a refuse fill may be related more to its settlement and foundation bearing capacity than to its slope failure.

Assessment of Bearing capacity of landfills- Thickness and the strength of the soil cover system play a very important role in foundation support. If the soil cover is relatively thick, then it may provide substantial bearing capacity for shallow foundations. However, the soil cover may often be thin compared to the foundation size. In this case, the load for the foundation will be transferred through the cover and will develop its bearing resistance in the waste. Therefore, a bearing capacity analysis will require evaluation of the strength of the waste.

Inherent Instability of the ground - is a major problem in these areas. As waste decomposes, the ground can settle. Stability can be compromised by differential settlement in the waste and the underlying soils. If the project atop the landfill is a golf course, that's not a big problem. This can be controlled by engineered improvement of the characteristics of the waste fill and the underlying soils

Differential settlement - The major engineering limitations associated with redevelopment of closed landfills are the potential for large total and differential settlement which can result in structural damage to buildings on the landfill and damage to the landfill cap and low bearing capacity, which either limits post closure development to light weight low rise structures or requires the use of deep foundations. Due to the large settlement potential, landfill redevelopment using shallow foundations is generally restricted to low - rise structures of one or two stories with raft foundations. Construction of taller structures using pile foundations is generally restricted to landfills without an engineered bottom liner system.

Foundation Design- for buildings on reclaimed landfills requires special consideration. It is a challenging task since it requires considering unusual aspects related to the mechanics of wastes. Suitable foundation design requires an evaluation of the total and differential settlement, the effect of the foundation on air and water quality due to possible puncturing through the liner system and impact of the landfill environment on foundations.

Table 3below summarizes the relative advantages and disadvantages of deep and shallow foundations on landfills. A detailed overview on foundations in landfills is given by Phillips et al. (1993), Dunn (1995) and Bouazza and Seidel (1999).

Table 3

	DEEP FOUNDATIONS	SHALLOW FOUNDATIONS
Bearing Capacity	Excellent	Limited to very lightly loaded structures
Relative Settlement	Poor	Good
Differential Settlement	Excellent	Acceptable
Maintenance	High	Low
Foundation Type	Pile foundations for larger buildings constructed on closed MSW	Spread footings, reinforced concrete mats, and grid foundations
Design consideration	Pile foundations requires an analysis of the vertical and lateral pile capacity, down drag loads, the impact of the construction on the landfill environment including the likelihood of punching through the landfill liner and corrosion resistance of the pile	Additional reinforcement is used in these shallow foundations to be able to tolerate the stresses developed due to differential settlement. In most cases, an engineered fill is provided which provides the required bearing capacity.

3. Environmental Challenges

Risk of soil & water contamination by leachate - As the waste sinks and settles over time not only do depressions develop on the surface of the site, but leachate (fluid that trickles out of a landfill) passes through the waste carrying contaminants thus polluting ground water and the surrounding soil.

Landfill gas migration represents a major concern for the redevelopment of MSW landfills as the gas or vapors from the decomposing material works its way into surrounding soil and then up and out of the ground into the atmosphere. If there are no structures on top of the site, the gas releases into the air. If it's trapped by a building's foundation, the result can be a dangerous accumulation of gas.

Risk of fire and explosion associated with methane with health risks associated with some of the non - methanogenic organic constituents.

To mitigate the risk - Methods of controlling gas in modern landfills include the creation of physical and pneumatic barriers, passive venting systems and active gas collection/ treatment systems, both within the waste and under structures.

Approval time frame - Perhaps the biggest obstacle to such a project, is the extended timeframe it takes to obtain statutory approvals and NOC's from concerned authorities. The clients, however, who have their sights set on landfills for re - development go ahead with complex projects like these

4. Case Study

Electrical Substation and associated Cable works built above Municipal Solid Waste (MSW).

Table 4: Summary of the Electrical Substation and Cable Project

Project	Site Area	Type of Landfill	Type of Foundation
Electrical Substation Project	36, 821 m2	MSW	Pile
Cable Shifting Works		MSW	Engineered Fill

Overview of substation and cable project
The Project is an Electrical substation. Based on the Geotechnical investigation uncontrolled fill material comprising of tires, plastic, wooden and organic pieces were encountered from 6 - 9m below the existing ground level. Pile foundation was recommended for all buildings including boundary walls. Settlement calculation for the pile was estimated to be.5% of the pile diameter. For the cable project, risk assessment and risk mitigation study was carried out by the Employer to evaluate the impact of the debris on the underground cables. Risk of heat impact on the cables due to chemical reaction within debris layers, risk of fire & explosion due to methane gas emission, settlement due to soil liquefaction, seismic effect, heavy wind and rain impact on backfilling/cover and impact of increased ambient temperature on the debris material were studied and accordingly risk mitigation was prepared.

5. Conclusion

Developing landfill for building constructions not only requires substantial ground improvement schemes including settlement remedial measures but also ground water and landfill gas remediation measures. The geotechnical parameters required for the analysis of the landfill site can be derived from a combination of traditional and non - standard testing methods together with those determined from back analysis and observational methods of similar sites. The parameters derived can thus be used in approximate numerical relationship, both traditional soil mechanics and theoretically derived methods of analysis for assessing settlement and carrying out foundation design.