Vertical Expansion of Landfill by Creating High Free Standing Containment Wall to Increase Landfill Life Span with Coordinated Leachate and Storm Water Management System

Saravanan Mariappan[1]

[1]Nexus EC Sdn Bhd, Kuala Lumpur, Malaysia, e-mail: vanan.nexus@gmail.com

ABSTRACT: Obtaining land for landfill construction works always been a major challenge for the local and federal authorities to provide. It is tedious to obtain land to dispose waste or to build sanitary landfill by complying all the regulation in any country in the world. For the presents of landfill, the location required to be far from residential settlement, water catchment site, do not cause social disorder and etc. Hence, obtaining land for landfills are major challenge for all authorities. In many cases landfills in Malaysia are reaching the design life span which requires the authorities to perform safe closure. If safe closure were to be performed, new landfilling site required to be ready in time. Due to lack of space or availability of new sanitary landfills, the existing landfill life spans are extended further. To solve these problems, the current land space and land use can be revisited and reviewed carefully for the possibility of landfill vertical expansion program. Planning for re-engineering of existing landfill required to consider the upcoming future waste and the current incoming waste volume. The new vertical expansion landfill can be constructed with pockets of sanitary cells which will be lined together with adequate leachate collection system. Furthermore, for the economical scale of performing the vertical landfill expansion construction works, the new air space created could extend the life span for not less than 10 to 15 years more depending on site boundary conditions and constraints. Therefore, in order to create the air space required, high flexible free standing retaining walls are required to be constructed at perimeter of the existing landfill site boundary. This paper addresses technical challenges, design aspects and construction considerations for the vertical expansion of existing landfills. This paper also discuss the aspect of leachate and storm water management system adaptation for the vertical landfill expansion works. And all the key aspects required to consider to prevent the discharge of leachate to the environment. The paper will also address, measures which can be incorporated to upgrade the current leachate collection and storm water management system of existing landfill before the vertical expansion works can be implemented.

Keywords: Land, landfill air space, landfill vertical expansion, leachate and storm water management

1.0 Introduction

Obtaining land for landfilling works are lengthy and tedious process, which requires approval from both the authorities and the public. In many cases the public do not require or approve any landfilling activities near or next to their residential area. Due to the syndrome of "Not at My Back Yard". With current modern technology of waste management, landfilling works can be environmentally contained and friendly. However, due to "Not at My Back Yard" syndrome it is very difficult to obtain suitable and practical land for landfilling works. Hence, the option of vertical expansion of landfill could contribute in extending the existing landfill life span and also

a) Provide optimal use of current landfill area
b) Create higher air space for waste filling per unit area
c) Low construction cost as compare to developing new landfill.
d) Less public outcry
e) Practical to obtain new development order for vertical expansion.

Vertical expansion of landfill can be performed by vertical and/or lateral expansion in which the old landfill is encapsulated by new placement of waste as:

a) Vertical and lateral expansion of landfill as shown in Figure 1.0.

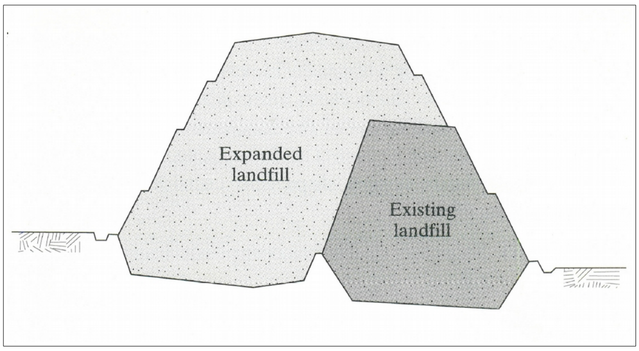

Figure 1.0: Cross Section of a Vertical and Lateral Expansion Landfill - (Qian, 2002)

b) Piggyback of vertical expansion of landfill as shown in Figure 2.0.

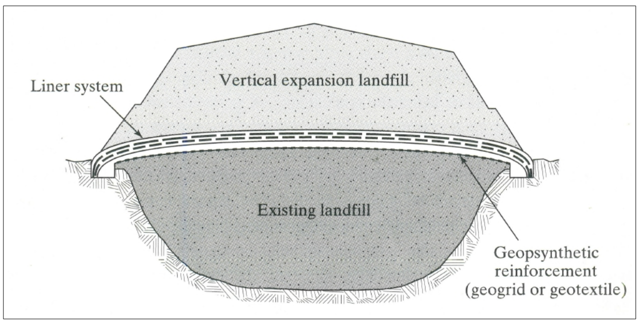

Figure 1.0: Cross Section of a Piggyback Vertical Expansion Landfill - (Qian, 2002)

2. Design Consideration

Expending the existing landfill which in many cases have reached the maximum permissible height, expending the height further could cause;

- could cause additional settlement which could cause damages to existing liner, with potential slope instability
- instability of vertical expansion slope is the most important factor to take into consideration, any slope failure in landfill could cause the environment to be damaged.
- potential malfunction of existing landfill, leachate collection and storm water management system
- possible interruption of existing landfill gas extraction and release mechanism.

Thus the long term performance of the system need to be taken into consideration. The settlement required to be control to ensure

- The tensile strain within the liner remains or do not exceed the tensile of the material (soil or geosynthetics). If the tensile strain exceeds, tension cracks will develop, reducing the effectiveness of the liner as a hydraulic barrier.
- The capacity of buried pipes for leachate collection and gas extraction do not exceeds the permissible wall compression and deflection limits.
- Also required to ensure the excessive settlement do not cause reversal flow of leachate in leachate collection pipe network, which could cause dangerous level of leachate ponding and cripple the leachate collection system and cause potential slope failure.

Other major design consideration for vertical landfill expansion includes (Qian, 1996)

- Selecting a suitable composite liner system for placement over the existing landfill.
- Estimating the overall total settlement and differential settlement of the existing landfill caused by new waste fill.
- Estimating the differential settlement due to the degradation of large objects in the old landfill, or reinforcing using the liner system to minimize the differential settlement.
- Calculating subgrade elevation changes beneath the existing landfill cause by differential settlement due to both existing and extra waste filling.

3. Factors to Consider for Vertical Expansion Liner Selection.

The waste composition and history of placement activities are the key factors required to be considered for vertical expansion liner selection. Example, vertical expansion liner for construction waste deposit will be different as compared to municipal solid waste, garden waste or hazardous waste. Secondly, it is also required to estimate the rate of waste placement activities in the vertical expansion air space, as rate of waste placement has direct relationship to rate of settlement and differential settlement of existing or old waste, influencing the stress and strains of vertical expansion liners installed.

(Qian, 2002) The settlement induce tensile strains and stresses can be have adverse affect to the integrity of liner components;
Example if compacted clay liner is proposed, it possesses very little tensile strength (allowable tensile strain is less than 1.0 percent) and is susceptible to cracking as a result of differential settlement which could seriously compromised in vertical expansion landfill. Hence, compacted clay liners are generally not recommended for vertical or lateral expansions. Geosynthetic clay liner (GCL) can be used as an alternative to a compacted clay liner. Geosynthetic clay liner are considerably more effective as impervious barriers. They can withstand relatively high in-plane tensile strains and stresses induced by differential settlement. The allowable tensile strain of geosynthetic clay liners range from 6 to 20 percent, contrasted to less than 1 percent for a compacted clay liner.

As for geomembrane components of a composite liner system placed over an existing landfill, several different geomembranes can be selected. These include linear low density polyethylene (LLDPE), flexible polypropylene (fPP), and polyvinyl chloride (PVC) geomembranes. It should be noted that high density polyethylene (HDPE) can also be considered if the tensile strain is mobilized slowly. The reason HDPE is often not used in these situations is that the test method used to stimulate differential subsidence (ASTM D 5617) applies load very fast in comparison to actual conditions in a landfill. The default pressure rate is 1.0lb/in^2/min; thus, stress relaxation does not occur and the HDPE fails at relatively low strains of approximately 25%. The other geomembranes cited fail at strains from 75% to 100%. A textured geomembrane should generally be selected to provide a relatively greater interface strength between geomembrane and geosynthetic clay liner or geosynthetic composite drainage layer. Because of the magnitude of the settlements that the liner system will experience and the possibility of “local” liner deformation due to localized subsidence effects, it is important to select a geomembrane with superior extension properties. For a number of reasons (differential settlement, substandard liner under existing waste, etc.) a double liner system is desirable under a vertical expansion.

Cross sections of typical double-composite liner systems used in vertical expansion of landfills are shown in Figure 3.0 and Figure 4.0.

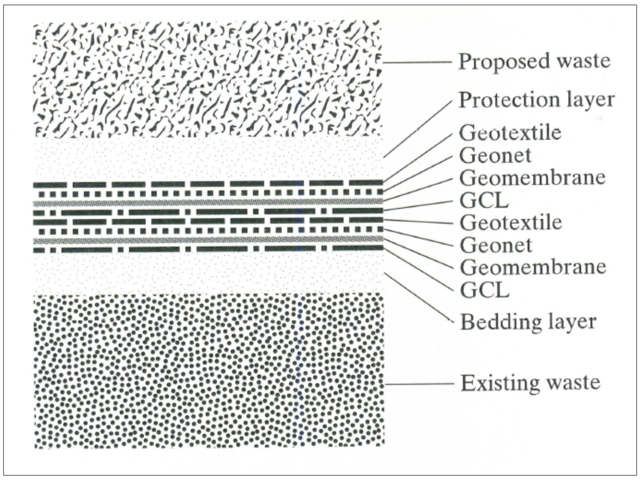

Figure 3.0: Double Composite Liner System over Existing Waste (Qian, 2002)

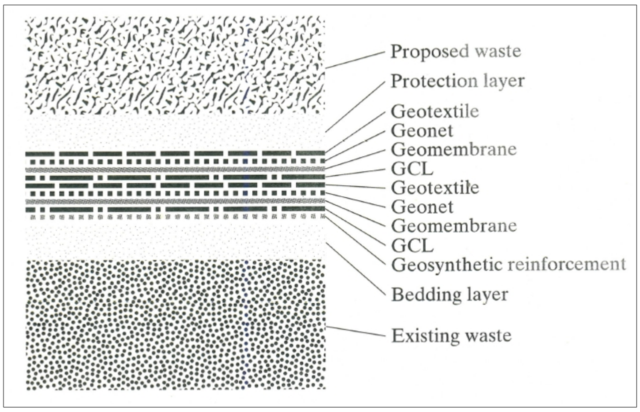

Figure 4.0: Double Composite Liner System Reinforced with Geosynthetic Reinforcement over Existing Waste (Qian, 2002)

The geosynthetic reinforcement can prevent excessive tensile strain in the liner system over the existing landfill.

4. Design Consideration of Vertical Expansion of Landfill

Various structures involved in landfill cell which could be affected by vertical expansion works, which includes

(i) Existing and new liner systems
(ii) Existing and new leachate collection and detention systems
(iii) Existing gas collection system
(iv) Existing waste mass
(v) Foundation of existing waste mass
(vi) Existing and new final cover systems
(vii) Underdrain system.

Table 1: Structural Consideration for Vertical Expansions (Qian, 2002)

Structure	Design Considerations
Liner [geomembrane, compacted clay liner (NR), and geosynthetic clay liner]	• Tensile strain of new liners over the existing waste • Stability of new liner system over the existing waste • Slope changes of the existing liner system
Pipe (leachate, riser, gas, and underdrain pipes)	• Strength and stability (bucking, crushing and deflection) • Slope changes
Geosynthetic Drainage Layer (geocomposite and geonet used in the existing leachate collection and detection system and underdrain system)	• Drainage capacity of geonet and geocomposite will be reduced due to extra waste fill.
Vertical Structures in the Existing Landfill (manholes, riser pipes and gas extraction pipes)	• Negative skin friction force due to waste settlement • Bearing capacity and stability of the vertical manhole and riser pipe foundations due to negative skin friction force and extra waste fill
Final Cover [geomembrane, compacted clay liner (NR), and geosynthetic clay liner]	• Tensile strain for the elements of the existing landfill cover caused by the extra settlement of the existing waste due to the extra waste fill. • Stability of new final cover
Landfill Subgrade	• Subgrade changes of the existing landfill caused by foundation soil settlement due to extra waste fill • Subgrade changes of the new landfill cause by the settlement of the existing waste.
Landfill and Foundation Stability	• Stability of the existing waste during the new waste filling • Stability of the soil foundation due to extra loading • Stability of combination of the existing and new landfills in various conditions.

NR = not recommended for liner systems of vertical expansions

As for the liner systems placed over the existing landfill, the tensile stress on the liner can be reduced by placing high strength reinforcement in the form of composite geogrids or composite high strength geotextile (composite with non woven geotextile).

The design approach of the high strength reinforcement would require to consider possible void formation or collapse of large objects within the old landfill mass. The reinforcement required to bridge across the void, supporting the overlying waste load and protect or limit the stress and strain imposed on the liner, as shown in the Figure 5.0, the reinforcement required to be design with long term design of 120 years.

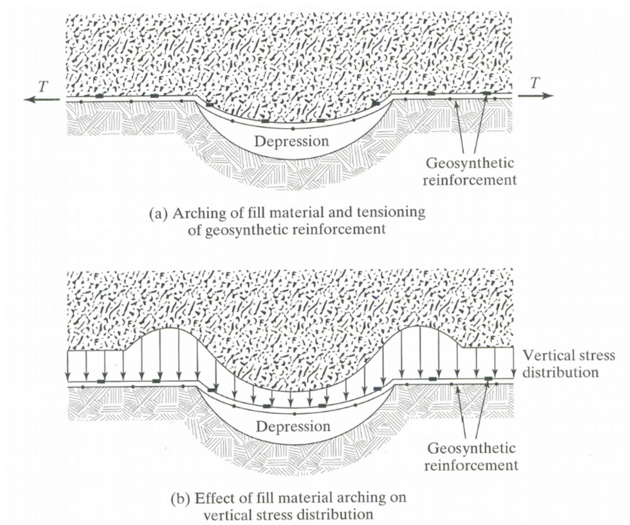

Figure 5.0: Load Carrying Mechanism (after TENSAR, 1989)

5. Maximizing the Air Space of Vertical Expansion

By considering all the above, the cost benefit of vertical expansion of landfill requires minimum 1.5 to 2.0 times airspace used by old landfill. Meaning the vertical expansion landfill life span should be 1.5 to 2 times the life span of the old landfill, not taking into consideration of increase in waste intake in the future. Hence in order to create such large volume of air space, it is required to build high retaining wall. Building retaining wall at landfill site requires to met various stringent criteria such as;

- Wall able to withstand the corrosive effect of leachate under long term conditions
- Wall required to be able to contain the leachate effectively
- The wall required to be very high exceeding 6m
- The wall required to be able to stand independently (free standing wall, refer Figure 6.0). Conventional walls are not free standing, it required to be leaning or backfilled to provide retaining support, refer Figure 7.0.
- The wall also required to be flexible and able to undertake various type of stress, deformation and unpredicted accidental loads.
- The wall required to tolerate the anticipated large settlement and do not crack and release the contained leachate.
- The construction of wall required to be cost effective by utilization of insitu on readily available material on site, such as earth, crush construction waste, rock and etc.
- Wall also required to have natural grass cover and green finish and environmental friendly.

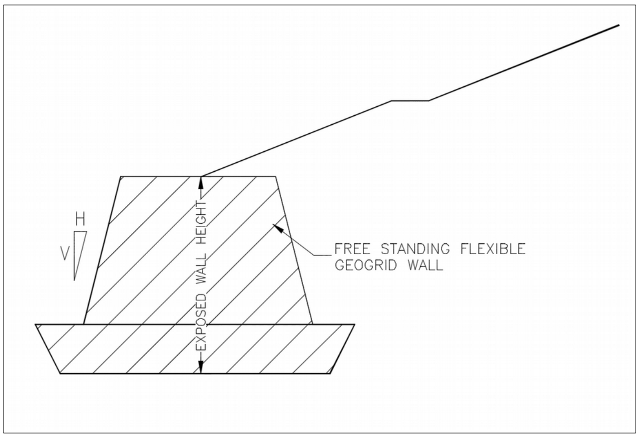

Figure 6.0: Free Standing Wall Flexible Geogrid Wall

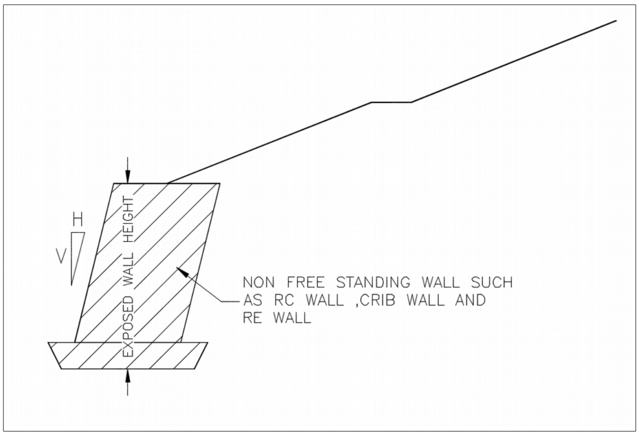

Figure 7.0: Non Free Standing Wall, such as RC Wall, Crib Wall, RE Wall and Geogrid Wall

With the above stringent requirements, the use of high strength geogrids or geotextile made of Polyester (PET) will be suitable to be used for the wall construction. The typical details of free standing wall is shown in Figure 8.0. (24m high wall); Also shown in Figure 9.0, typical cross section of air spaced created with the adaptation of high free standing wall.

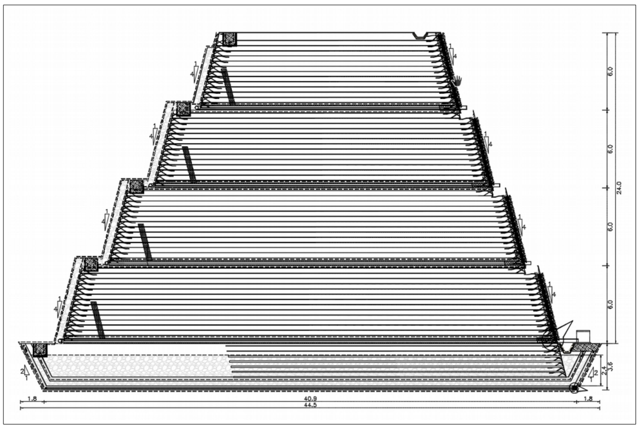

Figure 8.0: 24m High Free Standing Wall

Figure 9.0: Air Space Creation with the Adaptation of High Free Standing Wall

6. Leachate Collection and Distribution Network

The leachate required to be contained within the site by installing leachate interceptor subsoil drains. The leachate interceptor subsoil drains would required to be installed minimum of 600mm to 1000mm below constant or permanent ground water level by considering the fluctuation of water level. The location of these leachate interceptor subsoil drains shall be at external perimeter of the wall as shown in Figure 10.0.

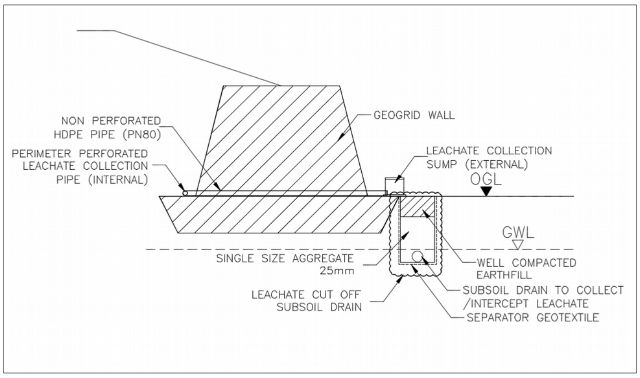

Figure 10.0: Leachate Interceptor Subsoil Drains

Leachate collection pipes are also required to be installed at internal section of the wall. The internally collected leachate would be channeled to external leachate collection sump and distribution network. The new vertical expansion works of the existing landfill would generate additional leachate, which would require upgrading works of existing leachate treatment plant. Hence space required to be provide to add extra leachate holding and aeration pond and also space for leachate treatment upgrading works.

7. Storm Water Management

Separation of rain water exposed to waste and rain water not exposed to waste is extremely important. Hence the existing landfill recommended to contained with perimeter containment bund, to prevent leachate runoff from the landfill cell. Once the perimeter bunds are established, external storm water monsoon drain required to be installed. In addition to that, the closure plan required to be systematically design to ensure all surface runoff are well intercepted and channeled to the external storm water monsoon drain. In order to compile to MASMA guidelines, suitable size storm water detention or rain water harvesting pond required to be provided. The recommended detention period is about 1 hour of heavy rainfall with return period of 100 years. The typical layout plan of perimeter bund and storm water detention pond are shown in Figure 11.0.

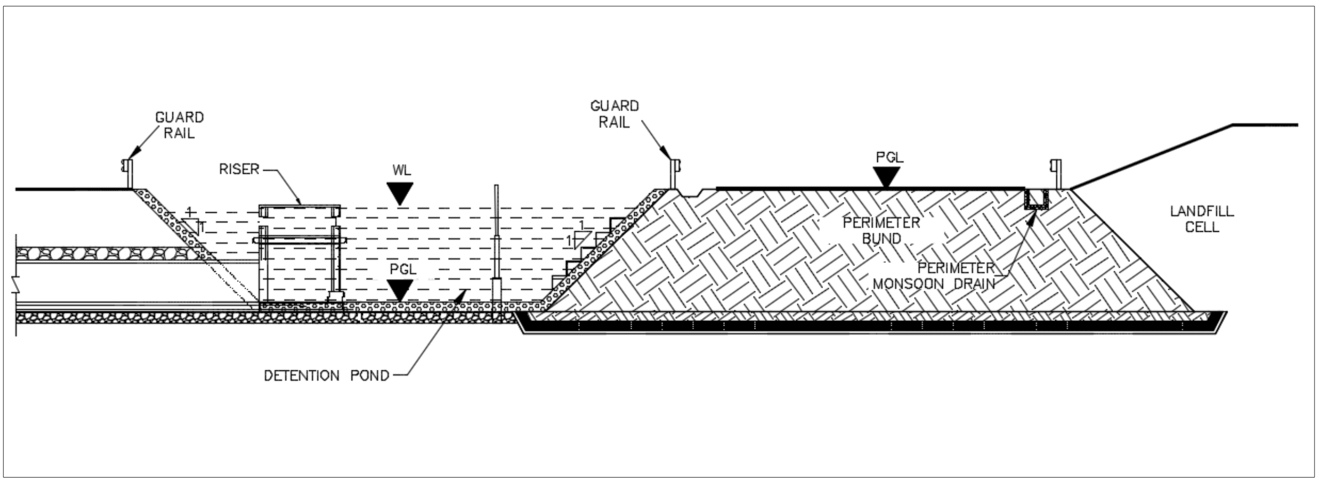

Figure 11.0: Typical Details of Perimeter Bund and Detention Pond.

Conclusion

With the adoption of high flexible free standing wall for landfill vertical expansion works, it is possible to obtaining

- Large air space to extend the life span of landfill
- Able to provide or construct stable landfill slope, (gentle final slope cover on top of the geogrid wall).
- The flexible wall can also be constructed on poor ground condition without the need for heavy foundation system.
- Able to manage the leachate collection and storm water management system effectively
- Extremely cost effective solution as compare to the development of new landfills
- The concept also can be used for development of new landfill
- The concept also can be used for development of new landfill to obtain higher air space within a small footprint.
- Construction can be performed with locally available material.

However landfill engineering related to environment and geotechnical required to be synergized to derive the workable solution, to prevent any unwarranted failures. With quality site investigation and well interpreted results the implementation of vertical expansion is possible, and practical should be implemented.

Reference

Qian, X., M. Koerner, R., & H. Gray, D. (2002). Vertical Landfill Expansion. In *Geotechnical Aspects of Landfill Design and Construction* (1st ed., Vol. 1, p. 717). Upper Saddle River, New Jersey: Prentice Hall.

Qian, Xuede, (1996). Design of Vertical Landfill Expansion. Michigan Department of Environmental Quality, Waste Management Division, Lansing, MI September.

TENSAR, (1989). “Design of Tensar Geogrid Reinforcement to Support Landfill Lining Cover System,” *Structural Synthetic Geogrid for Waste Facility Applications.* TTN:WM3, Tensar Environmental Systems, Inc., Morrow, GA