International Journal of Research in Advanced Engineering and Technology
Online ISSN: 2455-0876
www.engineersjournals.com
Volume 1; Issue 1; October 2015; Page No. 86-89

A study on the desiccation cracks and their significance

[1] Manoj Kumar, [2] Dr. DK Soni

[1] Research Scholar of Nims University

[2] Professor and head civil Engg. Deptt, NIT Kurukshetra, Haryana, India.

Abstract
Industrialization brought forth with it the associated problems. The industrial activities generated large quantities of wastes. Part of these wastes in different physical forms such as solids liquids and gases turn as pollutants in due course. Based on the safety level, these wastes can be hazardous or non-hazardous. Wastes can be controlled by different options such as waste reduction at source, resource recovery through separation and recycling, resources recovery through waste processing, waste transformation and environmentally sustainable disposal on land. Despite all efforts, to minimize waste, and to neutralize it, the requirement for storage or disposal still exists.

Keywords: desiccation cracks, significance, Wastes

Introduction

The most frequently used disposal option for solid waste in the land fill because of its low cost and efficiency. The landfill plays a vital role in the whole waste treatment/disposal process. The basic philosophy of all engineered landfill should revolve around environmental protection through containment and controlled release, physical compatibility of the final landform to the surroundings, longevity for the design period, appropriateness to the type of waste and cost effectiveness. The main components of an engineered landfill are a liner system at the base and sides of the landfill which prevent migration of leachate or gas to the surrounding soil, a leachate collection facility which collects and extracts the leachate from within and from the base of land fill and then treats the leachate, a gas control facility which collects and extracts gas from within and from the top of the landfill, a final cover system which enhances surface drainage intercepts infiltrating water and supports surface vegetation.

The final cover system can comprise of multiple layers of soils. Environmental protection Agency (EPA) has laid down norms for the selection of suitable standard liner materials. With regard to the long term satisfactory performance of landfills, the liners covers play a very vital role. The most common land fill liner materials are clayey soils of low permeability, since they satisfy the EPA standards. Clayey soils pose numerous problems to geotechnical engineers because of their high compressibility and poor shear strength. The high compressibility of clays which leads to large scale volume changes is always a cause of concern to the field engineer. However there are occasions when clayey soils can be utilized such as control of permeability in clay liners, stabilization of bore holes etc.

Here the geotechnical engineer is posed with the problem of suppressing the negative aspects of the clayey soils to the minimum while utilizing the positive aspects to the maximum. Volume changes in clayey soils occur in many ways. One is due to the expulsion of pore water from the voids upon static surcharge. This behaviour, termed as consolidation is a well-known and well defined phenomenon. The other volume change is due to the shrinking of clay soils during drying.

Desiccation is the continuous process of pore water loss from a soil exposed to a warm environment. In response to drying, soil water volume decreases and in consequence the soil shrinks. If shrinkage is restrained, soils can crack during desiccation as and when the tensile stresses that develop within the soil exceed the tensile strength of soil. The desiccation cracking of a clay mass can have a significant impact on the performance of clayey soils in various geotechnical, agricultural and environmental applications. Cracks affect the compressibility of the soil, its time rate of consolidation, its strength and the rate at which water can re-enter. Thus, several geotechnical constructions are affected directly or indirectly by the presence of cracks in a soil mass. Many earth structures are constructed of clayey soils which have a tendency to shrink and swell when subjected to cycles of drying and wetting.

During dry periods, clay near the surface of the slope shrinks, resulting in desiccation cracks. Deep cracks expose the interior of the soil mass, thus allowing further cracking to occur. When subsequent wetting of the slope occurs during rainfall, the extensive network of cracks and fissures created during shrinkage, permits rapid percolation of rain water into the soil mass. As the cracks fill with water, the exposed clay surface along the crack swells, the clay softens resulting in loss of strength along the cracks and fissures. Over a period of time, the seasonal shrinking and swelling may result in further propagation of the cracks and ultimate failure of the slope.

Review of Related Literature

Kim (2002) [1] explained the effects of freezing on hydraulic conductivity of compacted clay as the effectiveness of system is controlled by the hydraulic conductivity of the compacted clay. The hydraulic conductivity of specimens compacted dry of optimum increased approximately two to six times their original values. The hydraulic conductivity of specimens compacted wet of optimum increased about two orders of magnitude. He also explained that the freeze-thaw would likely damage compacted clay and increase its hydraulic conductivity.

According to Shelly (2003) [2], Shakoor and Cook (2000) [3], for gravel contents less than 60%, it has the beneficial effects of slightly lowering the hydraulic conductivity of the kaolinite and simultaneous broadening of the range of molding water content by which minimal hydraulic conductivity was achieved. The objective of compaction is to remould clods of the soil into a homogeneous mass that is free of large continuous inter-clod voids. The water content of the soil, method of compaction and compactive effort has major influence on the hydraulic conductivity of compacted soil liners. Soil liners have traditionally been compacted in the field to a minimum dry weight over a specified range in water content. With soil liners, hydraulic conductivity is usually paramount importance.

Daniel & Benson (2000) [4] presented data to show that the water content – dry density criterion for compacted soil liners can be formulated in a manner that is different from the currently used approach in which the adequate strength and permissible compressibility is ensured. The approach recommended by them is based on defining water content – dry density requirements for a broad, but representative, range of compactive energy and relating those requirements to hydraulic conductivity.

Clay is the most important component of soil liners because the clay fraction of the soil ensures low hydraulic conductivity. According to EPA (2009), the soil liners be built so that the hydraulic conductivity is equal to less than $1x10^{-7}$ cm/sec. To meet this requirement certain characteristics of soil material should be met.

First, the soil should have at least 20% fines. Secondly, the plasticity index should be greater than 10%. Soils with very high plasticity index, greater than 30 to 40% are sticky and are difficult to work with. Also high plasticity index soils form hard lumps when the soils are dry and difficult to breakdown during compaction.

Thirdly, the coarse fragments should be screened to not more than about 10% gravel size particles. Soils with a greater percentage of coarser fractions can contain zones of gravel, which will have high hydraulic conductivity. Finally, the material should not contain soil particles or chunks of rock larger than 1 to 2 inches in diameter, which may form a permeable window through a layer.

According to Daniel (2003) [5], for any material to be used as a liner, it should have the following properties:

(i) The fluid transmission capability of a soil is defined as the permeability of the soil. Permeability, which is also a measure of the materials ability to contain the leachate. A low permeability generally 10^{-89} m/sec. is required.
(ii) Durability and resistance to weathering is the quality of the material to withstand the forces of alternating wet/dry and freeze/thaw cycle.
(iii) Constructability, which means the material, should be reasonably workable in terms of placement and compaction under field conditions.
(iv) Compatibility with leachate: the liner material must maintain its strength and low permeability even after prolonged contact with leachate.

According to Kays (2006) [6], the clay material used as a liner may be the native clay soil or a bentonite – sand mixture. Bentonite slurry is often used as a sealant. Edil and Muhanna (2002) [7] observed that the ability of a bentonite slurry to rapidly form a filter cake of low permeability on a porous formation is not only important for general stability, but also for sealing qualities.

The use of bentonite alone or amended with natural soils for construction of liners for water – retention and waste containment facilities is common. The importance of bentonite content in reducing hydraulic conductivity of liners is well recognized.

Sivapullaiah. (2000) illustrated the role of the size of the coarser fracton in controlling the hydraulic conductivity of the clay liner. It has been shown that at low bentonite contents the hydraulic conductivity of the liner varies depending on the size of the coarser fraction apart from clay content. At given clay content, the hydraulic conductivity increases with an increase in the size of the coarser fraction; the hydraulic conductivity is controlled primarily by clay content alone.

When montmorillonite clays are in contact with water or water vapour, the water molecules penetrate between the unit layer. This inter layer swelling is evident from an increase of the basal spacing of the clays to definite values of the order of 12-20A depending upon the type of cation. The amount of water held between the layers varies from one to four molecular layers depending on the type of cation and the vapour pressure (van Olphen, 2003).

When four layers of water molecules are adsorbed on the surfaces of dry clay, the volume of dry clay can almost get doubled. For the combination of sodium montmorillonite and fresh water, the fluid that enters the particles, forms a thick viscous diffuse double layer around the sheets, causing the montmorillonite particles to swell, possibly to the extent of complete separation of the sheets. For the combination of dry sodium bentonite and a saline solution, less fluid is required to neutralize the negatively charged sheets. If the ion concentration is large or the valences of the cations are large, the separation distance between sheets will remain small. The fabric of bentonite in this case will consist of swollen but intact montmorillonite particles, surrounded by thin viscous diffuse ionic layers (Fernandez and Quigley, 2008; Kenney et a., 2002).

Research Methodology

As per the standards prescribed by Environmental Protection Agency the material for compacted clay liners should necessarily satisfy the following norms for the co-efficient of permeability/hydraulic conductivity, plasticity index, minimum fines content, and maximum gravel content. Obviously, only clayey soils will satisfy the above conditions.

As per the current practice, bentonite enhanced by sand is the most popular liner material. The present study aims at investigating the properties of bentonite sand mixture vis-à-vis crack development and propagation along with ways and means to control them. A review of the literature indicated that marine clays can act as a substitute to bentonite sand mixture. Thus two soils were selected for the present investigations on clay liner.

The bentonite used in this study is commercially available, highly expansive clay. The percentage of water present in bentonite sand clay liner varies depending upon the climatic conditions, since bentonite, which belongs to the montmorillonite group, has great affinity for moisture. Hence, the bentonite, which was procured for the complete investigations, was thoroughly mixed for uniformity and then preserved in double layer of polythene bags.

Marine clay used in the study was collected from Mundamveli, in Cochin on the Western coast of India. The earlier investigation reports show that in almost all locations in Greater Cochin area, thick uniform layers of marine clays could be obtained after 3 to 9 meters.

Hence, bulk samples of the clay were collected by bore holes advanced by shell and auger method. Bore holes were taken to the clay layers for collection of samples. The boring operations were carried out as per the direction given in IS:1892-2009 (Code of practice for surface investigation for foundations). Care was taken not to include bentonite slurry during the boring operations as it might contaminate the soil samples. For uniformity among the samples collected from different bore holes, representative samples collected from same depth but different bore holes at various locations of the same site were pooled together and mixed thoroughly into a uniform mass and preserved in polythene bags. This is designated as the moist sample of Cochin marine clay.

However, this moist-marine clay does not satisfy the requirement with regard to plasticity index. Earlier researchers have shown that sundried marine clay will satisfy the EPA norms. Sun dried marine clay (SMC) specimens were prepared by spreading the representative samples of moist clay in large trays and exposing to sunlight and drying to constant weight. The lumps formed during drying were broken by a wooden mallet. The samples towards the end of drying were pulverized using a heavy hammer and passed through 425µ sieve without any loss of material. All the clay samples so prepared were kept in polythene bags.

Investigations were carried out to compare the behaviour of the montmorillonite group with kaolinite. The kaolinitic soil used in the present study was collected from Kalamassery, about 12 km from Cochin. The samples were collected by open excavation. They were dried, sieved through 425µ sieve and stored in polythene bags.

Even though, bentonite is impermeable as a liner material, the volume change is of a very high order. Earlier investigators have added sand in different proportions to bentonite to reduce the volume change, and have suggested that a combination of 80% sand to 20% bentonite satisfies the liner requirements. The sand used in the study was collected from the bank of river Periyar in Kerala. The sand was dried and sieved, the portion passing 425µ sieve and retained in 75µ sieve was collected and kept in air tight bins/plastic bags.

Physical experiments were performed in two phases. The former involved the behaviour of the two fine grained soil, when subjected to alternate wetting and drying techniques. Techniques were developed to measure the cracks developed due to desiccation with electronic methods. In the latter, attempts were made to control crack development and propagation using reinforcements in order to maintain the integrity of the compacted clay liner.

In the preparation of all specimens air dried soil was used as compaction is an important variable controlling the hydraulic properties of the soil liner materials. Soils compacted at water contents dry of optimum tend to have a relatively high hydraulic conductivity, whereas soils compacted at a water content wet of optimum tend to have a lower hydraulic conductivity. A typical construction specification requires that the soil, compacted over a specified range of water content, shall not to exceed the optimum water content by 4%, and a minimum dry unit weight of 95% of the maximum dry unit weight obtained from Standard Proctor compaction. In this study, the test specimens were compacted at their respective maximum dry density unless otherwise specified, and 3% above optimum moisture content (OMC)

During the life of landfill system, the clay cover liner will be exposed to numerous climatic cycles. These cycles include repetitious dry and wet seasons. During the wet season, a significant fraction of the run off that is generated on the land fill surface infiltrates through inter connected conduits to the topmost layer of the compacted clay. This causes the moisture in the clay liner to increase. During the dry season, the excessive moisture in the clay cover liner will be reduced and desiccation cracking may occur. The fluctuation in the degree of saturation of the clay cover liner during its life time was simulated in this study by alternate wet/dry cycles.

Most of the construction activities of liner inevitably are carried out during the dry season, as the onset of monsoons can disrupt construction activities. It is expected that after construction, some desiccation of the liners and covers will take place before the rains will gradually wet and eventually saturate the compacted soil. Hence the investigation of wet-dry cycling effects was carried out in the following sequence: drying of compacted soil, then wetting to saturation, followed by drying and so on. This sequence can be expected to simulate adequately the field conditions.

Several tests were conducted using soil samples to determine the duration of drying and wetting periods. The soil was compacted in the mould and kept for drying. The soil sample was weighed every 24 hours. It was found that the change in weight was insignificant after 5 days.

Mi (2005) has showed that the crack propagation ceased after approximately 120 hrs from the start of the drying process. Hence the first drying period starting from the end of compaction was kept as 5 days, the drying period after complete saturation of the sample was kept as 7 days, based on similar tests. In order to determine the duration of wetting period two soil samples were compacted, dried for 5 days and then water was ponded on top of the sample by placing the collar to the mould. Every two days, soil specimens were removed from the mould for the determination of the water content at the base of the mould. It was found that after 6 days of wetting, the soil was fully saturated and therefore a 7 day period was taken for the wetting period. The experiments were conducted for 3 wet / dry cycles for unamended soils and for amended soils it varied between 1-3 wet/dry cycles.

Conclusion

Cracks create zones of weakness in a soil mass and cause reductions in the overall strength and stability as well as increase in the compressibility of the soil. Structures that are constructed over fine grained soils such as foundations and embankments can be affected by mechanical changes caused by cracking. Cracks are also a possible precursor for inception of failure surface at the top of dams and embankments. Desiccation cracking is a common phenomenon in clayey soils and can change the hydraulic conductivity of soil. Drying fractures strongly affect permeability and may compromise such structures as clay buffers for nuclear waste isolation, barriers such as landfill liners, top covers, etc. Compacted clay liners are essential components of both municipal and hazardous waste land fills and their design has typically been based on the premise that little leakage will occur if the soil has a laboratory measured hydraulic conductivity of less than 1x10-9m/s. Hydraulic conductivity of clay liner material may increase from $1 x 10^{-9}$m/s for wet and intact soil, to $1 x 10^{-6}$m/s for the material after cracking. Desiccation of landfill clay liners is a major factor affecting the performance of landfills. Desiccation leads to the development of shrinkage cracks. Cracks provide pathways for moisture migration into the landfill cell which increases the generation of waste leachate and ultimately increases the potential for soil and ground water contamination.

References

1. Kim. Behaviour of granular soils reinforced with discrete randomly oriented inclusions, Geotextiles and Geomembranes. 2002; 10:319-333.
2. Shelly. Using fibers to reduce tension cracks and shrink/swell in a compacted clay. Geoenvironmental 2000, Geotechnical Special Publication. 2003; 46:791-805.
3. Shakoor and Cook. Geotechnical engineering and soil testing, Saunders College Publishing, New York, NY 2000.
4. Daniel & Benson. Permeability of microcracked fiber reinforced containment barriers, *Waste Management*, 2000; 15(2):171-177.
5. Daniel. Volumetric shrinkage strain measurements in expansive soils using digital imaging technology, Geotechnical Journal. 2003; 27(6):1-10.
6. Kays. Shear strength of kaolinite fibre soil mixtures, Proceedings of the first international conference on soil reinforcement, 2006; 1:11-16.
7. Edil and Muhanna. Fundamentals of digital image processing, Dorling Kindersley (India) Pvt. Ltd. 2002.