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A study on the techniques to improve desiccation cracks

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Abstract
A variety of research efforts have attempted to address the problem of desiccation cracking. Some have considered the use of surface moisture barrier above the clay liner, but case histories show that repeated cycles with seasonal temperature changes result in significant desiccation of the clay layer and associated cracking. Use of fibres to reduce the desiccation cracking in compacted clay has caught the attention of geotechnical engineers. An attempt is therefore made herein to study the development of cracks in clay liner materials and to control the desiccation cracks by use of randomly distributed discrete fibres. Since the 2000's, awareness of landfill problems and their solutions has increased to a point where waste disposal by landfill has become a technology in its own right (Kalteziotes *et al*, 2004).

Keywords: techniques, desiccation cracks, Wastes

Introduction

The disposal of waste-municipal, industrial, hazardous—in an acceptable manner has become a challenge. Waste disposal methods include deep well injection, incineration and landfills. The most frequently used disposal option for solid waste is the landfill because of its low cost and efficiency. The landfill plays a vital role in the whole waste treatment/disposal process. This is because most ashes produced by incineration and many sludges from water treatment plants end up in landfills. It is therefore, important to focus attention on landfills, which go a long way to reducing public health risk and protecting the environment. The most common landfill lining materials are clayey soils of low permeability although there is a rapidly growing use of man- made synthetic membrane lines (geo-membranes). Nearly all geo-membranes used in landfills are thin sheets of flexible thermoplastic or thermo-set polymeric materials.

In concrete liners, the aggregate is stone and sand, which is then mixed with cement to which water is added to make the final product. It can be reinforced with wire mesh or reinforcement bars depending on conditions of sub grade. Its strength is greater than that of shotcrete, but it suffers a drawback in that construction and expansion joints must be incorporated in the pour, both of which are subject to leaks. This might not be compatible with the leachate that will eventually develop in the landfill. The paving of side slopes with angles greater than 30° to the horizontal presents major construction problems when using concrete, and the materials high cost greatly limits its use.

Soil-Cement Liners are meant to duplicate the qualities of concrete as closely as possible but more cheaply by using on site materials and construction methods. The major problem in this type of liners is the final homogeneity of the material. Bituminous Concrete (asphalt) has been used often for landfill liners. The technology follows asphalt pavement procedures as used in highway engineering and construction but places greater emphasis on permeability considerations. In this type of liners, the major consideration is the chemical compatibility between the landfill contents and the bituminous material used in the liner of lesser concern, but still problematic are the accelerated aging of bituminous liners and the weed growth that can occur through them producing preferential seepage paths for leachate and other landfill contents.

Shrinking soils often crack then they dry.

Cracking occurs under different conditions and it cannot always be explained in the same way. Thus, the pastelike muds and sediments that are left behind after flooding or from puddles, crack on drying into a mosaic of polygons. Clods lying on the surface of the soil after tillage often breakdown into smaller fragments on drying. In hot dry regions, where drying can be rapid and intense, many clays do this naturally—the so called self-mulching soils. Peds are by definition units of soil separated from each other by surfaces of weakness which are actual or incipient cracks. Long meandering vertical cracks often appear across fields during particularly dry seasons. In some of the examples mentioned above, shrinkage sets up tensile forces that must exceed the tensile strength of the soil for cracking to occur. In other differential shrinkage, through for example non-uniform drying, sets up complex patterns of shear stress in which the shear stress must exceed the shear strength for cracking. In yet other examples, the cracks may be permanent features that simply open and close in response to drying and wetting, and do not involve strength at all. Cracking is an important component of the soil processes that are vital in various geotechnical, agricultural and environmental applications.

Review of Related Literature

The containment of hazardous wastes is certainly one of the most urgent problems faced by civil engineers. Among these materials, compacted clay liners have the longest history of successful applications (Kays, 2006) [1], although concretes, asphalts, soil, cement and more recently polymeric membranes have all been widely used. Of the different liner materials presently in use to contain hazardous wastes, the local availability of suitable clayey soils in many regions make use of the soil liner as an economically attractive design alternative. There are various types of liner materials available for the construction of impermeable barriers like compacted fine grained soils, admixtures, polymeric membranes, sealants etc. Easy availability and economic feasibility make clayey soils the most preferred liner materials. Natural clay deposits can provide an effective barrier in many situations and are used for disposal of municipal wastes and sometimes even for the hazardous wastes (Cherry, 2007 and Fetter, 2000) [2]. However, they may not be suitable for all the situations, i.e. they may not be having sufficient thickness to prevent migration of contaminants. Hence in such case, compacted clays can be used as liner materials. Compacted clays comprise of naturally occurring clayey soils, mixes of clayey soils or mixes of processed clay mineral with soils.

The compacted clay liners are usually 0.3 to 1.2m thick with coefficient of permeability less than 10^{-7} cm/sec. The clay material owing to their low permeability and economic viability are often used as impervious liner for waste impoundment sites. The clay liner prevents pollution of surrounding environment by

(i) Controlling the amount of seepage and thereby mitigating pollution by dilution
(ii) Delaying pollution by containment for certain prescribed period and
(iii) Causing a temporary or permanent decrease in the solute concentration by undergoing physico-chemical interaction with solute (Folkes, 2002).

According to Kays (2006) and Daniel (2003) [1, 3], even though, questions have been raised about clay waste interactions which may degrade clay soils and possibly increase their hydraulic conductivity, current EPA guidance allow single and double liners of compacted clays across sections to be installed at hazardous waste disposal sites. Soil liners are preferred because of their low cost, large leachate attenuation capacity and resistance to damage and puncture. Clays also possess sorptive and or attenuative capacity and reduce the concentration of contaminants in leachate. This capacity relies on chemical composition and on mass of the liner. Soils generally have large capacity to sorbs materials of different types, but some soils do not provide an impermeable boundary. These properties can be enhanced by the use of soil additives. Of the two types of liners viz. soil and synthetic liners commonly used in waste disposal facilities, soil liners seems to be indicative of the extensive use of clay soils as pollution barriers.

El-Shoby and Rabba (2001) [4] from their investigations, arrived at the conclusions that the influence of initial water content on swelling is not appreciable for values of it below the shrinkage limit of the soil. However, as the values of initial water content exceed the shrinkage limit, the influence is significant. The swelling potential of a clay is determined by the activity of the clay fraction. The higher the value of the initial dry density, the greater is the swelling potential. El-Shoby and Mazen (2003) [4, 5] also confirmed the influence of the mineralogical composition as a controlling factor governing the swelling behaviour of expansive clayey soil. The swelling of montmorillonite soil was explained by Ranganathan (2007) [6] with the diffuse double layer theory. The clay particles with charge excess sites on the surface cause ion concentration in the diffuse double layer to exceed that in free water. The difference in ion concentration results in the diffusion of water those forces the clay particles apart causing swelling. Basma and Al-Sharif (2004) [7] studied treatment of expansive soils and concluded that initial water content of the soils had a great influence on the amount of swelling. The swelling properties are reduced drastically when the initial compaction water content is increased. They also found that the dry unit weight of specimens is a very important parameter affecting the swelling properties. They proved that increase in initial dry unit weight of the specimens resulted in decrease in the swelling properties.

The presence of salt in pore fluid resulted in the reduction in swelling. However, it is also obvious that after reaching certain salt concentration within the pore fluid, no reduction in swelling characteristics is recorded. As per the observations made by Katti and Katti (2004), the causes of swelling are clay mineral with an expanding lattice and the dipolar nature of water. High liquid limit, plasticity index and low shrinkage limit may be attributed to high Base Exchange capacity in the montmorollonite clay mineral.

Research Methodology

Measurement of Cracks Crack dimensions are usually measured using approximate methods. In most cases, qualitative descriptions are provided to estimate the extent of cracking. The irregular shape and complex geometry of cracks prevent accurate measurements of length, width and depth. The width and depth of a crack are not uniform along the length of a crack. Maximum length, width and depth are commonly recorded using measurements with rulers and/or thin gauge wires. Kleppe and Oslon (2005) developed a scale that ranged from 0 to 4 to describe severity of cracking. A crack severity number of 0 indicates absence of cracking, whereas, cracks with width >20 mm and with substantial depths are described by a crack severity number of 4.

Based on the above definition of CI, the width and length of cracks, 2 mm deep or more, were measured at the end of shrink cycles. Al Wahab and El-Kedrah (2005) did not present methods for the determination of the length and width of cracks. This potentially leads to overlooking the effects of the irregular shape of cracks in the calculation of the cracking index. Mi (2005) and Miller *et al*. (2008) adopted a similar approach. The surfacial cracked area was used to determine the crack intensity factor (CIF). Crack intensity factor is defined as the percentage of the cracked area to the total surface area of the sample The cracks that were included in the CIF analysis, were those whose widths were more than 1 mm. Miller *et al.* (2008) has not presented the determination of CIF.

Of the two parameters, mentioned above namely crack index and crack intensity factor, the latter has greater acceptability. Thus attempts were made to measure CIF using the techniques of digital image processing. To understand, the digital measurement method for evaluating CIF, a brief introduction to Digital image Processing is given in this section. The important aspect in digital image processing is image representation. Any monochrome image can be represented by means of a two dimensional light intensity function f(x, y), where x and y denotes spatial co-ordinates and the value of x at any point (x, y) is the gray level or the brightness of the image at that point. The original is taken at the top left corner of image and the horizontal line and the vertical line through the origin are taken as y and x axis, respectively. The monochrome image f(x, y) is discretized both in spatial co-ordinates and gray level values to obtain the digital image. A digital image can be represented as a matrix whose rows and columns are used to locate a point in the image and corresponding element values give the gray level at that point. Each element in this matrix/digital array is called as picture elements or pixels.

A pixel is the smallest part of a digital image which can be assigned a value. The physical size of the piece of photograph represented by each pixel is determined by how precisely we wish to record the data. To produce the digital version of a photograph, we take samples of its brightness at regular intervals. The process involves laying a sampling grid over the data and then measuring the average brightness in each square of the grid. There are 16 rows of samples and each row contains 16 samples. The sampling process itself takes the average brightness of the picture underneath each square in the sampling grid and assigns it a value. That value is placed in an array of numbers at the location corresponding to the position of the square in the grid.

The values used correspond to the brightness. In this case, 0 represents black and 255 represents the brightest area which the sampling system can record. This image is called the grey scale for the image. 255 may seem like a strange choice for the maximum brightness. It is, in fact, the largest value which can be represented in a single byte of computer storage. A byte consists of 8 bits. Each bit can take the value 0 or 1. Using standard binary number representation the values 0 to 255 can be encoded in a single byte. A byte is normally the smallest unit on which a general-purpose computer can conveniently perform standard arithmetic operations. Brightness values between the extremes of 0 and 255 are represented on a liner scale. The term resolution is used to describe the level of spatial detail captured by the digital image. Any measure of resolution is specified only in terms of number of pixels. The density of pixels in an image reflects the resolution of the image. As the resolution increases, the storage requirement also increases.

Conclusion

Individual clay-sized particles in expansive soils are anisotropic in nature with respect to swelling. Studies conducted by Sivapullaiah *et al*. (2006) on the swelling behaviour of mixtures of bentonite and non-swelling coarser fractions of different sizes and shapes revealed that generally, the swelling of soils occurs in three distinct phases: inter-void swelling, primary swelling and secondary swelling. The inter-void swelling is due to finer expansive clay present in the voids, which in turn created by coarser non-swelling particles. But, this does not contribute to total volume increase. At the end of inter-void swelling, a large increase in swelling occurs and constitutes about 80% of the total swelling. The slow and continued swelling with time after primary swelling is called secondary swelling.

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