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Very Low Permeability Geomembranes Geosynthetics Design and Analysis of Its Erosion Control Behavior.

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Abstract- Geopolymers emerge as an ecological alternative for construction materials. These consist of a mixture of aluminosilicate sources and an alkaline solution that dissolves the silicon and aluminum monomers that come from the source to generate a gel called N–A–S–H that will control the main properties of the geopolymer. The geopolymer stands out for having good resistance to compression, as well as good resistance to high temperatures and corrosive environments. They have great potential as a replacement for classical technologies such as concrete, however, require further applied research to determine their feasibility on an industrial scale.

Keywords- geopolymers; gel N–A–S–H; aluminum; silicon; sodium

I. INTRODUCTION

A geomembrane is very low permeability synthetic membrane liner or barrier used with any geotechnical engineering related material so as to control fluid (liquid or gas) migration in a human-made project, structure, or system. Geomembranes are made from relatively thin continuous polymeric sheets, but they can also be made from the impregnation of geotextiles with asphalt, elastomer or polymer sprays, or as multilayered bitumen geocomposites. Continuous polymer sheet geomembranes are, by far, the most common.Geomembranes are thin, flexible materials that are manufactured in factories in a controlled environment. Geomembranes can be permeable or impermeable. Impermeable geomembranes are often used as a water barrier in hydropower structures, while permeable geomembranes are applied for the seepage water to pass by without taking away the soil.

Geomembrane products are engineered to help provide cost-effective solutions and to meet specific design requirements in fluid barrier, containment and other geotechnical applications. Geomembranes have been used since the 1950s and their use has steadily increased as a result of water resource concerns.

It is now common to find local and state regulations calling for infrastructure designs that use geomembranes for containment, lining, and capping. Whether for potable water or animal waste, these materials have become central to project acceptance and success. Geomembranes are available in a variety of physical, mechanical, and chemical resistance properties designed to meet the requirements of a wide range of applications. For example, the products can be compounded for exposure to ultraviolet light, ozone and microorganisms in soil. Different combinations of these properties exist in various geosynthetic lining materials to cover a wide spectrum of geotechnical applications and designs. Several methods are used to join the geosynthetic lining materials in the factory and in the field. Each material has highly developed quality-control techniques that govern its manufacture and installation. In straightforward terms, geo signifies earth while the membrane is a layer. So, geomembrane is essentially an impermeable layer used for separation. It is a geosynthetic liner. Far more effective than traditional concrete, compacted clay, or asphalt, the economical geomembranes are the norm today in a broad array of industries.

The most common types of geomembranes are:

- High-density polyethylene or HDPE Geomembrane sheets
- Low-density polyethylene or LDPE Geomembrane
- Ethylene propylene diene monomer or EPDM Geomembrane

This geosynthetic material is very slender, and it consists of impermeable layers of polymeric materials that are used for mainly lining and covering liquid or storage structures such as landfills, canals, including other containment facilities.

Fig.1 Geomembranes.

GEOMEMBRANE WORK

Geomembrane work is very useful when dealing with dams. Seepage control is just one use for geomembranes. They can be used when working with canals, reservoirs, storage basins, dams, and tunnels. In Europe, geomembranes have been used to repair old concrete and masonry dams. A geomembrane is a polymeric membrane that constitutes a flexible, watertight material with a thickness of one-half millimeter or more. The manufacture of geomembranes is done with a wide range of polymers. The types of polymers used can include plastics, elastomers, and blends of polymers.

In the old days, geomembranes were installed on the upstream side of structures with either nails or adhesives. More recently, stainless steel anchors are prolific. This type of system uses two vertical U-shaped anchors. One anchor is larger than the other. The smaller anchor is fastened to the face of the structure first. Then the larger anchor is placed over the smaller one and connected to the face. This creates two voids to be filled with geomembranes.

II. POLYMERIC GEOMEMBRANES

Polymeric geomembranes are widely used as liners and covers for ponds, canals, reservoirs (liquid containments), and landfills (solid-material containment). The water vapor transmission values of thin (less than 1 mm thick) PVC and polyethylene membranes are very low, corresponding to hydraulic conductivities in the range 10^{-12}–10^{-15} ms^{-1}. Therefore, the simplest applications of geomembranes as hydraulic barriers (e.g., canal lining) rely on high-quality manufacturing (limited defects), field seaming, and minimization of installation damage. These issues are addressed by specifying minimum values of the membrane thickness, puncture, tear, and impact resistance. Liner designs always include a protective soil cover to minimize risks of puncturing the membrane during service and to reduce problems of polymer degradation (due to UV exposure, etc.). Side-slope stability (raveling of the cover soil) is controlled by the interface shear resistance, while tensile strength parameters can be evaluated by considering the anchorage forces on the stretched membrane. Liner designs for storage of liquid chemicals are clearly intended to prevent transport of these contaminants into the underlying groundwater system. These situations favor the most chemically stable polymeric materials such as HDPE, while defects in the membrane (and/or its seams) will control the overall transmissivity of the liner. Geomembranes are often used together with a compacted clay liner to reduce the mass transport of chemicals.

Stringent US government regulations (EPA) instituted in the early 1980s aim to prevent leachate migration from landfills through the design of leachate collection systems, using (chemically stable) geosynthetics for filtration and drainage, and may include two separate liner systems (separated by a leachate detection system). Regulations require the use of geomembranes within the liner system in order to overcome construction/material defects that are inevitable in compacted clay barriers. Geomembranes also offer advantages by reducing the overall thickness of the lining system and, hence, maximizing the space available for waste storage. The designs of landfill liner systems follow the same principles outlined above, but are made more complex by uncertainties in the volumes and chemical composition of the leachate stream.

III. SCOPE OF WORK

Research indicated some noticeable drawbacks of fly ash based geopolymer like hardening characteristics, cracking with age, efflorescence, low reactivity level etc. Studies on the water cured fly ash based geopolymers, has not received proper attention in the past. Some more drawbacks may be noted here. It is observed that dissolution of sodium hydroxide in lower ambient temperature (in winter) is very low. The optimization of temperature level of activator prior mixing is essential to overcome this problem and have a considerably better geopolymer. Again, the rate of poly-condensation is dependent on the choice of oxide/combination of oxides in activator solution for different base and supplementary material/additives. Slow synthesis may provide an amorphous structure but partly crystalline. The sequential development of crystallized compound within the pores affects the product performance.

IV. LITERATURE REVIEW

[1]Base Paper-ShahinGhazizadeh, Failure mechanisms of geosynthetic clay liner and textured geomembrane composite systems: The objective of this study was to evaluate shear behavior and failure mechanisms of composite systems comprised of a geosynthetic clay liner (GCL) and textured geomembrane (GMX). Internal and interface direct shear tests were performed at normal stresses ranging from 100 kPa to 2000 kPa on eight different GCL/GMX composite systems. These composite systems were selected to assess the effects of (i) GCL peel strength, (ii) geotextile type, (iii) geotextile mass per area, and (iv) GMX spike density.

Three failure modes were observed for the composite systems: complete interface failure, partial interface/internal failure, and complete internal failure. Increasing normal stress transitioned the failure mode from complete interface to partial interface/internal to complete internal failure. The peak critical shear strength of GCL/GMX composite systems increased with an increase in GMX spike density. However, the effect of geotextile type and mass per area more profoundly influenced peak critical shear strength at normal stress > 500 kPa, whereby an increase in geotextile mass per area enhanced interlocking between a non-woven geotextile and GMX. Peel strength of a GCL only influenced the GCL/GMX critical shear strength when the failure mode was complete internal failure.

[2] Daniel D. Jones, PCB containment using geosynthetics in Canada's Arctic: Two funnel-and-gate permeable reactive barriers (PRBs) with settling ponds comprised of a composite liner (geomembrane and geosynthetic clay liners (GCL)) were installed at Resolution Island (BAF-5), Nunavut to contain residual polychlorinated biphenyls (PCBs) moving with the sediment and annual snowmelt. The long-term performance of the geosynthetics used in the PRB funnels is studied for physical integrity and diffusive barrier properties after nine years of operation. Exhumed geomembrane specimens are compared with virgin material by index testing: diffusive resistance to benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds, as well as puncture, burst, and tensile strength. Exhumed GCLs are evaluated concerning hydraulic conductivity, the mass of bentonite per unit area, and swell index.

The migration of PCBs through the composite liner system by diffusion is modelled and the diffusive and sorptive properties of the geomembrane ($D_g = 1.7 \times 10^{-14}$ m2/s, $S_{gf} = 160{,}000$) and GCL ($D_e = 3.1 \times 10^{-10}$ m2/s, bentonite plus fibers layer $K_d = 15$ mL/g, cover geotextile $K_d = 12{,}000$ mL/g, and carrier geotextile $K_d = 16{,}000$ mL/g) were calculated. Modelling results estimate that the composite liner was successfully containing PCBs. This was confirmed by downgradient monitoring. The challenges of the location and terrain, PRB design, construction, and maintenance are discussed along with recommendations for designing PRBs in other remote and cold region environments.

[3] Rizwan Khan, Multi-scale understanding of sand-geosynthetic interface shear response through Micro-CT and shear band analysis: To understand the process of mobilisation of shear strength in sand-geosynthetic interfaces at a fundamental level, it is essential to precisely characterize the size and shape of the grains and the shear-induced surface changes in geosynthetics.

[4] AbdelmalekBouazza, Analytical modelling of gas leakage rate through a geosynthetic clay liner–geomembrane composite liner due to a circular defect in the geomembrane: An analytical model was developed to predict gas leakage rate through a GM/GCL composite liner with a circular defect in the geomembrane. The predictions of the proposed analytical model were found to be in good agreement with experimental results for specimens with moisture content higher than the so-called critical moisture content.

[5] S. Dickinson, Deformations of a geosynthetic clay liner beneath a geomembrane wrinkle and coarse gravel: Experimental results are presented on the deformations of dry and hydrated geosynthetic clay liners (GCLs) when buried beneath 50 mm coarse gravel and a 1.5 mm high-density polyethylene geomembrane containing a wrinkle and then subject to simulated earth pressures. The effect of the wrinkle on GCL deformations and the effectiveness of different protection layers to minimize GCL deformations are examined. Although the wrinkle experienced a decrease in height and width, the gap beneath the wrinkle and GCL remained, even up to applied pressures of 1000 kPa. The thickness of the GCL decreased beside the wrinkle and increased beneath the wrinkle from bentonite extrusion towards the gap beneath the wrinkle. The gravel backfill itself induced large variations in the thickness of the GCL when tested without a protection layer. These variations were induced by bentonite extrusion directly beneath gravel contacts to zones in between contacts. The 1200 and 2000 g/m2 nonwoven needle-punched geotextile protection layers tested were not effective at reducing the number and magnitude of these indentations.

[6] Abdulmuttalip Ari, Effect of fractal dimension on sand-geosynthetic interface shear strength: In this research, the effects of particle shape and surface structure on sand-geosynthetic interface shear strength were quantitatively investigated using fractal theory. Three different sand samples were prepared by considering the particle shape with overall regularity. Three geomembranes with different surface roughness and three EPS geofoams with various densities were selected to include the effect of surface roughness and hardness on the interface shear strength. Sand particles and geosynthetic surfaces were analyzed using image processing technique to measure the fractal dimension of the materials.

[7] R. Kerry Rowe, Effects of perfluoroalkyl substances (PFAS) on antioxidant depletion from a high-density polyethylene geomembrane: To safely contain Per-and Polyfluoroalkyl substances (PFAS) in municipal solid waste landfills and contaminated soil monofills, it is necessary to understand how these substances interact with components of engineered systems designed to contain them. This paper examines the interaction between one of the most critical components of the system: a high-density polyethylene (HDPE) geomembrane. The same geomembrane is immersed in PFAS solution and synthetic municipal solid waste leachate containing PFAS for 2.5 years, and the effects of PFAS on antioxidant depletion time is examined. The geomembrane is incubated in ovens at 85-40 °C to obtain data for Arrhenius predictions at typical landfill temperatures. When exposed to PFAS solution alone, the antioxidant depletion times are smaller than when the same geomembrane is immersed in synthetic municipal solid waste leachate alone.

[8] GregórioLuís Silva Araújo, Influence of micro and macroroughness of geomembrane surfaces on soil-geomembrane and geotextile-geomembrane interface strength: The interface shear strength involving

geosynthetics and other materials can be influenced by various parameters, such as the material type and the normal stress on the interface. Although several investigations have been conducted over the years on this topic, the large variation of interfaces that can be used has led researchers to develop other sources of information to improve design methods.

[9] Prateek Malik, A comprehensive review of soil strength improvement using geosynthetics: Geosynthetics are revolutionary products and has tremendous uses in the field of road construction and are widely used as reinforcement to increase the strength of soil/Slope stabilization. Use of geo-synthetic material reduces the sub-grade thickness and hence cause a reducing the utilization of natural resources.

[10] Fernando Luiz Lavoie, Service life of some HDPE geomembranes: This study evaluated nine exhumed high-density polyethylene (HDPE) geomembranes from different Brazilian civil construction facilities under several exposure times, from two to fifteen years in service. Physical and thermal analyses were performed to understand the behavior of the geomembranes' samples in the final condition after the environmental exposure and, in some cases, also after contact with residues.

V. RESEARCH HYPOTHESIS

Due to growing industrial production, the generation of wastes has been increased many folds with time and disposition is a challenging problem. On the other hand, carbon dioxide emission has increased to a great extent causing global warming. There is scarcity of ore also. Under this circumstances fruitful application of the waste materials is the need for the day. Limited use of waste materials (like slag, fly ash etc.) are made in cement manufacturing but major portion is used in road construction or for any filling purpose. This may create ground water contamination problem due to leaching of toxic and heavy metals, ultimately reaching to underground water reservoir. Joseph Davidovits introduced geopolymer as a synthetic material primarily. Later on it is observed that geopolymer may be developed from the waste materials containing silica and alumina, in an alkaline environment.

VI. GEOPOLYMER AND ZEOLITE

The term Geopolymer and Zeolite are referred to an X-ray amorphous structure and fine crystalline structure respectively [13] .

The activation process of the material comprising of silica and alumina, follows four consecutive steps: firstly, the surface disbanding of Al, Si within alkaline medium; secondly, the dispersion of the disbanded species through the solution; thirdly, the poly-condensation of the Al and Si with the added silicate solution and formation of gel; fourthly, the strengthening of gel phases towards final polymeric outcome [5]. Now, zeolites are generally synthesized from a gel comprising of an insoluble solid phase and confined liquid phase which in fact maintains a balanced distribution of silicate and aluminosilicate anions, the supply of which is controlled by the dissolution of the solid phase [5]. The degree of crystallization is greatly influenced by the condition of synthesis of geopolymer [6]. In most of the existing literature the presence of nano-crystalline particles (zeolite structure) within the body of geo-polymeric structure was found [5], [6] and [17].

The chances of formation of amorphous and crystalline structure depend on several factors like curing profile, curing type, rest period (time lag between mixing and curing), alkaline activator concentration, composition of base material (fly ash, slag, silica fume etc.), water to base material ratio, environmental coverage and others [5, 7, 5, 6, 9, 6, 3]. In AAFA (alkali activated fly ash) system, hydroxide activator emphasizes the production of more crystals in compare to silicate activators (like sodium silicate). Again, the zeolite phase formation is enhanced by the presence of sodium ion rather than potassium ion [5, 6 and 6]. Synthesis of zeolite-phase is also influenced by the existence of high volume of water within the mixture [2]. Earlier study suggested that the mild curing temperature is appropriate for the formation of zeolite-phase [3]. Sometimes the vitreous component of fly ash is rapidly dissolved in alkali activator without forming well-crystallized structure because of the limited time and space [3], [8], [6] .

VII. SUPPLEMENTS WITH BASE MATERIALS

Some studies have been done on fly ash based geopolymer. Fly ash contains large amount of silica and alumina. It is understood that geopolymerization process mainly includes alkaline activation of base material by alkali activator (alkali hydroxide/silicate solution) followed by heat curing [1]. The geopolymer chemistry explains the development of 3D polymeric chain by Si-O-Al-O bond with alkali activation of the base material rich in silica-alumina [2] . Though the geopolymer material shows notable performance [3] in compare to conventional cement concrete but the performance of geopolymer changes with the combination of base materials and alkalis [9]. It is really important to search new type of geopolymer to achieve better properties associated with it. An idea of blended geopolymer may be tried to improve the microstructural and mechanical properties.

Previous study [7] explored that incorporation of calcium supplements may improve hardened characteristics of fly ash based geopolymer under ambient heat curing. Calcium compound in geopolymer improves microstructural morphology and strengthens the geopolymer by enhancing amorphous framework through polymerization. Some literatures [6] suggested that GGBS generates calcium containing composites like silicates, aluminate hydrates and silico-aluminates associated with calcium which affects consistency at green level indeed [9]. Gaining of higher early strength was observed for geopolymer prepared from calcined material while non-calcined materials provides notable strength with time [8]. Jaarsveld et al. [10] described a typical context where better strength was found for the geopolymer comprising kaolin. Though the literature in this connection is limited but quite enough to realize the influence of calcium on strength and durability of fly ash based geopolymer.

Presence of water in higher extent is the prime drawback of developing better geopolymer composite. In fact, the sodium silicate solution is the prime source of water which itself contains a huge amount of water. Sequentially additional water makes the structure more porous and sometime permeable to some extent. To eliminate this problem and initiate faster reaction, a suitable compensator of sodium silicate like micro silica or silica fume may be introduced as the primary source of reactive silica. Use of new supplements comprising reactive silica, alumina or calcium in fly ash based geopolymer, is required. New research should be executed on blended geopolymer. Blending of two or more base materials may be tried. An idea of blending of base materials to produce better fresh/hardened geopolymer in micro and macro level. Again, parametric studies of blended geopolymer should be revisited.

VI. CONCLUSION

From the previous brief review of some research, which covered the main three axes, included that the effect of slag addition, and the effect of solution ratios, also, the effect of adding fibers and Nano silica to geopolymer compounds on the mechanical properties of geopolymers, we can conclude with the following observations:

1. The addition of slag to geopolymer mixtures (paste, mortar, and concrete) significantly improved mechanical properties by 2 times such as compressive and tensile strength, while reducing fresh properties such as flow-ability and setting time by 85 to 92 %.

2. At certain proportions, found that increasing the concentration of sodium hydroxide solution and increasing the ratio of sodium silicate/sodium hydroxide, lead to the development of compressive strength of geopolymer mixtures. While increasing the ratio of fluid to the binder and adding external water, improves flow-ability, but reduces compressive strength. It is worth noting that the use of the superplasticizer improves fresh properties such as flow-ability and setting time.

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