

Paper Clay Utilization In Engineering Applications

Charles E. Ochola¹, Horace K. Moo-Young²

Abstract: The application of biosolids on land is probably the largest beneficial use, but is relegated to the utilization of municipal wastewater sludge due to its composition consisting of nutrient-rich organic material. Paper mill biosolids (paper clay) have a different composition and therefore require a different application to benefit from its reuse. The use of paper clay as a construction material is a relatively new innovative application, and this paper looks at the various applications where paper clay can be used, and also at the physical behavior of this material. Generally high water contents, high organic contents, high compressibilities and low shear strengths characterize paper clay. Exploitation of these characteristics will determine what uses this material can be applied to. Various researchers have shown that paper clay can be utilized as a landfill-capping barrier primarily due to its ability to achieve low hydraulic conductivities, and several nations around the world are currently investigating this proposed use. Due to the high organic content of this material, its ability to adsorb various contaminants such as heavy metals warrant investigation of its use in geo-environmentally related containment systems. A combination of this material with other materials to enhance various properties is currently being investigated.

Paper clay is generated during wastewater treatment processes at a rate of approximately 11×10^9 kg per year in the United States alone (Springer 1986, Gregg et al. 1997). By diverting this material from the waste stream, significant savings in landfill space can be realized. Furthermore, by avoiding landfill-tipping fees, the paper clay can be provided as a low or no cost barrier material.

Paper clay generally contains organic fibers and tissues (lignin and pulp), clay fillers, and trace components (resins, starch, etc. added to produce specific paper products). Paper clay has several properties, which make its use in reactive barriers very promising. It can be compacted to very low permeability values (10^{-9} m/sec to 10^{-11} m/sec), and has a high organic content which may act as a potential carbon source for microbial growth and sorption sites for heavy metal attenuation. Further, paper clay generally has a high water content (150% or greater), and a low initial solids content (15-20%) which compares favorably to the common bentonite slurry material (5-15% solids) before the addition of soil. The paper clay utilized in this testing program was obtained from Erving paper mills, and Ponderosa Fibers of Pennsylvania (PFP), which are both recycling paper mills.

Tests conducted on the paper clay included specific gravity testing, grain size analysis, filtration testing, slump testing, and batch sorption testing. The specific gravity of PFP paper clay was 1.76, while that of Erving paper was 1.78, which compares favorably with the results from other researchers (Moo-Young and Zimmie 1996, Kraus et al. 1997).

¹ Graduate Research Assistant, Civil & Environmental Engineering, Lehigh University, Bethlehem, PA, 18015, USA

² Assistant Professor, Civil & Environmental Engineering, Lehigh University, Bethlehem, PA, 18015, USA

A grain size distribution test was performed on the samples. The testing of paper clay material was difficult to perform and interpret mostly due to the fibers present. According to ASTM Test Method for Particle Size Analysis (D 422), a representative sample should be air dried and well pulverized prior to sieving. However, in this study, the goal was to evaluate the “as-received” characteristics of the paper clay. Therefore, the paper clay material was not pulverized prior to sieving to estimate the “as-received” size distribution of the clods. This yielded a distribution of the clods (which naturally form in the paper clay sample) rather than individual particles-sizes. Previous research has indicated that for compacted clay barriers the size of clay clods has a strong influence on the hydraulic conductivity of compacted clay (Benson and Daniel 1990). Since paper clay is 50% kaolinite clay, the clod size may impact hydraulic conductivity behavior. Figure A7 shows the clod distribution curve for the paper clay in three physical conditions: oven dried, as-received water content, and hand crushed at the initial water content. In this study, the paper clay clod size ranged from 19 mm to 2 mm, 2 mm to 0.425 mm, and 19 mm to 0.15 mm for the as-received, hand crushed, and oven dried samples, respectively. In the study conducted by Benson and Daniel (1990), there was an increase of several orders of magnitude in hydraulic conductivity of compacted clay caused by increasing clod size. Similar to compacted clays during compaction, the clods in paper clay must be broken down mechanically as small as possible to reduce the effects of large clods on hydraulic conductivity.

The paper clay used in the filtration experiment was at extremely high water contents (320% - 450%). A head of water was also applied at the top of the paper clay. The water content of the paper clay increased throughout the experiment to the point where it was saturated with water. Thus, there was no need to discard the remaining slurry and replace it with only water. Pressure applied to a saturated material such as paper clay is expected to behave as if it was pure water. The results from the filtration experiments showed that the permeability of paper clay as slurry is of relatively constant magnitude between 10^{-5} cm/sec to 10^{-6} cm/sec. Varying the initial water content and initial head had no effect on the magnitude of the paper clay permeability, i.e., there was very little change in the calculated permeability as the pressure and water content was increased. The magnitude of permeability observed for the paper clay filter cake was on the order of 10^{-6} cm/sec. The permeability values for the filter cakes essentially did not change as the initial head and even second/final head were increased. This is an interesting result since it deviates from typical soil behavior where larger formation heads produce greater consolidation pressures and reduce void ratios in the filter cakes therefore it is expected that for slurries, filter cake and hydraulic conductivity decreases as formation head increases (Henry et al., 1998). Most importantly, the permeability values obtained for paper clay filter cakes, fall within the permeability range of soil-bentonite filter cakes presented in technical papers on the subject matter (Xanthakos 1979, Ryan 1987, Evans 1991).

The results from the slump test showed that PFP paper clay lacks plasticity and cohesiveness at water contents below 279.5%. At water contents below 279.5% PFP paper clay behaved in such a manner that the top half of the sludge sample fell over to its side a few seconds after removing the mold. This behavior is by no means considered true slump according to ASTM standards. The slump values obtained throughout these experiments showed that at optimum moisture contents paper sludge is unworkable in accordance with Moo-Young and Zimmie (1996).

However, at water contents greater or equal to 292% proper or actual slump as defined by ASTM standards was observed.

Batch testing was utilized to obtain the equilibrium sorption capacity of a given sorbent for an individual sorbate. A series of batch tests were conducted on paper clay with various heavy metals utilizing Environmental Protection Agency (EPA) procedures developed by Roy et al. (1991). It was generally found that the paper clay was able to sorb a portion of heavy metal ions from solution.

References

- Benson, C. H. and Daniel, D. E., 1990, "Influence of Clods on Hydraulic Conductivity of Compacted Clay," *Journal of Geotechnical Engineering*, American Society of Civil Engineers, Vol. 116, No. 12, pp. 1811-1830.
- Evans, J.C., 1991, "Geotechnics of Hazardous Waste Control Systems," Foundation Engineering Handbook, Hsai-Yang Fang, ed., Van Nostrand Reinhold, New York.
- Henry, L.B., Filz, G.M., and Davidson, R.R. 1998. "Formation and Properties of Bentonite Filter Cakes." *Filtration and Drainage in Geotechnical /Geoenvironmental Engineering*, Geotechnical. Special. Publication. No.78, Lakshmi N. Reddi and Mohan V.S. Bonala, eds., American Society of Civil Engineers, Reston, Virginia, pp 69-88
- Kraus, J. F., Benson, C. H., Van Maltby, C. and Wang, X., 1997, "Laboratory and Field Hydraulic Conductivity of Three Compacted Paper Mill Sludges," *Journal of Geotechnical and Geoenvironmental Engineering*, American Society of Civil Engineers, Vol. 123, No. 7, pp. 654-662.
- Moo-Young, H. K., and Zimmie, T., 1996, "Geotechnical Engineering Properties of Paper Mill Sludges for Use in Landfill Covers," *Journal of Geotechnical Engineering*, American Society of Civil Engineers, Vol. 122, No. 9, p. 768-776.
- Roy, W. R., Krapac, I. G., Chou, S. F. J. and Griffin, R. A., 1991, *Batch-Type Procedures for Estimating Soil Adsorption of Chemicals*, U.S. Environmental Protection Agency Technical Resource Document, Washington, D. C., Doc. No. EPA/530-SW-87-006-F.
- Springer, A. M., 1986, *Industrial Environmental Control – Pulp and Paper Industry*, John Wiley and Sons, New York, New York.
- Xanthakos, P. 1979, *Slurry Walls*, McGraw-Hill Book Co., Inc., New York, New York.