Low Carbon Stabilization and Solidification of Hazardous Wastes

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Chapter 4

Biocementation technology for stabilization/solidification of organic peat

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4.1 Introduction

Peat soil, known as one of the most problematic soils in the fields of civil and environmental engineering, is formed by the accumulation and decomposition of organic materials (derived from plant remains) under the waterlogged environment where there is lack of oxygen (O'Kelly, 2015). Basically, the soil with an organic content greater than 20% is defined as organic soil, yet the peat soils are defined to have organic content above 75% (Huat et al., 2014; O'Kelly, 2017). The plant remains in peat can be found at various degree of decomposition (ranging from undecomposed to highly decomposed stages); therefore the peat soil often exhibits a dark brown to black color and spongy consistency with a distinctive odor. Based on the degree of decomposition and fiber content, the peat can be categorized into three types: (1) fibrous peat, (2) hemic or semifibrous peat, and (3) sapric or amorphous peat (Zulkifley et al., 2014). The degree of decomposition of fibrous peat is low, hence the plant structure can easily be recognized (fiber content over 67%). Hemic peat exhibits a moderate degree of decomposition, in which the fiber content can be in a range from 33% to 67%. Sapric peat, on the other hand, is highly humified, and the plant structure is no more visible (fiber content less than 33%).

The peat deposits are found to be distributed in many countries all over the world, occupying nearly 5%−8% of land surface of the Earth (Mesri and Ajlouni, 2007). A recent study on peatland mapping has reported that the total area of the peatland is 4.23 million km^2 (Xu et al., 2018), and the major distributions are summarized in Table 4.1. A high distribution of peatlands can particularly be seen in the northern hemisphere (including Canada, Russia, and Finland). In Japan the peat deposits are mainly found on Hokkaido island (the northernmost of Japan's four main islands), yet a minor distribution exists in other islands as well. In Hokkaido, around 2000 km^2 is occupied by peat deposits, which has been reported to be approximately 6% of the flat land in Hokkaido (Noto, 1991).

The peat soils are much weaker and extremely compressible compared to the other soil materials (i.e., inorganic minerals), requiring special considerations for amending the deposits to be suitable for engineering purposes and sustainable preservations. The major undesirable characteristics of peat and the associated challenges are briefly outlined below.

1. *Weak skeleton*: the major solid compound of the peat is organic matter. The extremely weak sponge-like skeleton of the organic material (unlike inorganic minerals) does not provide adequate strength and stability for infrastructure developments (Huat et al., 2014).
2. *Spatial and temporal variabilities*: high degrees of spatial and temporal variabilities are often major hurdles when dealing with peat deposits. The spatial variability is mainly attributed to different inherent characteristics of plants and rate of decomposition. The plant remains with soft inner walls (such as leaves, mosses, and sedges) decompose first, followed by the gradual decomposition of hardwoods (such as stems and roots), suggesting the process of humification is not uniform, and varies considerably even over short distances. In addition, the microbial inhabitance tends to degrade of cellulose, phenolics, pectin, starch, chitin and other biopolymers, deteriorating the biochemical constancy and microstructure of organic content, hence weakening the engineering responses of peat (Moayedi and Nazir, 2018; O'Kelly and Pichan, 2014).

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1. The CaO_2, the product widely used for the fertilizing purpose, was shown to have high potential for pH regulation in peat soils. The results indicated that 0.5% (by weight) would be adequate to rise the pH value of the peat, providing desirable environment for urea hydrolysis.
2. The finding demonstrated that the initial concentration of biocement resources (calcium chloride and urea) needs to be carefully chosen for an effective stabilization of peat soil. Mixing the resources at 1 mol/L concentration showed better enhancement in measured strength and dispersion. On the other hand, when the concentration was increased to 2 or 3 mol/L, the mineralization of calcium carbonate was significantly affected.
3. The fiber that has been used to control the excess moisture content of the peat revealed a high water absorption capacity. For a 50% addition (by weight), peat could show a massive reduction in water content (from 800% to around 150%). The fiber used in this work was paper fiber derived from the wastepaper material; therefore this approach suggests an additional merit that sustainable utilization of waste material for engineering purposes.
4. The study also showed that amending the biocement treatment with fiber addition could markedly enhance the stabilization of treated peat. When the biocementation was applied without fiber addition, the effective carbonate bonds between adjacent solids were limitedly attainable due to high water content and low density, leading to less strengthening (around 12 kPa). But, when the treatment was amended with the fiber addition, it helped to absorb the pore water, decrease the floating effect, increase the density of the peat and increase the interfacial effective contact area. As a result, precipitated calcium carbonate could effectively bind adjacent solid materials and lead to the marked increase in undrained shear strength (up to 250 kPa).
5. The similar tendency of strength could also be observed in the dispersion crumb test. The fiber addition could evidently decrease the crumbling of peat materials, whereas the treatment without fiber addition showed high dispersion of particles. This was found to be attributed to the encapsulation of organic fines and colloids within the densified and cemented fiber matrix. The principle mechanisms that contributed were supported using carbonate measurements, SEM, and XRD analysis.

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