RESPONSE SHEET

REVIEW COMMENTS

This is a very interesting study about the bio-treatment of soil to achieve the stabilization. The whole manuscript is very concise and easy to understand. However, I suggest the authors provide more background information including

(1) Why stabilization of soil is important in actual life?

(2) Existing common stabilization method including the cement-treated soil (base) and the geopolymer stabilization. Also a lot of waste materials can be used to reduce the cost of stabilization such as fly ash, slag, coal-gasification fly ash etc. The recently published papers should be reviewed. (Utilizing lowly-reactive coal gasification fly ash (CGFA) to stabilize aggregate bases; Evaluation of glass powder-based geopolymer stabilized road bases containing recycled waste glass aggregate).

RESPONSE: The INTRODUCTION has been totally revised to include the suggestions made by the reviewer as shown below.

1 Introduction

Soil stabilisation or improvement of soil is employed when it is more economical to overcome a deficiency in a readily available material than to bring in one that fully complies with the requirements of specification for the soil [1]. Stabilisers and modifiers could be organic or inorganic chemical compounds, organic compounds being resinous and bituminous materials acting as water-proofers and sometimes behaving similarly to glue to add cohesive strength. Inorganic chemical compounds include Portland cement, lime, slag, sodium silicate, phosphorus compounds and sometimes a combination of various inorganic salts, such as sodium chloride and calcium chloride that have been long used in stabilisation. Their main function is to reduce plasticity and facilitate densification [2].

Previous research on soil improvement considered using conventional additives such as bitumen, lime, cement, pozzolanic material, agro-industrial waste, etc., which are either expensive or harmful to the environment and hence not sustainable. According to [3], soil improvement techniques like chemical grouting or mixing with cement have shown positive outcomes. These can be described as artificial injection of chemical formulas that, most times, alter the soil pH level and cause soil and groundwater contamination; this is not unconnected to hazardous / toxic nature of the additives [4, 5].

Too much dependence on industrially manufactured soil improving additives (e.g., cement, lime, and bitumen) has kept the cost of stabilisation high. Consequently, underdeveloped and poor nations are unable to provide accessible roads for their rural dwellers that constitute a higher percentage of their agrarian population. Also, a large quantity of carbon dioxide is released during the production of cement, which is a major construction material worldwide.

Based on the foregoing, a better, environmentally friendly, efficient, and effective remedial technique suitable for soil stabilisation might be the biogenic/microbial technique of soil improvement. This trending microbial geotechnology has proven to be highly effective and efficient in soil improvement works with ease and reduced cost, and it enhances environmental sustainability [6].

Microbial-induced calcite precipitation (MICP) is a bio-chemical process of soil strengthening that utilises urea hydrolysis, sulphate reduction, denitrification, aerobic oxidation, and other processes to produce calcite [7]. When compared to other investigation procedures, urea hydrolysis yields the highest rate of calcite precipitation [1]. During urea hydrolysis, the urease enzyme, which is either externally supplied [8] or produced by micro-organisms *in situ* [1] facilitates a chemical reaction in which urea ($CO(NH_2)_2$) is broken down. This microbial bio-cementation process has very little or no harmful effect on the environment. Microorganisms, in particular bacteria, can alter the arrangement of the soil particle sizes, influence the arrangement of the soil matrix by enhancing crystallisation within soil matrix. Subsequently, after these activities, the soil may behave differently (e.g., there may be an increase in hydrodynamic dispersion, chemical retardation, or the migration of fine particles) [1].

Laterites are formed by the process of laterisation, which takes place in a weathering system, resulting in the permanent deposition of sesquioxides (i.e., Al_2O_3 and Fe_2O_3) by the breakdown of ferro-aluminosilicate minerals [9]. Most laterites in their natural states are deficient for use in construction works and require some improvement, especially in areas where erosion is a problem. Researchers, over the years have been looking for less expensive and more environmentally friendly strategies to enhance the properties of these deficient soils [4]. The MICP technique of soil improvement modifies the arrangement of the soil particle sizes and influences the arrangement of the soil matrix by enhancing crystallisation within the soil matrix. Therefore, this study was aimed at the assessment of the impact of different cementation reagent concentrations on the index and physico-chemical properties of the lateritic soil bio-treated with Bacillus *sphaericus.* The objectives include culturing of micro-organism from the lateritic soil in large quantities required for the soil improvement process, characterisation of the natural soil and B. *sphaericus* from the soil, evaluation of the plasticity properties of the natural and bio-treated soil, and micro-analysis of specimens of the natural and bio-treated soil using scanning electron microscope (SEM).