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SILTY SOIL STABILIZATION WITH LIME AND RICE HUSK ASH AND REINFORCED WITH WASTE PLASTIC FIBER

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Abstract: Although abundant plastic waste contaminating the environment may be utilized as reinforcing materials, a potential pozzolanic material (rice husk ash blended with lime) possesses superior properties in stabilizing soils. Engineering behavior of the stabilized clayey/silty soil reinforced with randomly distributed discrete plastic waste fibers is investigated in this paper. The results indicate that the proposed method is very effective to improve the engineering properties of the clayey/silt soil in terms of compressive, tensile, and shear strength, which further enhanced the stability and durability of the soil. Based on the compressive strength, California bearing ratio (CBR), shear strength, and failure characteristics, the optimum amount of fiber mixed in soil/lime/rice husk ash mixtures ranges from 0.4-0.8% of the dry mass.

CE Database subject headings: Fibers; Lime; Soil stabilization; Plastics; Waste management; Recycling; Subgrades; Fiber reinforced materials.

Author keywords: Engineering properties; Fiber; Lime; Rice husk ash; Soil stabilization; Plastic wastes; Subgrade.

Introduction

Disposal of different waste materials produced from various industries is a serious problem. The wastes pose environmental pollution problems for the surrounding disposal area because some of the wastes are not biodegradable. The utilization of industrial wastes in road construction has been of great interest in industrialized and developing countries during recent years. Such utilizations are commonly based on technical, economical, and ecological considerations. Lack of conventional materials and improvement of the environment renders it imperative to search for substitutions, including that of industrial wastes. Industrial wastes (e.g., fly ash, slag, and mine tailing) have been blended with lime and cement to improve the geotechnical properties of roadway subgrade (Balasubraniam et al. 1999; Kaniraj and Gayathri 2003; Bin-Shafique et al. 2010; Rahmat and Kinuthia 2011). Another waste that has potential for alternative materials is rice husk. Rice husk is abundant in rice-producing countries such as Indonesia, Thailand, Philippines, and many others (Hwang and Chandra 1997). It is sometimes burnt for parboiling paddy in rice mills. The partially burnt rice husk will contribute to environmental pollution. Significant efforts has been devoted not only to overcome the pollution problem but also to increase its added value by using it as substituting or secondary materials for limited-availability conventional materials.

During the last few decades, research has been carried out to investigate the utilization of rice husk ash as a stabilizing material in soil improvement (Lazaro and Moh 1970). Much research (e.g., Lazaro and Moh 1970; Rahman 1987; Ali et al. 1992a; Basha et al. 2005; Hossain 2011) has shown that rice husk ash (RHA) is a promising secondary material to improve lime or cement-stabilized soils. Addition of rice husk ash in lime or cement-stabilized soils enhanced the compressive strength significantly (Balasubramaniam et al. 1999; Muntohar and Hashim 2002; Muntohar 2002). How- ever, the stabilized soil exhibited brittle-like behavior (Muntohar 2002; Basha et al. 2005). The brittleness of the stabilized soil may be suppressed by inclusion of discrete elements such as fibers. Stabilized and reinforced soils are composite materials that result from an optimum combination of the properties of each individual constituent material. A well-known approach in this area is the use of fibers and cemented materials in composites. Experimental verification reported by various researchers (e.g., Messas et al. 1998; Muntohar 2000; Consoli et al. 2002; Ghiassian et al. 2004; Kaniraj and Gayathri 2003; Cavey et al. 1995) has shown that the fiber-reinforced soils are potential composite materials, which can be advantageously employed in improving the structural behavior of stabilized and natural soils. Other researchers (Consoli et al. 1998; Kaniraj and Havanagi 2001; Tang et al. 2007) have successfully used fiber reinforcement in a cement-stabilized soil. Fieldwork experience suggests that it is easier to control the fiber content in comparison with its length. Longer fiber will be more difficult to uniformly distribute in the soil-fiber interface and resulting slippage plane in the soil. Thus, it was suggested to limit the fiber length to be less than 50 mm in length (Al-Refei 1991; Santoni et al. 2001; Jiang et al. 2010). Previous studies have indicated that the fiber content is the most controlling strength parameter (Consoli et al. 2002; Gaspard et al. 2003; Muntohar 2009).

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The use of composite materials from industrial by-products is beneficial to the environment. Plastic waste materials, such as polyethylene terephthalate (PET) plastic bottles, polypropylene (PP) of plastic sacks, and PP of carpet, is plentifully produced every day. They are commonly discarded in storage or disposal sites. Nevertheless, little attention has been paid for such materials for applications in roadway and geotechnical construction. The utiliza- tion of lime/rice husk ash and plastic waste to stabilize and reinforce soils needs to be further investigated. The present paper examines the influence of the plastic-waste fiber to improve the engineering properties of the lime/rice husk ash-stabilized soils. The properties being evaluated are compressive and tensile strength, shear strength, and California bearing ratio (CBR) of the soil. In addition, environmental effects on the change of soil strength and the optimum fiber content required to improve the strength and durability are also reported in this paper.

Unconsolidated/Undrained Triaxial Tests: Effect of Fiber on Shear Strength

The UU triaxial test was conducted to evaluate the total stress shear strength parameter and failure behavior under different confining stresses. Normally, in saturated or near-saturated conditions, the failure envelope is usually in a horizontal straight line. Thus, the friction angle is almost zero or relatively very small. In this experiment, the degree of saturation was calculated, ranging from 0.51-0.53. For unsaturated or partially saturated conditions, con- solidation may occur when a confining pressure is applied and affects the undrained shear strength. The shear strength parameter measured from the research described in this paper will definitely it will just be an artifact of testing, and thus the parameter will only be used for comparison purposes between the unreinforced and reinforced soil samples. For determination of total stress shear-strength parameters *c* and ϕ, the failure deviatoric stress $(\sigma_1 - \sigma_3)_f$ was taken as the peak deviator stress for unreinforced specimens and reinforced specimens. The total stress shear-strength parame- ters *c* and ϕ were determined by drawing the *p q* plots (Fig. 4). Table 4 summarizes the values of *c* and ϕ. The lime-stabilized (S1) and RHA/mixed lime (S2) soils showed a higher shearing resis- tance by improving the cohesion intercept, but the effect on the friction angle was marginal. A similar result was indicated by Thompson (1965) for lime-stabilized fine-grained soils that yields a substantial increase in cohesion and minor improvement in the internal friction angle. A nonmonotonic trend was observed from Fig. 4 for S2-SR7 specimens.

A series of tests have been performed to study the effects of ran- domly distributed plastic-waste fiber reinforcement on the strength of stabilized soil with lime/RHA mixtures. The effects of fiber in- clusions in the soil and lime/RHA mixtures on the engineering properties were examined. It was observed from testing that these engineering properties of fiber/lime/RHA soil vary and depend on the fiber content. New empirical equations to estimate the secant modulus of elasticity have been developed as a function of fiber content, CBR, unconfined strength, tensile strength, and confining pressure in the triaxial test. The effect of the plastic waste fiber on the failure behavior was interpreted by the brittleness index. Environmental effects were simulated as wet/dry cycles in this paper. Based on the strength, CBR, shear strength, and failure char- acteristics, the optimum amount of fiber mixed in soil/lime/RHA mixtures range from 0.4-0.8%. Thorough this paper, the technique of a fiber-reinforced lime/RHA soil system is a very effective method of soil improvement, which improves the compressive strength, tensile strength, shear strength, and bearing of the soil; consequently, this improvement enhances the stability and durabil- ity of infrastructures such as foundations and roadbeds. Further- more, the following conclusions can be drawn from this paper:

- Lime and rice husk ash mixtures enhanced the compressive and tensile strength of the soil up to 4× and 5×, respectively. Inclusion of the plastic waste fibers played a significant role in increasing the tensile strength and strength ratio of stabilized soil. The compressive strength increased as the curing age increased.
- The shear strength of the soil increase by addition of the lime/ rice husk ash mixture. The inclusion of fibers resulted in a decrease in the friction angle. The cohesion of fiber-reinforced lime/RHA/soil mixtures increased initially and then decreased with increasing fiber content, and the maximum value was observed at a fiber content of 0.4%. Plastic fibers in the soil/ lime/RHA mixtures had a significant influence in development of the cohesion rather than friction angle of the soil.
- Inclusion of the plastic-waste fiber reduced the brittleness be- havior of the stabilized soil. Addition of 0.1% fiber was enough to decrease the brittleness of the stabilized soil. In general, in- clusion of the plastic-waste fiber increased the secant modulus E_{50} of the stabilized soil specimen.
- Regarding the strength behavior, the plastic-waste fiber-reinforced stabilized soil meet the requirements as subbase and base course materials in term of its CBR values. The CBR value of the soil increased up to 3.6× by mixing of lime/RHA. How- ever, the CBR value increased considerably up to 8.7× by adding plastic-waste fibers.
- The compressive strength of stabilized and reinforced soil/lime/ RHA/plastic-waste fiber was reduced by three cycles of wetting/ drying, and then a slight increase of strength was noticed when subjected to further wet/dry cycles. Adding plastic-waste fiber enhanced the residual strength of the stabilized soil.

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