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Recycled bassanite for enhancing the stability of poor subgrades clay soil in road construction projects

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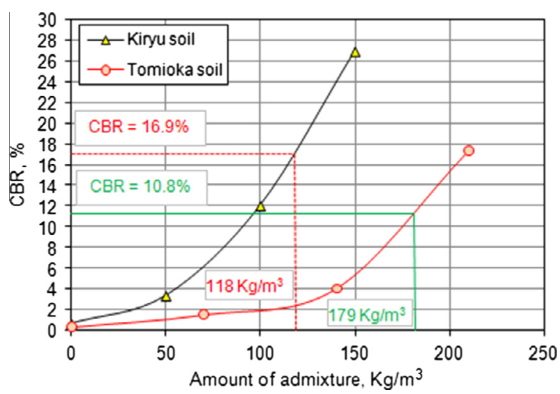
HIGHLIGHTS

- Recycled bassanite produced from gypsum waste plasterboards used in road construction.
- Recycled bassanite enhanced the stability and performance of weak subgrade soil.
- CBR and strength increased with the increase of bassanite content in subgrade soil.
- Soaking has no significant effect on swelling for samples stabilized with bassanite.
- Bassanite has no negative effect on the frost heave for subgrade soil.

GRAPHICAL ABSTRACT



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ABSTRACT

This research investigates the use of recycled bassanite produced from gypsum waste plasterboards to enhance the compressive strength, splitting tensile strength and CBR of weak subgrade clay soils used in roads construction. For this purpose, two types of soils which represent weak subgrade soils located at two different sites were used. This research is preliminary investigations of utilizing recycled bassanite in road construction projects. Recycled bassanite was mixed with furnace slag cement with a ratio of 1:1 to prevent the solubility of bassanite when water introduced as bassanite is a soluble material. Four different amounts of this admixture were mixed with the tested soils and then examined for compressive strength, tensile strength, CBR, volume change and capillary rise. Results showed that the use of recycled bassanite resulted in a considerable increase in CBR and compressive strength for the two types of soils used. The addition of recycled bassanite lead to a small improvement in the tensile strength compared to the improvement in compressive strength and CBR. The induced volume change in term of swelling, when stabilized soil samples soaked in water, increases with the increase of bassanite content in soil mixture. While in the case of un-soaked samples, volume change in term of settlement reduces with the increase of bassanite content in soil mixture. The induced volume changes for the different investigated cases in both soaked and un-soaked conditions are insignificant. The unit weight increased and water content decreased with the increase of bassanite content in soil mixture. The amount of bassanite in soil mixture had a significant effect on the reduction of capillary rise in the case of silt soil while it had insignificant effect in the case of clay soil. The use of recycled bassanite enhanced the performance stability of weak clay subgrade soils. The enhanced stability would result in longer service life and smaller thickness sections for road con-

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struction. Besides, the environmental and economic benefits associated with the use of wastes in construction, the use of gypsum wastes in road construction is attractive and support sustainable development in construction.

1. Introduction

The use of recycled and waste materials in road construction has a great history since it has many environmental and economic benefits. Subsequently, more attention has been paid for the use of waste and recycled materials as alterative materials in road construction due to the shortage of raw materials as well as the increasing cost of construction materials. There are many types of waste and recycled materials used successfully in the different applications of ground improvement projects such as embankments, roads and highways. Examples of these materials include cement kiln dust, waste plastic, waste tire, incinerated sewage, fly and coal ashes, factory-waste roof shingles, construction and demolition wastes, gypsum waste plasterboard, rice husk ash, burned olive waste and incinerated municipal waste [1–14]. Gypsum waste plasterboard is one of the serious problems in Japan since the cost of their disposing in landfill sites is very expensive. Moreover, there are environmental problems associated with the disposing of gypsum wastes especially in wet environments which may increase the emission of hydrogen sulfide gas and the release of fluorine beyond the permitted standard limits [9,15]. To solve this problem, researchers in Japan recently started to use recycled bassanite produced from gypsum wastes as a stabilizer material in ground improvement applications [12,15–17]. The application of recycled bassanite produced from gypsum wastes in ground improvement projects is limited, up to author's knowledge, since it is started recently in Japan. Also, recycled bassanite has not been applied before for the improvement of poor roadway subgrades clay soil in Japan. Improving the strength of weak roadway subgrades soil using traditional materials such as cement or lime requires larger quantities of these materials and consequently the construction cost of such roads will be increased. Recycled bassanite has a potential to be used as a stabilizer material since bassanite which is hemi-hydrate calcium sulphate ($Ca\ SO_4.\ 1/2H_2O$) reacts with water produced hydrate calcium sulphate ($CaSO_4.\ 2H_2O$) which is named gypsum. It is well-known that gypsum has a potential to develop adequate and rapid hardening between soil particles, especially in dry environment, subsequently the strength of the tested soil will be improved. This research investigates the feasibility of the incorporation of recycled bassanite produced from gypsum wastes as a stabilizer material for the improvement of two types of poor subgrades soils in terms of compressive strength, splitting tensile strength and California bearing ratio, CBR. This laboratory work is preliminary investigations and guidance for the application of recycled bassanite as a stabilizer material in two roads construction projects located at two different sites in Kiryu and Tomoika cities in Gunma prefecture, Japan.

2. Historical background

A wide range of investigations has been executed to facilitate the incorporation of waste and recycled materials in earthwork applications to protect the environment, cut down the cost of disposing and reduce the cost of earthwork projects. In Japan, there are more than 1.6–1.7 million tons of gypsum waste plasterboard produced annually during the three stages of production, construction and demolition [12,15,17]. Recycled bassanite produced from gypsum wastes started recently in Japan as a way to solve this problem since the disposing of such wastes in landfill sites has many environmental restrictions according to the Japanese environmental regulations. Recycled bassanite was produced from gypsum waste plasterboard by heating. The application of recycled bassanite as a stabilizer material to improve the strength and mechanical properties of sand and clay soil was investigated. For that study, four different levels of recycled bassanite of 0%, 10%, 20% and 40% based on dry soil mass were mixed with the tested soils to investigate their effect on the strength and mechanical properties of the tested soils. Results showed that both the strength and the mechanical properties of tested soils were enhanced with the increase of the recycled bassanite content in soil mixture. Recycled bassanite had a significant effect on the improvement of sandy soil compared to clayey soil [9]. Recycled bassanite was used as a stabilizer material for silty sand soil. For this purpose, four different contents of recycled bassanite of 0%, 55, 10% and 20% based on soil mass were mixed with silty sand soil to improve the performance of the tested soil. Stabilized soil specimens were cured for different ages in a controlled room and then measured their compressive strength. Results showed that the use of recycled bassanite improved the strength and mechanical properties of the tested soil. The early curing time had a significant effect on strength increase compared to the later curing days [12,15]. Another study investigated the addition of recycled bassanite produced from gypsum wastes on the mechanical and environmental properties of clayey soil. Two types of solidification agents including Portland cement and furnace cement were used to prevent the solubility of bassanite as well as to improve the environmental properties of the tested soil. Results showed that recycled bassanite had a noticeable effect on improving the performance of clayey soil. Both types of cement used had a positive effect on the prevention of solubility and improved the environmental properties of the tested soil. Results indicated that it is better to use furnace cement as a solidification agent for soil stabilized with recycled bassanite since it is friendly to the environment and it has low cost compared to the use of Portland cement [16].

3. Materials and methods

3.1. Materials used

Three different types of materials were used in this research include two types of soils, recycled bassanite and furnace slag cement type-B. Soil samples were brought from two different sites, Kiryu and Tomioka, and these sites were already selected as test sections to investigate the feasibility of using recycled bassanite in road construction. Soil samples at Kiryu site were taken from a depth of 1–1.30 m below the original asphalt level while soil samples at Tomioka site were taken from a depth of 0.50–0.75 m below the original ground level. Kiryu site is already existed and this road is constructed from few years ago while there are many damages in the pavement section due to the weakness of subgrade soil. Subsequently, there is a section with a length of 100 m was selected to reconstruct using recycled bassanite as a stabilizer material. Tomikoa site is a new road under construction and it is planned to construct using recycled bassanite as a stabilizer for subgrade soil. Samples were obtained by excavation method, i.e. using an excavator machine, and then placed in plastic bags to transport for laboratory. Samples were stored in the controlled room at a temperature of 20 ∓ 1 and relative humidity more than 90% to prevent any change in water content. Soil samples brought from Kiryu site are named as K-soil and soil samples brought from Tomioka soil are named as T-soil. The mechanical and physical properties for the two types of the tested soils are determined and presented in Table 1. Fig. 1 shows grain size distribution curves for the two different types of the tested soils. According to AASHTO classification system, both types of soils can be classified as clayey soil fair to poor (A 7-6). Moreover, according to unified soil classification system, USCS, Kiryu soil can be classified as clay soil of high plasticity (CH) and Tomoika soil can be classified as silt of high plasticity (MH).