TECHNICAL NOTE

THE CHARACTERISTICS OF QUICK LIME CONSOLIDATED BRIQUETTE AS A SOIL STABILIZER

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ABSTRACT

Recently as the increase of the execution of work for the educational town engineering, the number of the underground constructions have been greatly increased. These constructions are mostly done by making narrow ditches.

Although, when they are paved again after the work, enough rolling compaction is required, it is lacking due to the restricted time and the space. Thus in many cases, after the surface treatment with asphalt mixture, they are overlaid waiting the consolidation settlement.

To gain a sufficient rolling compaction the lime stabilization is applied in the refilling soil, and so the good effect has been achieved. This way has made good results, so far. But due to the life limit of the underground installments when a redigging is necessary, it is pointed out that there remains the difficulty of redigging.

To solve these difficulties, QCB as a treatment agent has been developed. The use of this agent increases the internal inflation in the filling soil and as the result redigging can be done easily. Not only that, when this agent is used in place of the quick lime in the lime piling which is used as the stabilization for the deepseated ground, bearing capacity of the mixed soil of both soft soil and the pile and better soil strength constant are improved, but also early bearing capacity and shear stress of the pile, which could not be expected from formal quick lime piling, can be obtained.

Key words: cement, compaction, compressive strength, engineering development, lime, soft ground, soil stabilization (IGC: K6/K5/D9)

INTRODUCTION

Nowadays soil stabilizers are classified broadly into two groups such as lime system

and cement system. These materials, owing to the development of working methods for various uses, are highly evaluated in improving soft soils. However, the complication in

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selecting a proper stabilizer for the properties of soils treated and occurrence of pollution under construction are pointed out as problems. To overcome those problems, quick lime consolidated briquette (abbreviated to QCB) has been developed.

QCB is a soil stabilizer of lime/cement complex composed of the following materials: quick lime (granulated or powdered) which swells and generates heat absorbing soil water and cement (or granulated slags) which promotes early solidifying as a hardening material in the ratio 1 to 1. The mixture of quick lime and cement is cast under high pressure, and hardened as stiff as aggregates after mixed with a small amount of alkali reaction material, Al powder, which leads foaming and hardening during hydration induced by reaction with alkali ingredients. We report the characteristics of QCB, which have the same density, moisture absorption and swelling effect as quick lime. QCB can be made into the form of light aggregates immediately after moisture absorption.

Fig. 1. Briquette systems and demensions

THE ACTIONS AND THE EFFECTS OF QCB

Each QCB is composed of the ingredients in the ratio shown in Table 1. The materials were mixed, given pressure of cast in the briquette machine (Fig. 1), and made into a large

Fig. 2. Pressure of cast and breaking load

Table 1. Component materials

Component QCB	Swelling Materials		Hardened Materials		Additives (NaPO_3) ₆
	Quick Lime	Al powder	Cement	Granulated Slag	
No. A	V/2	Small amount	V/2	—	—
No. B	V/2	Small amount	—	V/2	—
No. C	V/4	V/4	V/2	—	—
No. D	V/4	V/4	—	V/2	—
No. E	2 V/3	—	V/3	—	—
No. F	2 V/3	—	—	V/3	—
No. G	14 V/30	V/30	14 V/30	—	V/30

- V=volume of QCB
- (Note) • QCB used here are in the form of grain
- Al powder is used as a forming and hardening material

amount of almond shaped briquettes which has the density of 2.3~2.7 and initial breaking load of 20~50 kgf.

First, briquettes composed of the materials shown in Table 1 were produced under different pressures of 5t, 10t, and 30t in the briquetting machine and cured in loam. The change of its hardening strength is shown in Fig. 2. It is apparent that the pressure of cast affects hardening strength after moisture absorption.

Secondly, compaction test JIS A 1210-1980 (the second method) was carried out on the specimens of primary mixture of loam and QCB. Specimens contain loam at the water content of 15%, 20%, 25%, 30%, and 35%, respectively. QCB No. A, No. B, and No. E, which was 10% of each loam, were also admixed in the specimens, respectively. The relation between CBR and swelling ratio after four day submerged and unsubmerged curing is indicated in Fig. 3. The swelling ratios of the admixed soils were higher than those of the control loam, and the swelling effect, or internal inflation, of the QCB mixtures increased rolling compaction effects and reduced submergence of the refilled soil. Admixing QCB in loam also helped to increase bearing power of soil.

Principles of Reaction

The reactions are classified into three stages :

the first stage is the formation of dehydrated lime due to the reaction with soil water; the second stage leads foaming due to the reaction

Fig. 3. CBR and swelling content

Table 2. Acting principle of QCB

$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + 15.6\text{Kcal/mol}$					
[Molecular weight]	56	18	74		
[Specific gravity]	3.3	1	2.2		① Slaking and moisture absorption
[Weight ratio]	1	0.32	1.32		② Swelling
[Volume ratio]	1		1.99		③ Heat generation
$\text{Ca(OH)}_2 + 2\text{Al} + 2\text{H}_2\text{O} \rightarrow \text{Ca(AlO}_2)_2 + 3\text{H}_2\uparrow$					
[Molecular weight]	74	54	36	158	6
[Specific gravity]	2.2	2.6	1		
[Weight ratio]	1	0.73	0.49	2.14	0.08
	(1.32)	0.96	0.65	2.82	0.11
[Volume ratio]					⑤ Moisture absorption
<div style="display: flex; align-items: center;"> <div style="margin-right: 20px;"> [Foaming] $\left\{ \begin{array}{l} 54 \\ 0.01\text{g} \\ (0.02\text{g}) \end{array} \right.$ </div> <div style="margin-right: 20px;"> $\xrightarrow{\quad\quad\quad}$ </div> <div> 22.4×3 X $=12.4\text{ml}$ $(=24.8\text{ml})$ </div> </div>					
					⑥ Foaming (Swelling)
					⑦ Formation of hardened product
$\text{Cement} + \text{H}_2\text{O} \rightarrow \text{Hydrated hard product}$					
[Molecular weight]		18			
[Specific gravity]	3.2	1			⑧ Moisture absorption
[Weight ratio]	1	0.30	1.30		⑨ Formation of Hydrated hard product
[Volume ratio]

Fig. 4. Moisture absorption time and temperature rise

of the dehydrated lime and Al powder; in the third stage hydrated hard product is formed owing to the reaction of cement (granulated slags), dehydrated lime, and soil water.

The first stage caused quick reduction of soil water and swelling. In the second stage, Al powder acted upon dehydrated lime and caused the formation of hydrogen and foaming, so that swelling effect in the first stage was promoted and the product, $\text{Ca}(\text{AlO}_2)_2$ was formed. In the third stage, after cement (granulated slags) reacted to dehydrated lime and water, consolidation was promoted, and swollen QCB were quickly consolidated into the form of light aggregate. The reaction is summarized in Table 2.

On QCB No. A, No. A(S) containing powder quick lime in place of granulated ones, and quick lime, the absorption time and temperature rise were measured with a thermoelectric couple on the same number of those samples respectively. The result is shown in Fig. 4. It is indicated that QCB reacted slowly and had low temperature compared with quick lime.

Dehydrating Effect

QCB absorbs water from the surrounding soil since it requires a large amount of water for hydration. It has a great dehydrating effect for soft soil. Besides functions shown in Table 2, QCB has dehydrating effect due to swelling and consolidating, chemical dehydration, and dehydration due to evaporation. The water

Fig. 5. Mixed rate and water content

contents in quick lime and QCB No. A were obtained from the equation below taking those dehydrating effects into consideration, and the comparison of the calculated values and the values of the experimental is shown in Fig. 5.

$$\Delta W = \frac{1.32 \cdot w + 0.07}{1 + 1.32 \cdot aw_1} \times aw_1 + \frac{1.30 \cdot w + 0.30}{1 + 1.30 \cdot aw_2} \times aw_2 + \frac{2.82 \cdot w + 0.65}{1 + 2.82 \cdot aw_3} \times aw_3$$

ΔW : water content decrease

w : soil water content

aw_1 : quick lime

aw_2 : cement (granulated slag)

aw_3 : mixed rate of Al

It is indicated that the dehydrating effect (water content decrease) of QCB is no less than that of quick lime.

Swelling

The volume of dehydrated lime in QCB increased to approximately 1.5 times of its initial volume after moisture absorption and slaking following swelling when the volume of quick lime contained in each QCB was half of the whole volume. Furthermore, hydrogen (foaming) was formed by the reaction of dehydrated lime, Al powder (the required reaction volume is 0.02% the volume ratio), and soil water, and the QCB swelled by 50% more of the initial volume.

Then, the volume of QCB after moisture

Fig. 6. Moisture absorption time and swelling

(Before Reaction) (After Reaction)
 (primary mixture in loam 2 weeks after mixing)
 Photo. 1. Swelling Effect of QCB

Fig. 7. Breaking load of QCB

absorption and swelling became double of the initial volume, and QCB showed the same swelling effect as when quick lime was solely used.

Fig. 8. Mixed rate and unconfined compressive strength

Fig. 9. Mixed rate and CBR

Column specimens (ϕ 3.5 cm, L 2.5 cm) were made of QCB No. A, No. A(S) containing powdered quick lime, and quick lime respectively, and moisture absorbing time and swollen volume are shown in Fig. 6. It is indicated that the volume of QCB after swelling increases by double of the initial volume.

Self-hardening

QCB became itself a self-hardening material

Fig. 10. Time and unconfined compressive strength

Fig. 11. Compressive strength of pile

in hydration, and when admixed in, it solidified soon under the swollen condition into the form of lightweight aggregate. ϕ 15 cm mold was applied to cure QCB No. A and No. A(S) in loam. The breaking loads to each QCB under curing are shown in Fig. 7. Also the relation between the QCB mixed rate in secondary mixed QCB No. A (admixed again one hour after the primary mixing) and the unconfined compressive strength is shown in Fig. 8, and the relation between the QCB mixed rate and the CBR is indicated in Fig. 9. Fig. 10 illustrates the relation between the curing time and the unconfined compressive strength.

When QCB was placed in the form of a pile, it gave the same dehydrating effect and solidifying effect to the surrounding soil as those of

[pile 40cm in diameter and 13m in length immediately after driving into silt soil]

Photo. 2. QCB introduced

[pile 40cm in diameter and 13m in length 4 weeks after driving into silt soil]

Photo. 3. Pile hardening

the usual quick lime pile. Furthermore, after swelling, the QCB pile hardened itself immediately and played a perfect role as a bearing pile,

so that it increased bearing power of the mixed soil.

Piles made of QCB No. A, No. A(S), and quick lime 30 cm in diameter and 3 meter in length were driven into silt ($w_0=45\%$, $G_s=2.650$), respectively. Fig. 11 illustrates the compressive strength of cores (ϕ 5 cm, L 10 cm) after reaction and curing. QCB pile was 20 times stronger than usual quick lime piles. As a result, more stabilizing effect can be expected.

RESULT

Quick lime consolidated briquette shows the same moisture absorption and swelling effect as quick lime has, and its main properties are comparative slow reaction, low temperature under reaction, and quick consolidation after reaction. Therefore, QCB is easy to handle and superior in practical use compared with quick lime which shows sudden reaction and high temperature in reaction.

When drilling and back refilling, giving primary mixture of QCB and rolling compaction stabilize the refilled soil quickly due to the moisture absorbing, consolidating, and swelling effect of QCB (increase of rolling compaction on the refill and bearing power), so that submergence of surface layers caused by live loads

can be reduced.

When executing the treatment of surface soil, in addition to the primary mix, admixing a proper amount of QCB in the soil treated helps to stabilize the soil quickly.

Furthermore, when QCB is placed in the form of pile, QCB admixed soil can be an improving method for soft ground since its quick hardening effect to the surrounding soil brought about by the moisture absorbing and swelling effect of QCB increases the strength of the ground quickly. On the course of the reaction, QCB pile itself hardens rapidly and turns into a consolidated pile, so that the shear stress and the bearing power of the pile become satisfactorily strong and the soil becomes more safe from sliding and breaking.

Quick lime consolidated briquette requests less expensive cost and shorter working term and has a quick improving effect as well as reliability. It is also economically superior, and the wide scope of its usage can be expected when present high technology is applied.

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