

EFFICIENCY OF ALBUMIN AND EGGSHELL POWDER IN SOIL STABILIZATION

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ABSTRACT

A new approach to soil stabilization is presented in this study using two newly introduced materials, artificially manufactured albumin and eggshell powder (E.S.P.). Albumin, which was used a long time ago in some middle east countries as a water-proofing agent (prime coat) under painting, and in Japan as a main component of the mortar in building masonry-arch bridges, is used here in an attempt to improve and stabilize the problematic *Shirasu*. Eggshell powder was tried also in the hope of some similarity to albumin. *Shirasu* was mixed with 1.0%, 1.50% and 2.0% of albumin and with 5.0%, 10.0% and 15.0% of eggshell powder based on its dry weight and then compacted to a constant density before being oven dried at different temperatures. Direct shear tests, unconfined compression tests, slaking tests and permeability tests were performed. All tests produced very good results, especially in raising the shear strength and the unconfined compressive strength, with albumin; they did not give the desired results with eggshell powder.

Key words: albumin, biodegradability, eggshell, permeability test, slaking test (IGC: D6)

INTRODUCTION

In Japan earth reinforcement has become a very important issue because the country has so many problematic soils such as Ariake clay and *Shirasu*. This paper describes the use of new materials for *Shirasu* improvement and stabilization, albumin and eggshell powder. Natural albumin has been used in some middle east countries since ancient times as a water-proofing agent against humidity under paints. Furthermore it was used in Japan as a mortar in building masonry-arch bridges still in service until now (Yamaguchi, 1992). This gives a clear indication of the long term performance of albumin, especially against biodegradability. Eggshell powder was used in the hope of some similarity to albumin. Since albumin is composed of many chemical materials, it is not yet known which part of the albumin plays the major role in soil improvement. The main purpose of using eggshell powder in this research was to obtain a well stabilized soil at low material cost. Temperature also plays a major role in stabilizing soil when using albumin and eggshell powder in *Shirasu* improvement. In this paper the treated *Shirasu* was dried at different temperatures range from 30–50°C. In order to investigate the effect of albumin and the eggshell powder on the improved *Shirasu*, four kinds of tests were performed. These tests were direct shear test, unconfined compression test, permeability test and slaking test. All tests produced very good results

when using albumin but did not give the same results with eggshell powder. This is due to the difference of the chemical components of the two materials. Since there is no literature concerning the use of albumin in the field of soil improvement, it is hoped that this paper may lead to further research using albumin for the improvement of other kinds of soils.

OUTLINE OF USED *SHIRASU* AND ALBUMIN*Shirasu*

Shirasu which originated from pyroclastic flow deposits in Kagoshima prefecture at the southern part of Kyushu Island, Japan has the property of soft rock in its undisturbed state. This is due to thermal welding and metamorphism. In Japan, *Shirasu* is considered a problematic soil because of its strange engineering behavior when compared with other soils (Yamanouchi et al., 1976). An example of this is its low permeability coefficient, even though its void ratio is high. The apparent cohesion of *Shirasu* is also higher than other kinds of soil, due to strong interlocking between its particles. The main problems of *Shirasu* are a) erosivity of slopes against heavy rains, b) when disturbed it does not exhibit any sign of strength and c) collapsibility of *Shirasu* slopes under heavy rains. *Shirasu* has a specific gravity of 2.45, uniformity coefficient of about 13, permeability coefficient of 4.3×10^{-5} cm/s, quartz content of 70%,

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and silica content of 15% (JSSMEE Kyushu Chapter, 1974); its grain size distribution (gravelly sand with 12% silt) is shown in Fig. 1 and moisture content-dry density relationship is shown in Fig. 2.

Albumin

Albumin's chemical composition is shown in Table 1, this shows that it contains a large percentage of water and protein. In this research, artificially manufactured albumin was used which is being manufactured in Japan. Among the components of albumin it is as yet unknown which part is responsible for *Shirasu* hardening. For eggshell powder, we used the real thing after crushing it

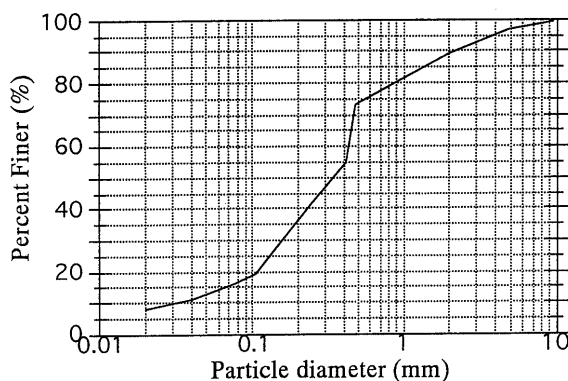


Fig. 1. Gradation curve of *Shirasu*

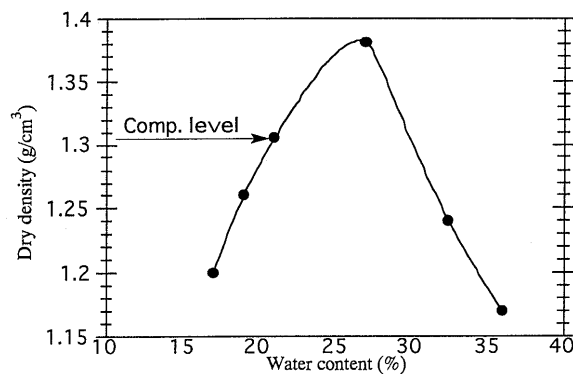


Fig. 2. Water content-dry density curve of *Shirasu*

Table 1. Components of albumin

Components	Percentage (%)
Water	87.66
Protein	10.4
Fat	0.9
Ash	0.7
Calcium	0.009
Phosphorous	0.011
Iron	0.0001
Sodium	0.18
Potassium	0.00059
Vitamin	0.14

After Q.P. The manufacturing company of albumin.

into a power form. The components of the eggshell are still unknown.

METHODOLOGY AND TEST SPECIMENS

Shirasu was obtained from a slope failure in Kagoshima city. A standard proctor test was conducted in order to ascertain its water content-dry density relationship. The normal particle size of *Shirasu* was used without any sieving. All the specimens were prepared and compacted up to 90% of the optimum moisture content at a dry density of 1.30 g/cm³ and at a water content of 21%. For the direct shear test a total of 27 specimens were prepared by mixing *Shirasu* with 1.0%, 1.50% and 2.0% of albumin based on the dried weight of *Shirasu*. This was followed by adding the proper amount of water and compacting each specimen in a small cylinder 60 mm in diameter and 20 mm in height; this was specially designed in order to have the specimens size exactly the same as the size of the direct shear test apparatus box. The compaction of these specimens was achieved by using a long metal rod attached to a circular metal base 50 mm in diameter and with a thickness of 10 mm. The proper compaction was achieved by making the soil sample fit the predesigned cylinder. This was followed by oven drying the specimens at different temperatures of 30, 40 and 50°C. For eggshell powder specimen preparation, the above procedure was followed exactly with the only change being in the percentage of eggshell powder: 5.0%, 10% and 15%. For the unconfined compression test and slaking test specimens the same procedure of mixing was followed and the soil was compacted in long side cylinders 110 mm in height and 50 mm in diameter for three layers using a 1 kg hammer with a circular base. Then all the specimens were oven dried at different temperatures. For the permeability test, *Shirasu* was mixed with albumin and with eggshell powder separately at the same percentages of the direct shear test specimens and compacted inside a mold 110 mm in height and 100 mm in diameter in three layers by giving 25 blows with a 2.5 kg hammer. This was followed by placing the mold with the specimen inside in the oven to be dried at different temperatures.

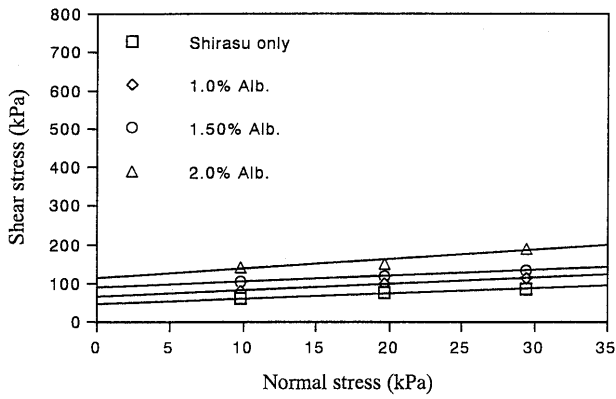
RESULTS AND DISCUSSION

Direct Shear Test

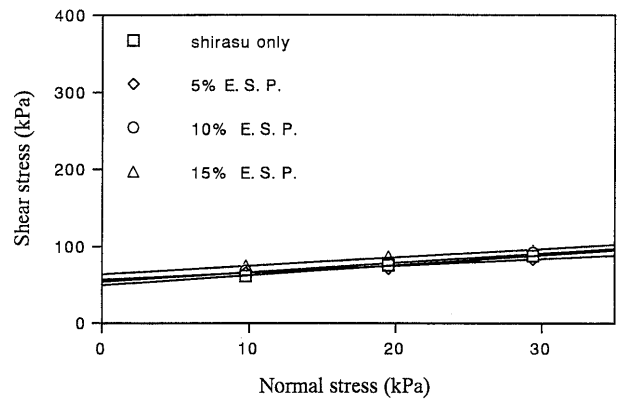
Figures 3(a), 3(b) and 3(c) show the results of the direct shear test on 27 specimens using albumin at different temperatures and at different percentages. These tests were strain controlled and easy to perform because the specimens did not change in volume even though they were oven dried. Based on these figures, changes of cohesion and internal angle of friction are well observed. As an example, the cohesion of *Shirasu* was increased up to three times at 2.0% of albumin at a temperature of 50°C. Changes of cohesion and internal angle of friction are summarized in Table 2. These results may be due to the strong bonds created as a result of chemical reactions be-

tween sodium, calcium and the silica which might form a kind of silica gel between *Shirasu* particles. *Shirasu* improved with eggshell powder produced different results.

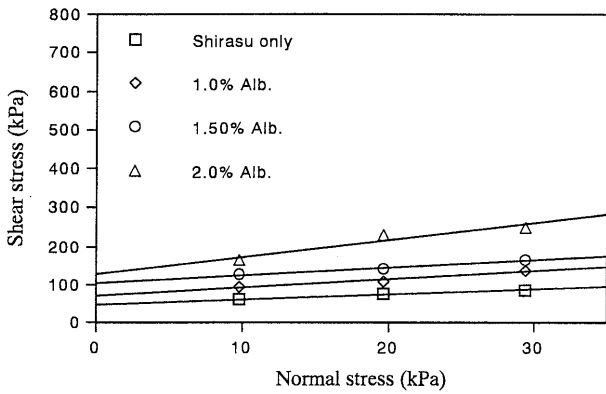
The general trend of the treated *Shirasu* at low temperature is an increase in cohesion and a decrease in the internal angle of friction. This is in contrast to the behavior of



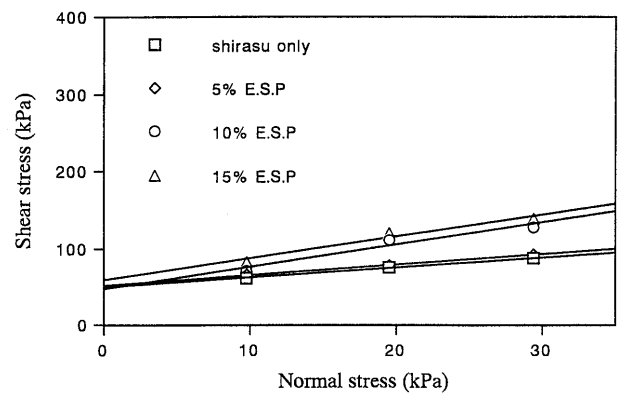
(a) 30 °C



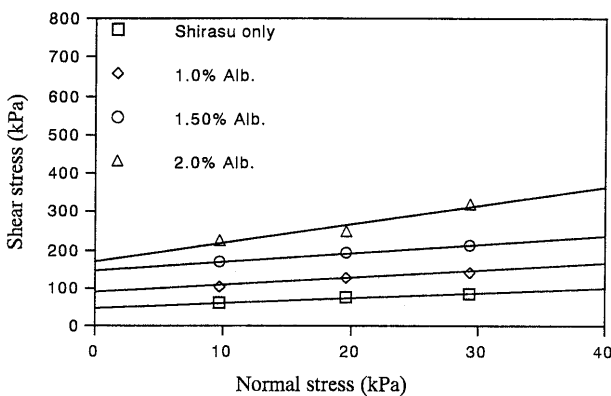
(a) 30 °C



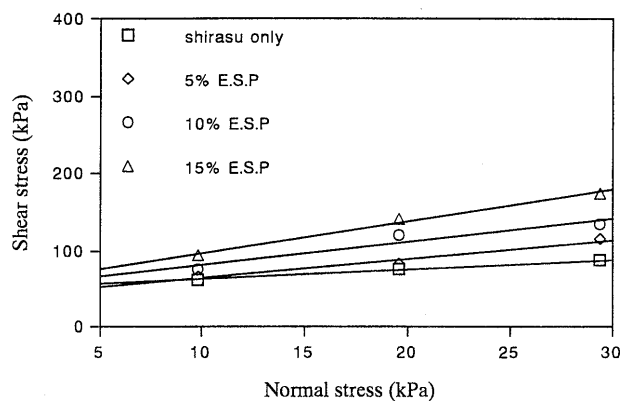
(b) 40 °C



(b) 40 °C



(c) 50 °C



(c) 50 °C

Fig. 3. Direct shear test results of *Shirasu* mixed with albumin at different temperatures

Fig. 4. Direct shear test results of *Shirasu* mixed with eggshell powder at different temperatures

Table 2. Changes of cohesion and internal angles of friction with increase of albumin percentages and temperature

	<i>Shirasu</i>				<i>Shirasu</i> + 1.0% Alb.			<i>Shirasu</i> + 1.50% Alb.			<i>Shirasu</i> + 2.0% Alb.		
Temp. (°C)	20	30	40	50	30	40	50	30	40	50	30	40	50
ϕ (deg.)	52	58	66	58	55	63	66	69	77	79			
<i>C</i> (kPa)	49	64.68	68.6	90.16	88.2	104.86	147.98	110.74	127.4	149.94			

Table 3. Changes of cohesion (c) and internal angle of friction (ϕ) as obtained by direct shear test

1) Dried at temperature of 30°C

E.S.P. (%)	c (kPa)	ϕ (deg.)
5%	55.86	44
10%	53.9	51
15%	64.68	47

2) Dried at temperature of 40°C

E.S.P. (%)	c (kPa)	ϕ (deg.)
5%	51.94	52
10%	46.06	70
15%	58.8	71

3) Dried at temperature of 50°C

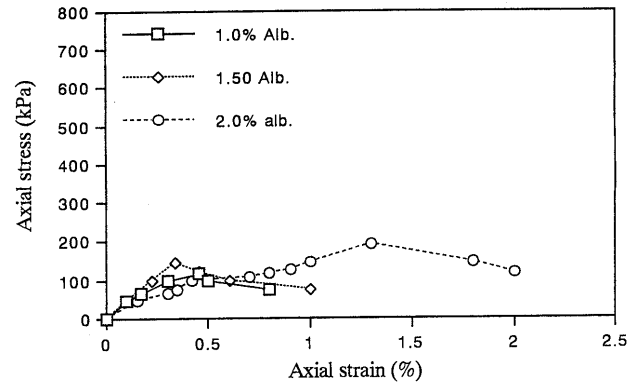
E.S.P. (%)	c (kPa)	ϕ (deg.)
5%	38.22	68
10%	49	72
15%	55.86	76

Shirasu when oven dried at high temperature, because it shows an increase in the internal angle of friction with no noticeable changes in cohesion. Figures 4(a), 4(b) and 4(c) together with Table 3 show the complete results of the direct shear tests on *Shirasu* treated with eggshell powder. For albumin, it is believed that performance in the field (heating) could be better than in the laboratory. This is because the albumin treated soil will be heated under full overburden pressure. The procedure of heating the soil in the field is performed by making a hole 10–20 cm in diameter vertically to the depth that requires stabilization. A burner utilizing fuel oil or gas with compressed air is introduced near the bottom of the hole to create a column of burning gases that heats the walls of the hole to a temperature exceeding 1100°C. The heat is then diffused into the soil by conduction (Sowers, 1970).

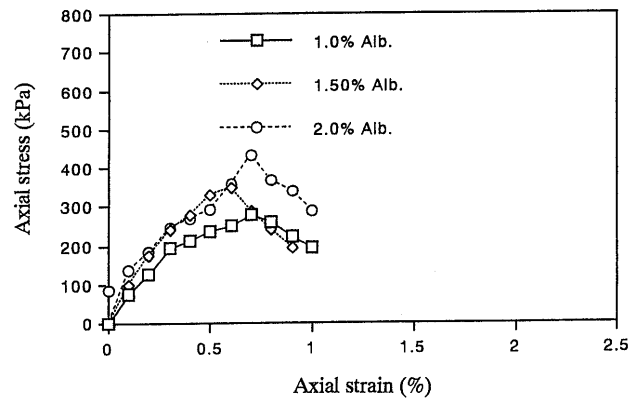
Unconfined Compression Test

Figures 5(a), 5(b) and 5(c) show the axial stress-strain curves of *Shirasu* improved with albumin at various conditions. The compressive strength increased remarkably with the increase of both the albumin percentage and temperature. These results are identical with the results obtained from the direct shear test in showing that the temperature plays a major role in the performance of albumin. Unconfined compression tests cannot usually be performed for testing cohesionless soils such as *Shirasu* (Jumikis, 1962); even so, it was successfully achieved by using albumin. These results indicate how strongly albumin functions as a bonding agent.

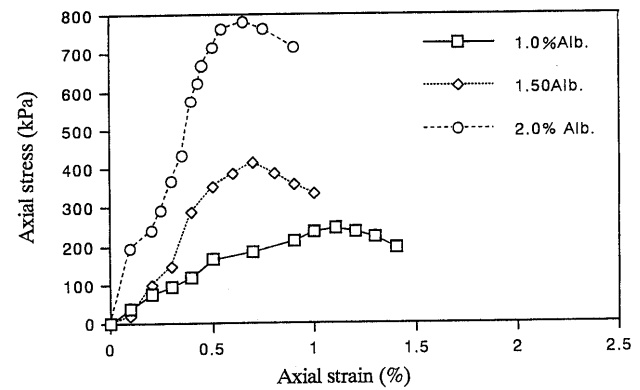
For the eggshell powder, however, results were different. As shown in Figs. 6(a), 6(b) and 6(c) the general trend of the eggshell powder-treated *Shirasu* is an increase in axial strength at moderately low temperature. Comparing Figs. 5(a) and 5(b) with Fig. 5(c), it can be seen that the axial strength of the improved *Shirasu* is proportional to the temperature up to 40°C, and beyond that it tends to decrease for all the percentages of eggshell



(a) 30 °C



(b) 40 °C



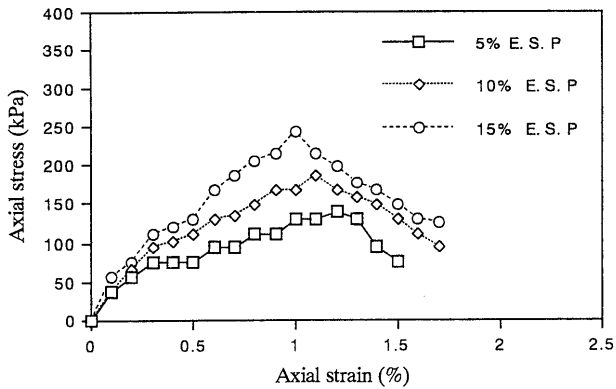
(c) 50 °C

Fig. 5. Unconfined compression test of *Shirasu* mixed with albumin at different temperatures

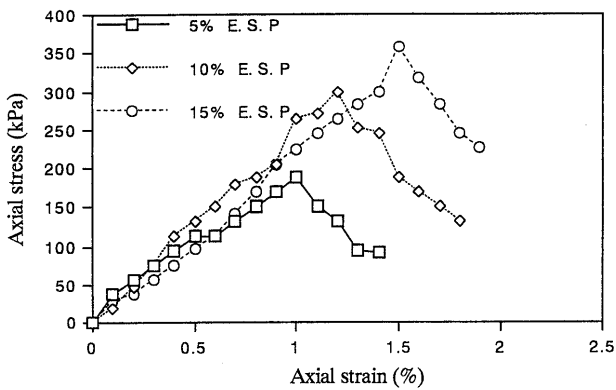
powder used. It is also evident that the highest strength obtained is only 1/2 of the strength obtained by the albumin.

Slaking Test

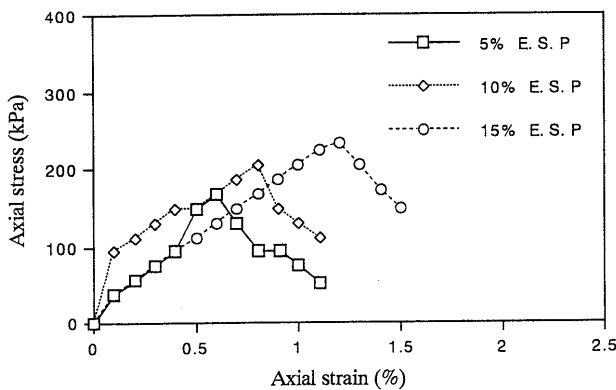
A slaking test is a simple test usually conducted by submerging the dry specimen in water and measuring the elapsed time before the upper half of the specimen collapses (Akagi et al., 1992). For specimens of *Shirasu* without albumin, the maximum elapsed time was about 40 seconds, while for *Shirasu* mixed with albumin at any



(a) 30 °C



(b) 40 °C



(c) 50 °C

Fig. 6. Unconfined compression test of *Shirasu* mixed with eggshell powder at different temperatures

percentage or any temperature none of the specimens collapsed before 15 days. In addition, specimens with 2.0% albumin at a temperature of 50°C collapsed after 125 days. The complete results of the slaking tests are shown in Fig. 7. These results indicate that albumin is functioning well in two ways: first as a bonding agent since the bonds which were created by the albumin were stronger than the build up pressure as water filled the voids. Second, as a water-proofing agent since at the beginning of the test many air bubbles were observed at the surface of the water. Inside these bubbles there were some *Shirasu*

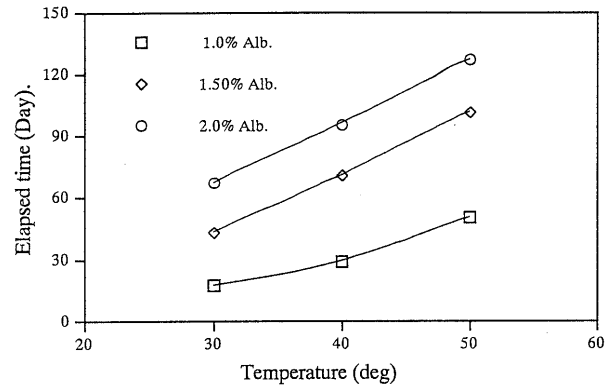


Fig. 7. Results of slaking test of *Shirasu* mixed with albumin at different temperatures

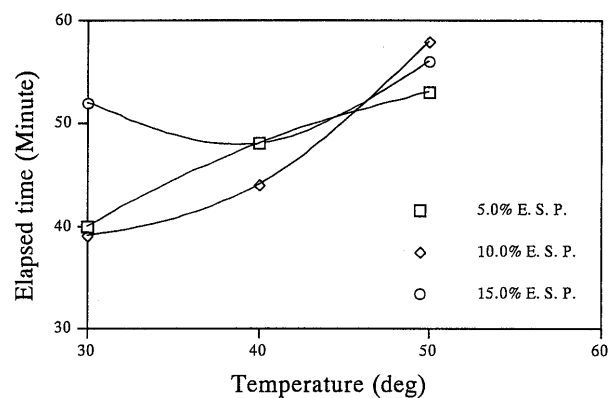


Fig. 8. Slaking test results of *Shirasu* mixed with different percentages of eggshell powder

particles. When breaking these bubbles and taking the *Shirasu* particles out of the water, the *Shirasu* particles were completely dry. This shows that the disintegrated *Shirasu* particles are sealed off with albumin.

In the slaking tests, 9 specimens were tested by using different percentages of eggshell powder. The specimens were dried at various temperatures and submerged immediately in a tank previously filled with water. As shown in Fig. 8 the maximum elapsed time was about one hour. There was no significant sign of change in the elapsed time with the change of the percentages of the eggshell powder used. From the results obtained it is concluded that there is no improvement in the slaking time of *Shirasu* using eggshell powder.

Permeability Test

Permeability is defined as the property of a porous material which permit the passage of fluid through its voids. Its importance in soil stabilization depends strongly on the nature and the desired function of the ground to be stabilized. In *Shirasu* stabilization, due to high tortuosity of pores, collapse under seepage forces is possible, so reducing the permeability of *Shirasu*, is desirable. As previously mentioned, albumin is expected to be a good water-proofing agent when mixed with soil. With

this in mind the coefficient of permeability of *Shirasu* was reduced to about one-sixth by using 2.0% of albumin at 50°C as shown in Fig. 9. In this research falling head permeability tests were performed. All of these tests were time-consuming because *Shirasu* treated with albumin does not absorb water easily. As an example, to get the specimens saturated before testing generally took 4 to 5 days. Complete results of these tests are shown in Fig. 9 which shows that the permeability coefficient decreases with increase of albumin at any temperature equal to or above 30°C.

Figure 10 shows the results of the permeability tests of *Shirasu* mixed with different percentages of eggshell powder. The general trend of the treated *Shirasu* is an increase in permeability over that of untreated *Shirasu*. The *Shirasu* was not heated at higher temperature because that was shown to be ineffective by the slaking test. When the eggshell powder percentage increases it is noticed that the permeability coefficient is less than when small amounts used. From this it is concluded that

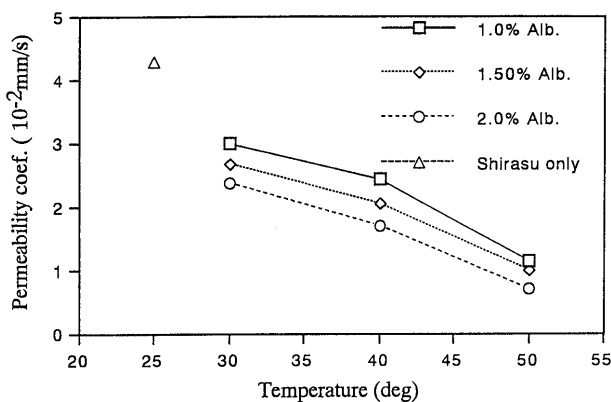


Fig. 9. Changes of permeability coefficient of *Shirasu* mixed with albumin

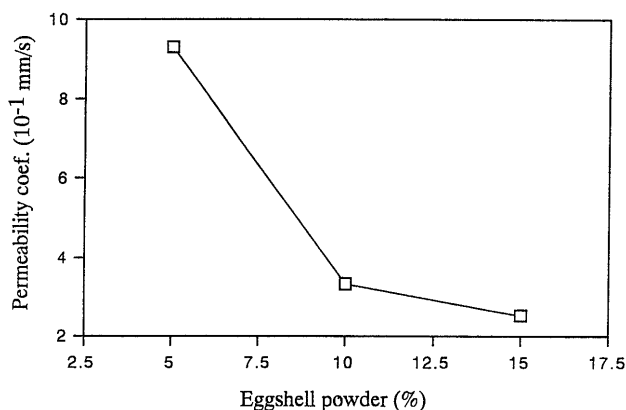


Fig. 10 Permeability test results of *Shirasu* mixed with eggshell powder at temperature of 40°C

eggshell powder is of inverse effect when used in *Shirasu* improvement for the reduction of permeability.

CONCLUSION

Results of this research have shown that albumin can be successfully used as a reinforcing material in the field of soil improvement and soil stabilization. As of now there is insufficient information available about albumin durability, except for the information about albumin use as a mortar or as a water-proofing agent in ancient times. Based on this little information, there is no signs of biodegradability in albumin. For mixing soil with albumin and raising the temperature of the mix, there are some easy methods that can be used. First, to use the albumin in grouting material, especially in places of slope-failure locations or high embankments, and then raise the temperature by making holes in the ground and using fuel oil burners as described by Sowers (1970). Second, if albumin is to be used in areas of shallow depth, such as road pavements, it can be mixed with water at high temperature and spread into the soil before compaction. Active lime may be used also to raise the temperature of the albumin solution. Eggshell powder was used in this research in the hope of some similarity with albumin but mixing *Shirasu* with eggshell powder did not yield positive results like albumin. Accordingly, it is understood that the use of eggshell powder in *Shirasu* improvement is of no significant effect due mainly to its loss of strength upon the absorbance of water, as proved in the slaking test. Finally, since the price of albumin is expensive further research is recommended in order to identify the exact compounds within albumin, such as sodium and calcium, that react with silica and alumina and other chemical compounds presented in *Shirasu* to form new chemical compounds that have a direct effect on soil improvement.

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