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Elasto-plastic Deformation of Compacted Shirasu

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Introduction

The southern part of Kyushu is widely covered with shirasu, which is said to be a pyroclastic flow deposit. It is a basic foundation that we can not avoid when beginning agricultural land improvement, the construction of facilities, or a land conservation project in Kagoshima Prefecture. Therefore, it is very important to grasp the physical and mechanical properties of this soil.

In recent years, there has been handled within a range of plastic deformation in engineering design because the actual soils show plastic deformations. And soil structure design by numerical calculation has been utilized a lot. It is necessary to determine the elasto-plastic deformation properties from experimental results in order to propose a constitutive model that can be incorporated in the analysis of shirasu as a numerical formula. The present study was carried out for the purposes of realizing the deformation characteristics of shirasu[1] and of examining the elastic and plastic strain components empirically[4].

For the reason mentioned above, two kinds of repetitional loading tests were attempted using a triaxial testing apparatus allowing any given stress path to be induced[2]. In addition, a study concerning the elastic strain and the plastic strain separated from the obtained data[5], was carried out.

Materials and Methods

1. Experimental materials and testing apparatus

The shirasu samples used for this experiment were taken from Mizobe, Kagoshima Prefecture. Physical properties are shown in Table 1. The water content of the shirasu was reduced by 15%, after natural drying in the laboratory and sieving through a net of 2.00mm meshes. The specimens were compacted using a rammer in a cylindrical mold 50mm in diameter and 125mm in height, so as to have a specified initial density. Furthermore, the layer and compaction numbers were set in accordance with the form of Proctor's equation to give to

Table 1. Physical properties of shirasu

Density of soil particle	Mg/m^3	2.422
Sand fraction	(%)	78
Silt fraction	(%)	19
Clay fraction	(%)	3
Coefficient of uniformity	U_c	38.9
Coefficient of curvature	U_c'	3.84

three kinds of density. Initial void ratios were 1.01-1.04, 0.86-0.89 and 0.75-0.80 in order of the loose samples, respectively.

Attention was paid to the adjustment of initial densities at the specimen preparation stage in order to allow a precise comparison of results. The triaxial testing apparatus enabled the axial and lateral loads to be controlled independently. The data from each sensor were batch-processed with a personal computer. Two kinds of experimental method were tried out. One involved the repetitional loading and unloading of stress isotropically. Another involved the repetition of the loading and unloading stresses only in a vertical direction after the isotropic consolidation stage was finished. Examples of stress path control are shown in Fig. 1. Due to the accurate measuring of drainage discharge, the specimens were saturated completely by the vacuum procedure[3].

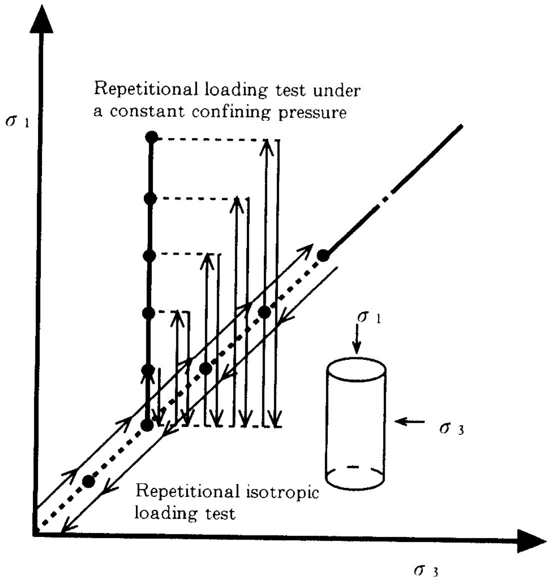

Fig. 1. Examples of stress path control.

2. Separation of the elastic and plastic components

At first, as the result of the repetitional isotropic loading tests, the axial and the lateral directions were loaded by 1.0kgf/cm^2 (98kPa). When the volume change rate reached less than 0.01%/min., stress was returned to zero. Then the stress was adjusted once again at 2.0kgf/cm^2 with the addition of 1.0kgf/cm^2, followed by unloading process. Thereafter the same operations were repeated. In the cases of the repetitional loading tests under a constant confining pressure, repetitions of loading and unloading were done only in the vertical direction. Furthermore, the maximum pressure was 5.0kgf/cm^2 (490kPa) under the compressor's available capacity.

When the stress was removed at a certain level as shown in Fig. 2, the strain did not wholly return to the initial point. If only the elastic strain component was returned, it would be possible to calculate the plastic strain by deducting it from the total strain at the time point of stress removed.

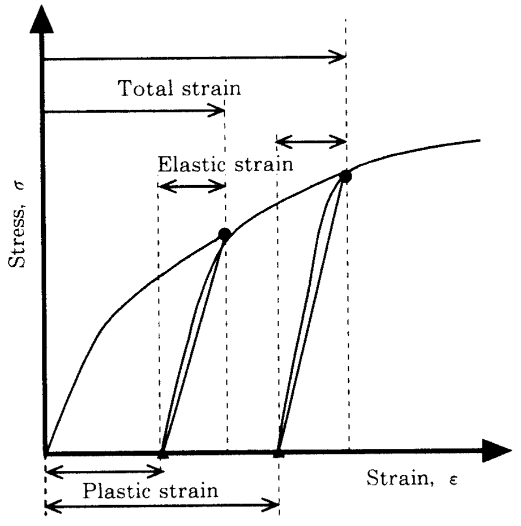

Fig. 2. Separation of elastic and plastic components.

Results and Discussion

1. Repetitional isotropic loading tests

Figs. 3 and 4 show the relationships between axial strain and isotropic stress and those of volumetric strain vs. isotropic stress by the repetitional isotropic loading tests, respectively. The some differences according to each initial void ratio could be noted, but the same loop lines were expressed before the failure of the specimens occurred. The relationships between volumetric strain and isotropic stress showed regularly a unique shape, but the specimens in which the failure occurred during the loading-unloading stages did not behave as seen before.

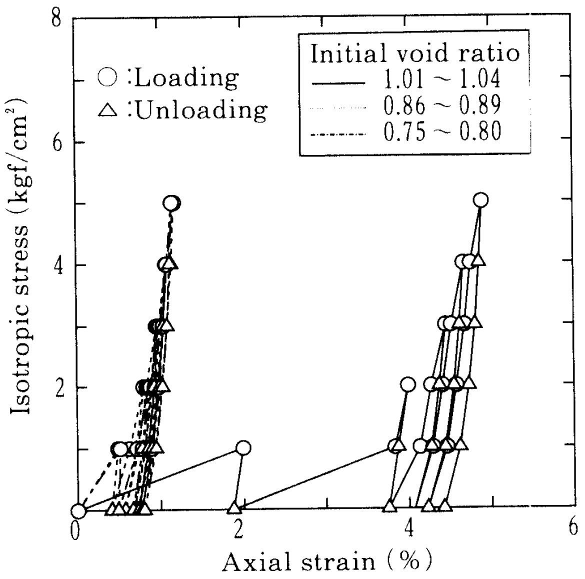

Fig. 3. Relationships between axial strain and isotropic stress.

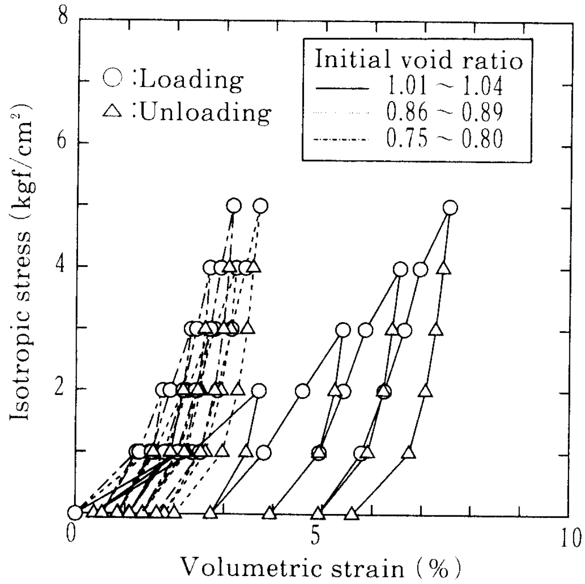

Fig. 4. Relationships between volumetric strain and isotropic stress.

The relationships between the axial strain and isotropic stress which was separated on the basis of these results to elastic component and to plastic one and those of volumetric strain vs. isotropic stress, are shown in Figs. 5 and 6, respectively. Judging from the differences among the respective initial void ratio, the denser was the specimen, the smaller was the value of the plastic component. It was noted that the higher was the stress, the larger was the differences. For example in Fig. 5, the value of the plastic component for the loose samples was approximately ten times as large as that of elastic component. On the other hand, from the denser specimens, no substantial differences were observed, as shown in Figs. 5 and 6.

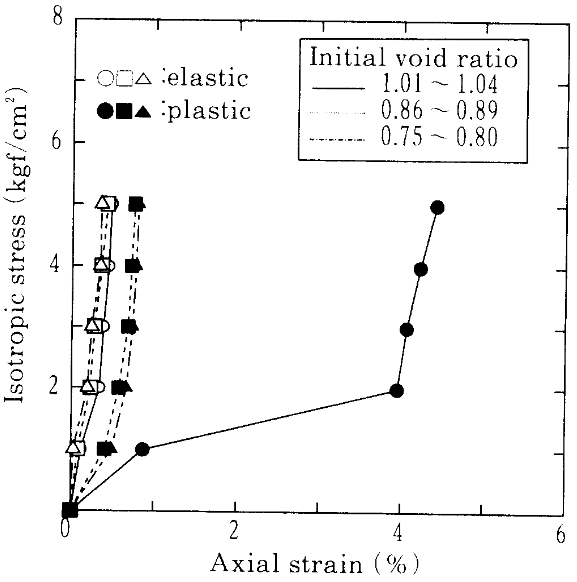

Fig. 5. Elastic strain and plastic strain in the case of axial strain due to isotropic stress.

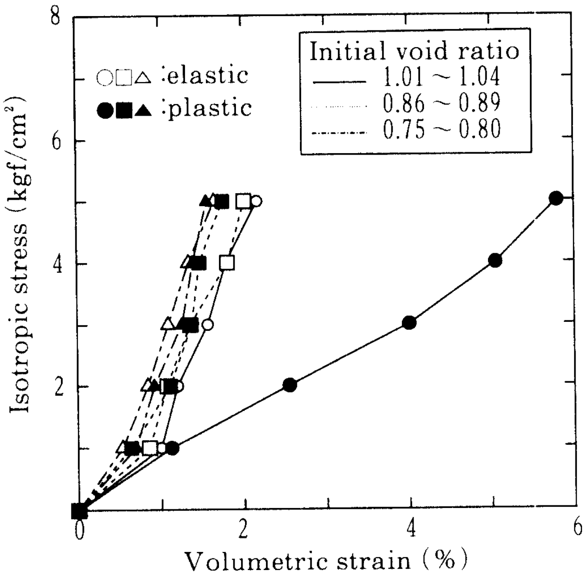

Fig. 6. Elastic strain and plastic strain in the case of volumetric strain due to isotropic strain.

If it may be granted that one-third of volumetric strain might be fixed as axial strain, it may be reasonably affirmed that this seems to be similar to the results obtained on the medium and dense samples. However, it was not possible to find the same inclination in the loose specimen, hence there remains the necessity to make further studies for in practical cases. Although the value of the included elastic component was assumed to be more than that of the plastic component, it was possible to confirm the existence of nearly the same quantities of strains in the saturated shirasu.

2. Repetitional loading tests under a constant confining pressure

The relationships between the axial strain and the deviatoric stress under a confining pressure of 1.0 to 5.0kgf/cm^2 at the three kinds of initial void ratios are shown in Figs. 7(a) to 7(e). Also, the relationships between the volumetric stain and the deviatoric stress are shown in Figs. 8(a) to 8(e).

In Figs. 7(a) to 7(e), these strain-curves were different from those for repetitional isotropic loading tests. Namely, they were represented in the shape of a convex curve running upward. In the early stages of loading-unloading for the loose samples, the inclination of stress-strain is related non-linearly, and the strain values increase with the increasing of confining pressure.

The relationships between the elastic strain and the plastic strain in the case of axial strain due to the deviatoric stress under a confining pressure of 1.0 to 5.0kgf/cm^2 at each initial void ratio are shown in Figs. 9(a) to 9(e). Also, the relationships between the elastic strain and the plastic strain in the case of the volumetric strain due to the deviatoric stress under a confining pressure of 1.0 to 5.0kgf/cm^2 are shown in Figs. 10(a) to 10(e). In Figs. 9(a) to 9(e), the elastic components included in the axial strain were quite small in size in comparison with plastic components. And they were independent of the deviatoric stress. From the relationships between volumetric strain and deviatoric stress, it was noted that elastic components after their consolidation showed some constant values under the lower pressure.

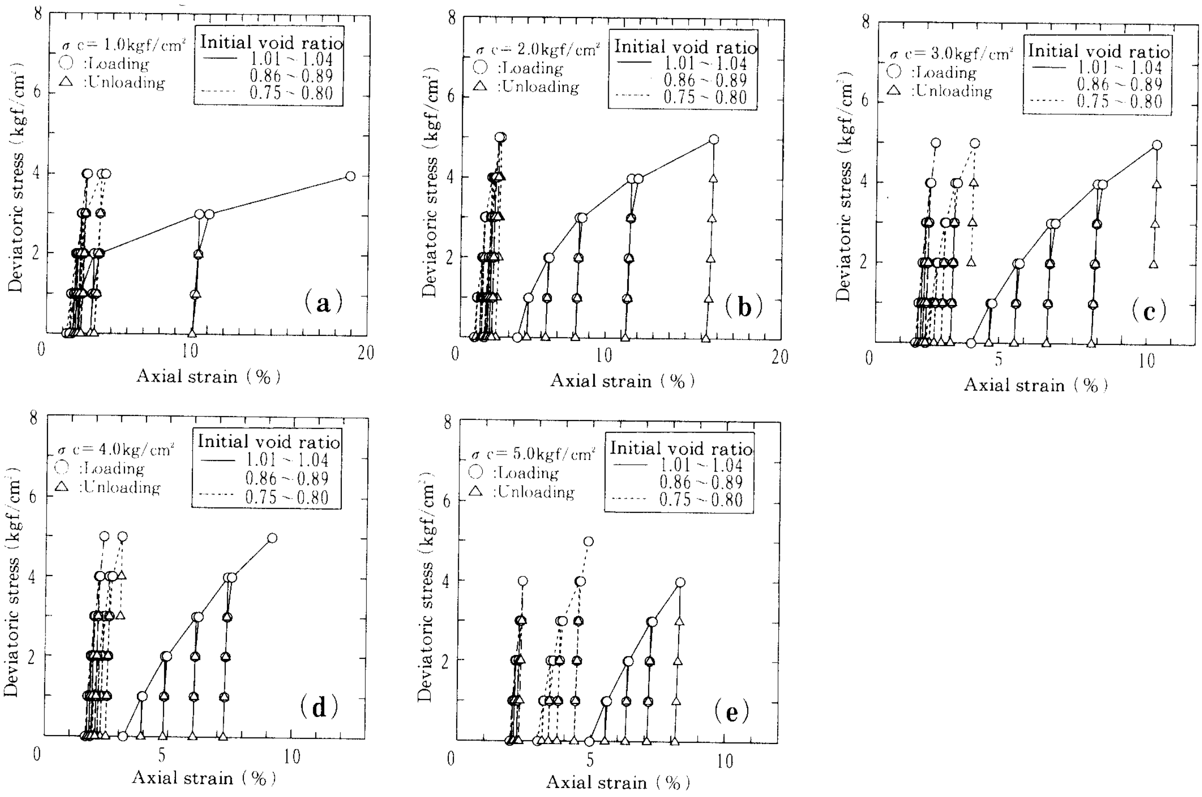

Fig. 7. Relationships between axial strain and deviatoric stress under a confining pressure of 1.0 to 5.0 kgf/cm².

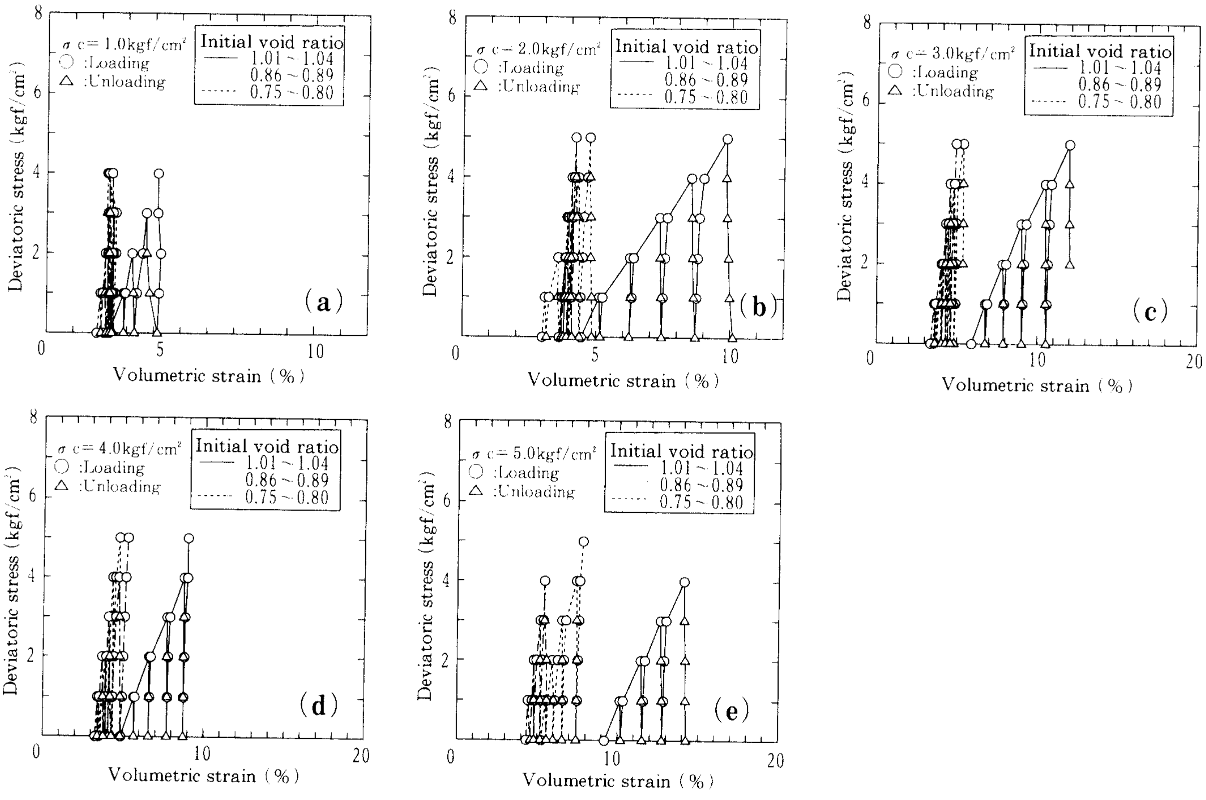

Fig. 8. Relationships between volumetric strain and deviatoric stress under a confining pressure of 1.0 to 5.0 kgf/cm².

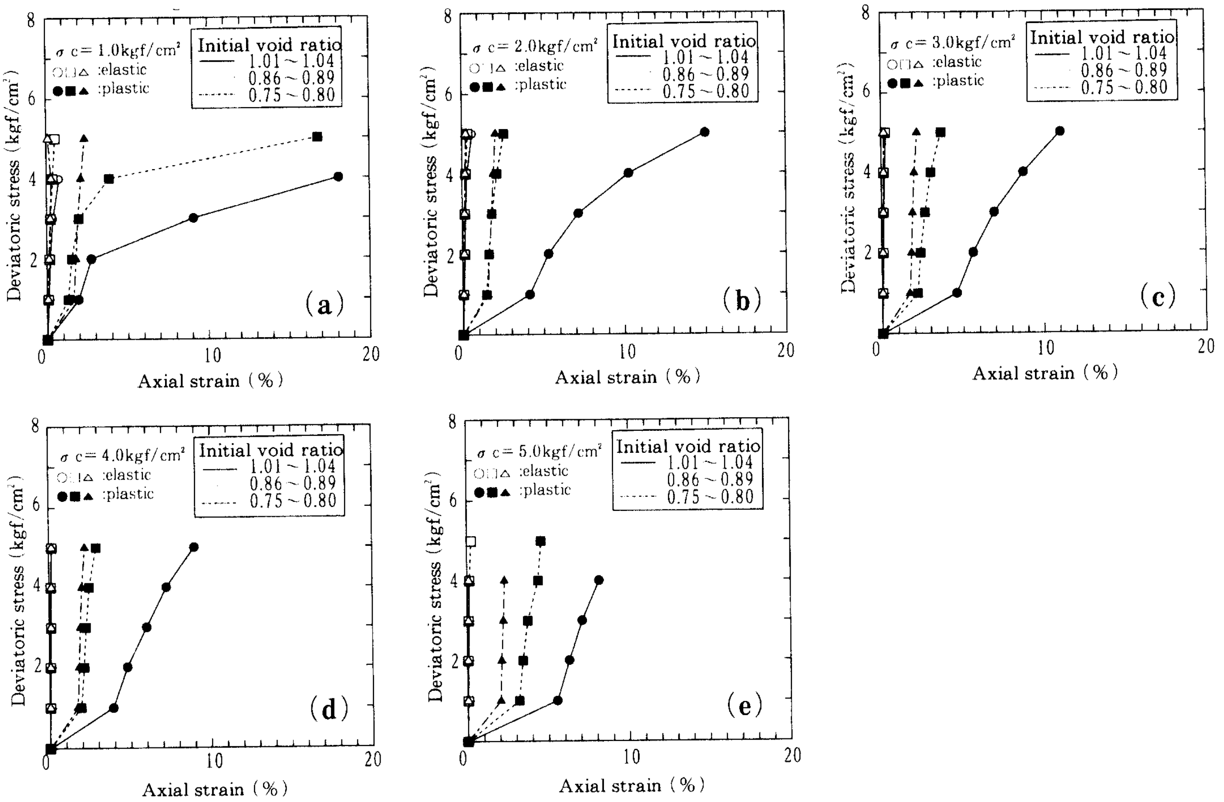

Fig. 9. Elastic strain and plastic strain in the case of axial strain due to deviatoric stress under a confining pressure of 1.0 to 5.0 kgf/cm².

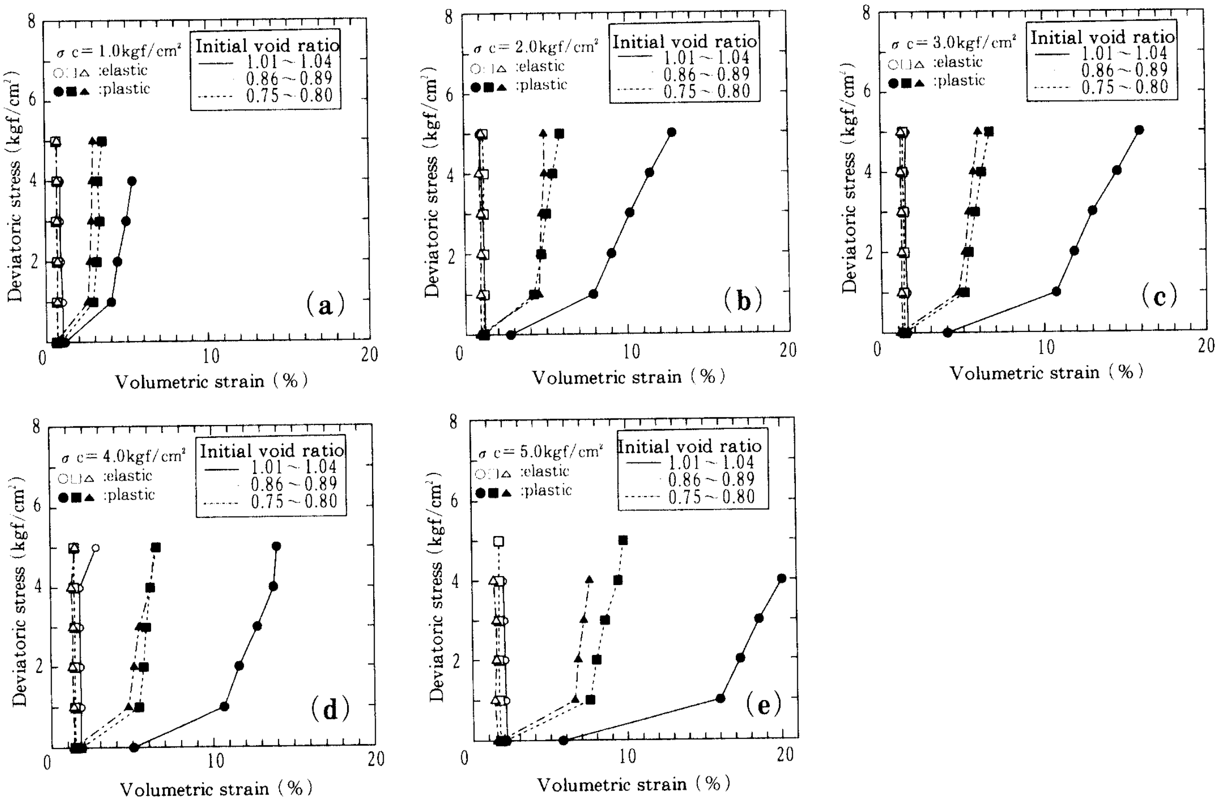

Fig. 10. Elastic strain and plastic strain in the case of volumetric strain due to deviatoric stress under a confining pressure of 1.0 to 5.0 kgf/cm².

Therefore, it was considered to be quite important to investigate the values of plastic components included in the total strain, in order to determine the yielding and failure of soil structures.

Summary

In order to clarify the elasto-plastic relationships in shirasu, two kinds of repetitional loading tests were performed on the compacted specimens with different initial void ratios. With the consideration of a slope failure caused by torrential rain, it was assumed that the increasing in the plastic components generated an increased likelihood of sliding failure and soil flow. Although this study was carried out chiefly on the deformation characteristics of shirasu, the results were summarized as follows.

From the repetitional isotropic loading tests, it was understood that the values of the elastic components and the plastic components in the total strains were approximately identical, when the sample was kept in a dense state.

On the other hand, from the experimental evidences obtained by the repetitional loading tests under a constant confining pressure, it was clarified that the elastic components were independent of the deviatoric stress, showing some constant values. Thus, it was assumed that the precise evaluation of the plastic components would indicate the determining factors in the yielding and failure.

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