# The Creep Behavior of Bottom Ash by controlling size at Undrained condition

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ABSTRACT

Bottom Ash is combustion byproducts produced from coal-fired power plant which is half proportion in the power production in Korea and it is increasing. 60% of Bottom Ash is dumped and recycling is urgent because landfill is going to reduce. Bottom Ash is used as embankment and drainage materials because Bottom Ash has properties similar to sand. But it is easily crushed so that makes bottom ash to act long-term settlement. Therefore the aim of the study is to find the characteristics of long-term settlement and to review the application of Singh-Mitchell creep equation to the creep behavior of Bottom Ash. In the undrained state, it was confirmed that creep behavior appeared in the range to 30-80% of the maximum deviator stress by applying condition in other three stresses through triaxial compression test after isotopically consolidation. And through sieve analysis, it was compared to each sample that was passing through 9.5mm, 2mm, 0.25mm sieves. Also, using Singh-Mitchell creep equation, it was compared between the theoretical behavior and the observed behavior for each sample. In the result, it is found that creep behavior of Bottom Ash is similar to the theoretical behavior of Singh-Mitchell creep equation and it is possible to predict creep behavior of Bottom Ash by that equation. Also, it is found that creep behavior of Bottom Ash appeared and the strain rate decreases over time, but the strain tends to continue to increase.

## Ⅰ. Introduction

Bottom Ash is combustion byproducts produced from coal-fired half proportion in the power production in Korea and it is expected to increase.[1] But the most of Bottom Ash are dumped near the power plant and recycling is urgent because landfill is going to reduce.

Generally, Bottom Ash is a good permeable material and has suitable strength and it can be used as road materials[2], sand mat[3], and backfill[4]. Also Bottom Ash has properties similar to sand and it can be alternative to sand compaction pile.[5]

Meanwhile, the soil which is used as embankment and backfill is under the long-term pressure and it makes the soil to act as long-term settlement. So this act must be studied.[6]

But the long-term settlement or creep behavior frequently occurs in clay condition and immediate settlement is known to govern the behavior in sand condition.[7] And also studies about long-term settlement in sand has been performed less than in clay.

Also the study related to the long-term settlement of Bottom Ash had not been performed alone and the study about the settlement of the fly ash and the fly ash mixed with Bottom Ash and the ponded ash and the Bottom Ash mixed with some other materials had been performed only.[8]

Therefore if the Bottom Ash is used as embankment or backfill materials, it is important to find the behavior characteristic of the settlement of Bottom Ash and in this study, the triaxial test was performed in undrained condition for figuring out this. Also applicability with this behavior was reviewed by applying with empirical model called Singh-Mitchell creep equation.

## Ⅱ. Materials and Methods

### 1. Materials

For this study, Bottom Ash was used from Yeong-Heung power plant, and the properties of Bottom Ash are as follows(Table 1, Fig. 1).

**Table 1 Physical properties of soils**

| $G_s$ | Passing sieve No.200(%) | $D_{10}$(mm) | $D_{60}$(mm) | $C_u$ | $C_g$ | USCS | PL |
|---|---|---|---|---|---|---|---|
| 2.21 | 7.52 | 0.10 | 1.37 | 20.1 | 0.80 | SW | NP |

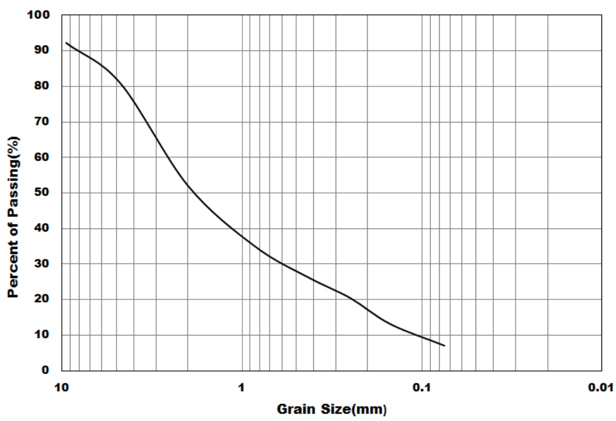



**Fig. 1 The particle size distribution curves of bottom ash**

The specific weight of the bottom ash in this study is lighter than general soils and can be classified as SW according to Unified Soil Classification System.

## 2. Methods

### a. Finding out Maximum deviator stress through the undrained triaxial test

In this study, Bottom Ash which was passing through 9.5, 2.00, 0.25mm sieves was compacted in nine times for six bedding and it is calculated by considering the value of the energy from Compaction A (KSF-2312). Also, bottom ash was compacted in 10% water contents for $\gamma_{max}$ and its maximum dry unit weight is 1.1t/m$^3$. After compaction, the sample was saturated during an hour in 150kPa back pressure for triaxial test. After saturation, isotropical consolidation was carried out and shear test was performed up to 15% strain for finding out the maximum deviator stress.

### b. Long-term settlement behavior test

After finding out maximum deviator stresses, it was figured out that the long-term settlement behavior of Bottom Ash applied with 40, 60, 80% of the maximum deviator stress. The process of making samples and consolidation was same way to triaxial test and after consolidation, anisotropic consolidation was performed in those conditions.

## Ⅲ. Results and Discussion

### 1. Finding out Maximum deviator stress

The maximum deviator stress of each sample through undrained triaxial test is as follows.

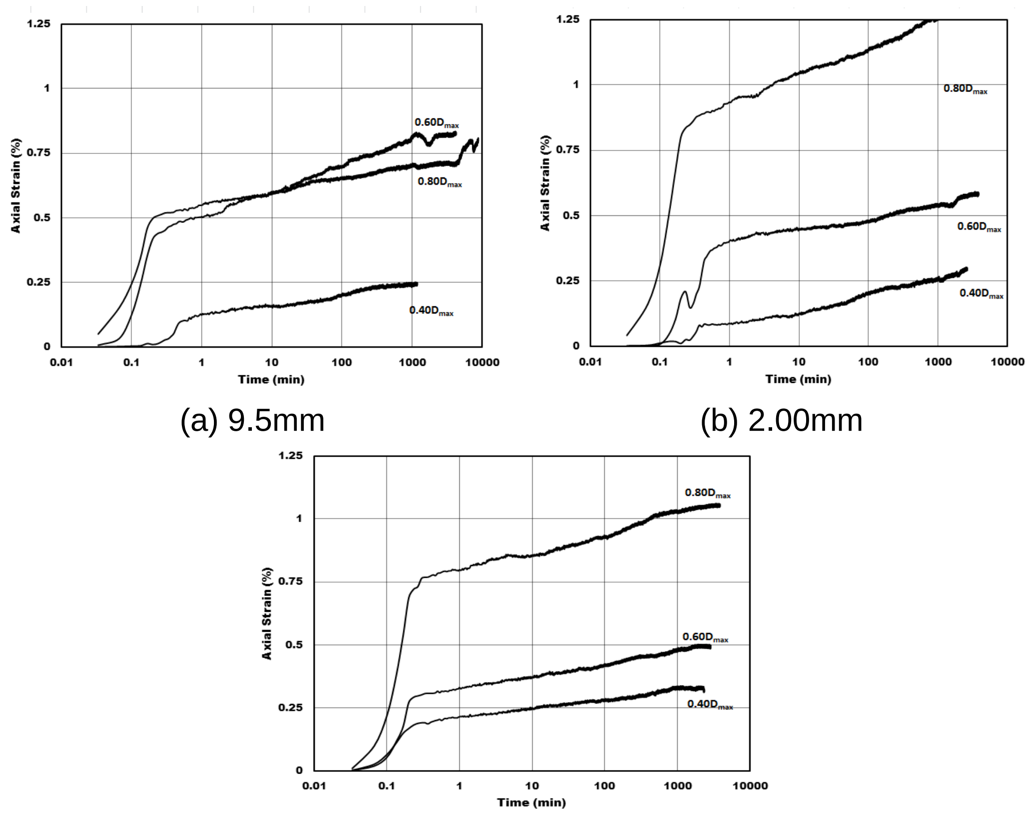
**Table 2 Maximum deviator stress of bottom ash**

| | Maximum deviator stress(kPa) |
|---|---|
| 9.5mm | 350 |
| 2.00mm | 350 |
| 0.25mm | 325 |

The samples passing through 9.5 and 2.00mm sieves had almost same the maximum deviator stress but relatively small grain size of 0.25mm sieve's sample had the maximum deviator stress lower than the former of those. It is concluded that the smaller grain size, the smaller friction and that makes it happened.

### 2. The empirical model of Singh-Mitchell and Application

From Fig. 2, Fig. 3, Fig. 4, it is expressed that time vs strain, strain rate according to stress levels and time vs strain rate was for applying the time-dependent behavior of each sample with Singh-Mitchell creep equation. For finding out creep parameters, applied standard time is 1 min and A means a deviator stress in standard time.

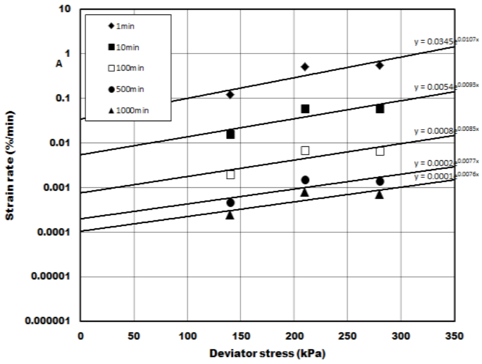



(c) 0.25mm

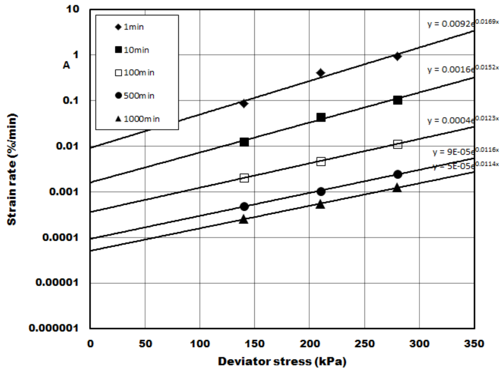
**Fig. 2 Relationships between Time and Axial Strain according to Maximum Grain Size**

From the result of each sample, the most strain rate was exceptionally appeared in 9.5mm with 60% stress level. Also the smaller grain size sample had more settlement in same stress levels and tended to quickly reach the secondary creep.
Furthermore, the difference between 40% and 60%'s strain rate tended to be bigger than that between 60% and 80%'s.

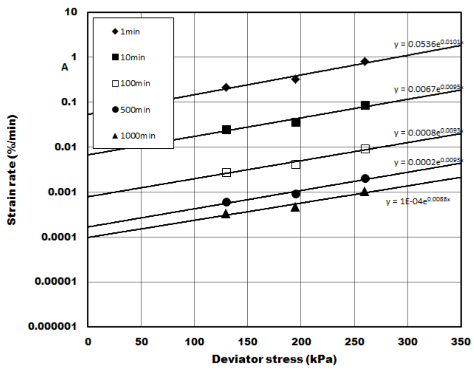
In addition, from Fig. 3, the proportion of strain rate in each stress level was constant when time went passes in 0.25mm but went down in 2.00, 9.5mm. It means that in early stage, the difference of strain rate was big according to stress levels but when time went passes, the effect of that reduced. However, in 0.25mm, the effect of stress levels according to time was small. Namely, the strain rate of Bottom Ash is effected by stress levels in early stage but in secondary stage, Bottom Ash has constant strain increasing rate.




(a) 9.5mm

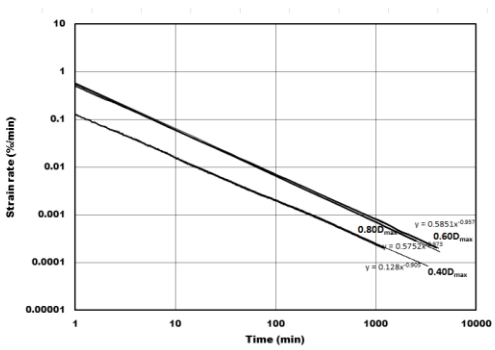



(b) 2.00mm

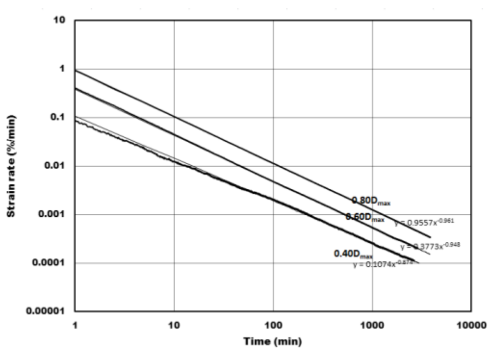



(c) 0.25mm

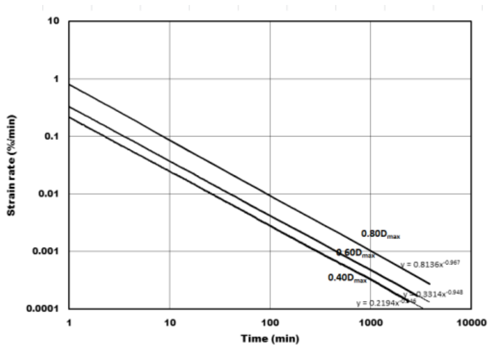
**Fig. 3 Relationships between Deviator Stress Levels and Strain Rate for various times**




(a) 9.5mm




(b) 2.00mm

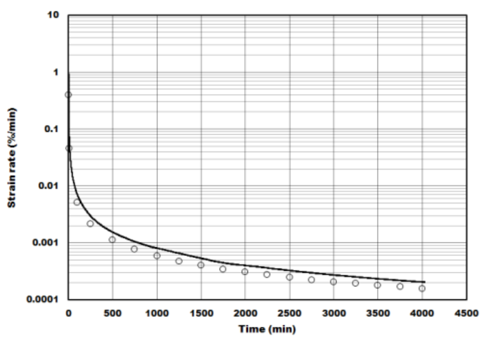



(c) 0.25mm

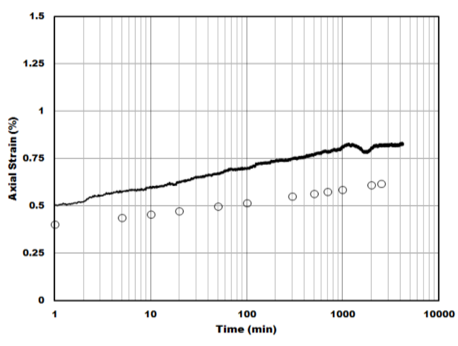
**Fig. 4 Relationships between Time and Strain Rate for various stress levels**

Figure. 4 was the graph for showing strain rate to time and the strain rate decreased having the constant slope during the consolidation process.

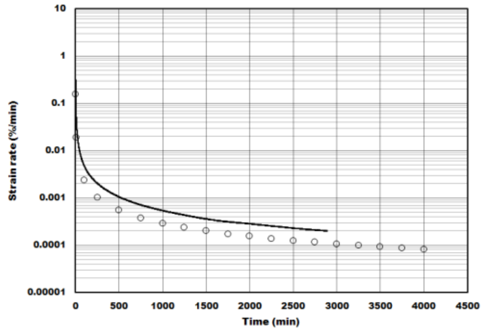
Exceptionally, in the stress level 40% of 2.00mm, the early slope was gradual and that means that the proportion of the strain decreasing rate was tardy compared to 60, 80%. This means long-term settlement potential was high and parameter m of 40% was under 0.90 although Bottom Ash is similar to sand. But it was confirmed that the slope of 40% got similar the slope of the other stress levels when time went up. So, it is considered that the level of compaction or the inhomogeneity of the sample makes strain rate low in early stage. Or by lower m value in 40% of 9.5mm, relatively low stress which makes rearrangement slow causes strain rate to be slow. And it must be considered when test which uses relatively big grain size materials is taken because this phenomenon did not happen in 0.25mm.



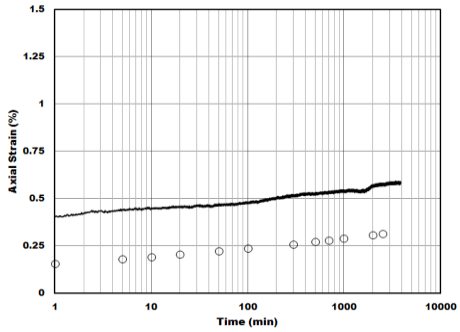

(a) Time vs Strain Rate (9.5mm)



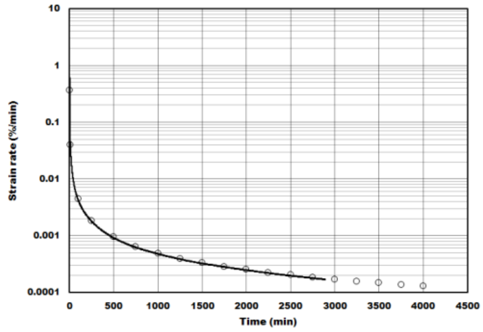

(b) Time vs Strain (9.5mm)



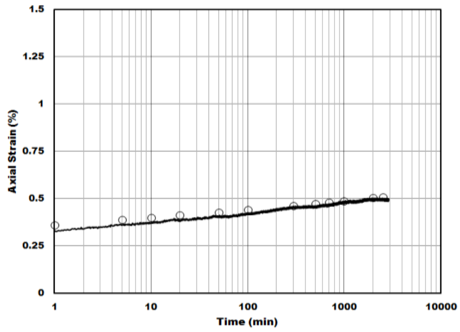

(c) Time vs Strain Rate (2.00mm)




(d) Time vs Strain (2.00mm)




(e) Time vs Strain Rate (0.25mm)




(f)Time vs Strain (0.25mm)

**Fig. 5 Comparison between Theoretical and Observed Time-Dependent Behavior in Singh-Mitchell Model**

Figure. 5 showed comparing theoretical and observed value in 60% based on creep parameters extracted from the result of the 40, 80%. It is showed that there was a difference between theoretical strain rate, strain and observed strain rate, strain in 9.5, 2.00mm. It is determined that the value of m came small at stress level of 40% and that made parameter A to be small. And theoretical result also came smaller than observed result due to it. But in 0.25mm, the theoretical equation matched the behavior of 60% well because the value of m at each stress level in 0.25mm was almost same. Therefore, if Singh-Mitchell model is applied with Bottom Ash, it must be careful to assume the behavior of Bottom Ash when the odd value of m appears.

## Ⅳ. Conclusion

In this paper, the undrained triaxial test was performed to find out the properties of the time-dependent behavior of Bottom Ash and the application of Singh-Mitchell creep model was reviewed. First, the time-dependent behavior of Bottom Ash was effected by the stress level of early stage but was not in later and in the condition of small grain size. Also, at 2.00, 9.5mm, the value of m at 40% of the stress level was relatively low and it was regarded as the phenomenon due to the inhomogeneity of the compaction or the slow rearrangement in low stress level.

Furthermore, considering above this phenomenon didn't appear at maximum grain size 0.25mm, if the stress level is low and a large particle diameter is determined, the initial potential creep which appears high shall be taken into account during the experiments.

Finally, using Singh-Mitchell model for predicting the behavior of Bottom Ash, it can be possible to get low theoretical strain due to above phenomenon. Therefore, when using this model, the range of parameter m must be considered. On the other hand, in the case of 0.25mm, it have little difference among each stress level and that makes Singh-Mitchell model matched with actual behavior of Bottom Ash well.

## Ⅴ. Acknowledgement

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