혼합토의 압밀 특성
Consolidation Characteristics of Mixed Soil

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개요 : 굴폐각은 굴양식 후 남는 것으로 남해안에서 주로 집중적으로 발생하는데 연간 28만톤의 발생량 중 상당양은 폐기물로 계속 누적되고 혹은 불법매립되어 환경오염 문제까지 발생시키고 있다. 본 연구에서는 산업폐기물로 분류되는 굴패각을 지반공학 분야에서 활용하기 위한 대안으로 해성점토와 혼합하여 매립재료로써의 적용성을 평가하기 위하여 대형 압밀기를 이용하여 실험을 실시하고 이를 토대로 기초자료를 획득하고자 하였다. 원형의 굴패각을 파쇄하여 입도별로 분류하고 이중 사질토 입경 크기의 재료에 대한 기본 물성치를 평가하고 지반 재료로써의 적용성를 분석하였다. 해성점토 내의 굴패각입자의 혼합비를 변화시켜 만들어진 혼합토에 대한 압밀 실험 결과 굴패각의 혼합율이 증가할수록 체적변화율이 작게 되고, 침하 속도는 빠르게 증가함을 알 수 있었다. 이는 압밀응력의 일부를 굴패각 입자의 골격구조가 부담함으로써 실제 점토부분에 작용하는 압밀응력은 굴패각 혼합율이 증가할수록 작아지는 것으로 판단된다.

Key words : Oyster Shell, Dredged Clay, Consolidation, Mixed Soil

1. Introduction

A port with waves or ocean currents, has soft ground by the accumulation of very fine particles from the river. Such a reaction that has high water content, and high plasticity clay can bury the marine route and source of contaminants in the port area. Therefore it needs to be removed, dredged, reclaimed, and disposed by a dredger regularly. However, dredged clay create environmental and economic problems because it takes time for stabilization of the consolidation settlement. This paper is focused on using oyster shells to stimulate the drain of reclaimed ground as a method of faster stabilization. Oyster farm is highly evaluated for its economical aspect; being a high profit business in marine producing farm around the southern sea of Korea. However, oyster shells can be accumulated as a waste matter in dump sites near the sea.
90% of the domestic oyster shell product is produced in Tongyoung, Geoje and Kosung area that can produce 280 thousand tons of oyster shell annually. 130 thousand tons of the production is recycled and the remaining 150 thousand tons are conformed in landfills or put aside. Therefore, over 150 thousand

tons of oyster shells are actually being accumulated annually. Now, the oyster shell is used as a fertilizing material, and oyster breedings. As a geotechnical application, oyster shell is mixed with sand to create a SCP (Sand Compaction Pile). However, construction of SCPs accompany a small amount of oyster shell usage, which is insufficient compared to the amount of oyster shells that become accumulated as waste source every year. Therefore the method of mixing dredged clay with oyster shells before reclamation is an effective plan to profit from the continuous accumulation of oyster shells.

The mechanical movement of foundation can be estimated by examining the properties of elements that constitute soil. Generally, soil is divided by two types, cohesive and cohesionless soil. Furthermore, site engineers have decided the soil types using appropriate soil indexes such as plasticity index. But in most construction sites, intermediate soils that can be characterized to be between cohesion and cohesionless are frequently found. This material is separated from intermediate soil or mixed soil, and the mechanical characteristics have much obscurity.

Hukue et al.(1986) showed the engineering characteristics of mixed soils by using void ratio in its evaluation. The compressibility of mixed soil largely effected by the decrease in fine granule content and the formation of coarse particle structure. Sivapullaiah et al.(1999) presented the results on the hydraulic conductivity of bentonite-sand mixtures. The results showed that when bentonite is mixed with any coarser fraction, the logarithm of hydraulic conductivity varies linearly with void ratio. And at any void ratio with the clay content being the same, hydraulic conductivity increases with increasing size of the coarser fraction. However, the difference is small at high bentonite contents.

The methods of study are as follows. A large size consolidation testing machine that is applied by Rowe cell consolidation instrument was produced, in order to measure the characteristics of settlement and permeability of mixed soil including oyster shell through consolidation tests. Especially, it is focused on the behavior of consolidation, permeability and characteristics of pure soil and mixing soil with oyster shells.

2. Test materials

The main composition of oyster shell has $CaCO_3$(about 90%) and a little amount of Concholin that is a kind of protein. For the analysis of the composition of oyster shell, we performed x-ray Flourescence Spectrometry test. To perform a XRF test, oyster shells need to be broken into a powder formula to pass the No. 200 sieve. The XRF test results of oyster shell is displayed in table 1.

Table 1. Results of XRF Analysis of Oyster Shell (%)

	SiO_2	TiO_2	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5	L.I.*	Total
Oyster shell	0.62	0.01	0.32	0.78	52.94	0.93	0.03	0.17	44.02	99.81

L.I.* : loss of ignition

The original form of oyster shell was crushed and classified by its particle size because of the limitation of the mold size in consolidation testing instrument. Before pulverizing, the natural oyster shell had a size of 80-130mm length, 30-80mm width, and 20-50mm depth. After pulverizing it forms a feature of a thin skin. The prepared material was divided into large oyster shells (4.75-2mm) and small oyster shells (2-0.074mm) by sieving the crushed oyster shell. In this paper, LOS represents lare oyster shells, and SOS represent small oyster shells, Figures 1, 2 and 3 show pictures of natural oyster shell, LOS, and SOS, respectively.

Fig 1. Natural Oyster Shell

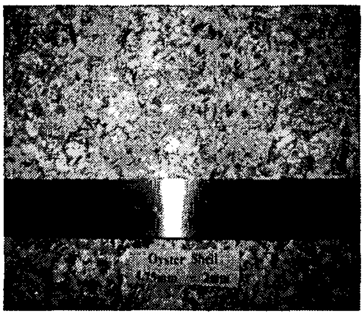

Fig 2. LOS (4.75mm-2mm)

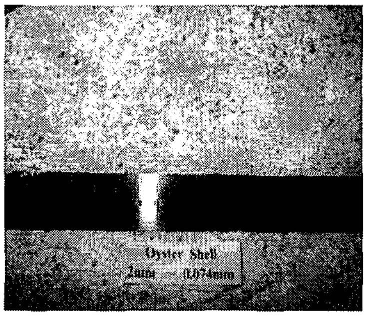

Fig 3. SOS (2mm-0.074mm)

Generally, the shape of the pulverized oyster shell shows the oval shape and flake. The specific gravity is 2.38 for LOS and 2.41 for SOS.
Particle distribution result of clay dredged from Tongyoung port showed a high silt particle content of 57%. Table 2 shows the physical characteristics of clay and oyster shell that were used in this research.

Table 2. Physical and geometrical properties of clay and oyster shells

Properties	Clay	LOS	SOS
Specific gravity (g/cm^3)	2.62	2.38	2.41
Liquid limit, W_L (%) Plastic Index, Ip	64 35	- -	- -
Ingredients	Sand 27 (%) Silt 57 (%) Clay 16 (%)	4.75 - 2 (mm)	2 - 0.074 (mm)

3. Test Procedures

Clay was taken by covering it with a wet rag in order to maintain a uniform moisture content. After pulverizing, naturally seasoned oyster shell does not affect the moisture content of mixed soil. And after the mixed soil is left as it is for 24 hours in uniform temperature, the test was performed. The mixing ratio of oyster shell was divided into 3 types, 0, 40, 80% of oyster shell percentages compared with the dry weight of clay. Consolidation test equipment was manufactured including large consolidation mold(Fig 4), 70mm diameter, 200mm height, in order to investigate the compaction and permeability characteristics of mixed soil with oyster shell. The drainage condition of consolidation test was both-sided, top and bottom drainage. The consolidation mold was made of Teflon to decrease the fraction between the mold and the soil particle. The opening water pressure meter was set up in porous box in order not to directly undergo consolidation pressure from the top. The consolidation stress was 98kPa, and the consolidation time was decided by the 3T method.

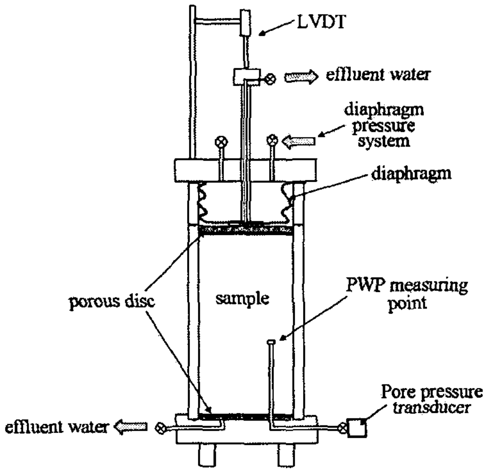

Fig. 4. Equipment for consolidation tests.

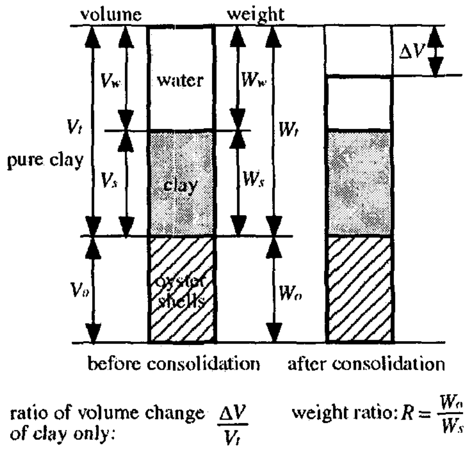

Fig 5 Definition of composition (mixing) ratios.

4. The Definition of Constituent

The oyster shell mixed soil is made up of water, Tongyong clay and oyster shell. Therefore, general moisture content concept of weight relationship formation between soil particle and water pertinent to the solid part of soil is difficult to use. Because, the moisture content differs between including oyster shells and not including oyster shells in case of the clay including different weight of oyster shell and uniform moisture contents. In this study, the solid part is divided into oyster shell and clay particle. Figure 5 shows the definition of constituent. In this figure, the subordinate characters, w, s, o mean the properties of void water, clay particles, and oyster shell, respectively. On the assumption that the saturation of mixed soil is 100% and the moisture content of smashed oyster shell is 0%, the relationship of mixed soil between volumes and mass can be expressed as the equation (1).

$$V = V_0 + V_s + V_w \quad (1)$$

The mixed ratio of oyster shell, R, is defined in the manner of equation (2)

$$R = \frac{W_0}{W_s} \times 100 \quad (2)$$

Moreover, the volume change of mixed soil is assessed at the volume change of the matrix part (clay) by means of consolidation stress.

5. Results

5.1. The Characteristics of Volume Change

Figure 6 shows the volumetric change ratio of clay in mixed soil. In early stage, the differences of volume change was not significant in accordance with the mixing ratio. However after 50min of consolidation time passed, the mixed oyster shell ratio became larger, the volume change became smaller and the settlement velocity became faster. From this result, the mixed oyster shell ratio was larger, the consolidation stress which was operated on real matrix part became smaller because the body structure of oyster shell particles endured a part of consolidation stress.

Omine et. al.(1993) suggested that the study of consolidation characteristics could be explained using this concept of stress allotment ratio. Omine showed the equation which calculated the stress allotment ratio from elasticity and Poisson's ratio of constituents on the assumption that the work quantity of mixed material and matrix part was identical. However, it is difficult that the elasticity and Poisson's ratio of each constituent were decided because these ratios vary according to stress condition, accumulation structure, loading direction, loading velocity, and so on in difference with general mechanic materials. Therefore, Omine suggested the concept that the study of consolidation characteristics could be explained using this concept of stress allotment ratio. Omine showed the equation which calculated the stress allotment ratio from elasticity and Poisson's ratio of constituents on the assumption that the work quantity of mixed material and matrix part was identical. However, the concept using the final void ratio of clay which was not gained from the soil indexes but directly from consolidation test was introduced. This method is that the relationship between loading-void ratios was obtained from the consolidation result of clay as shown in Fig. 7, and then the final void ratio of clay was decided from the consolidation result of mixed soil. The consolidation stress which is equivalent to the final void ratio can be calculated from the relationship of loading-void ratio. Figure 8 shows the stress allotment ratio which is decided by this method and assigned by clay. From this result, the mixed oyster shell ratio shows an increase, and the stress distribution ratio of clay shows a decrease.

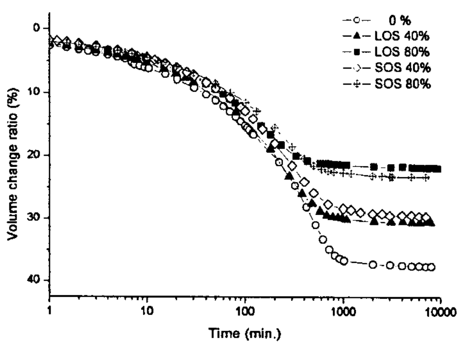

Fig 6 Volume change ratio

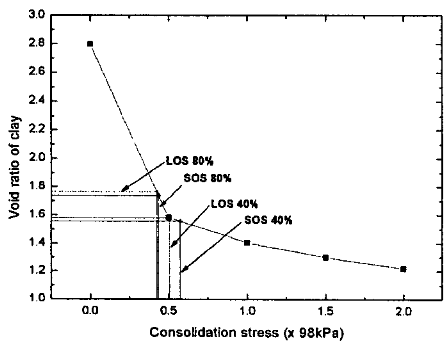

Fig 7 Stress allotment ratio on clay using the final void ratio of clay

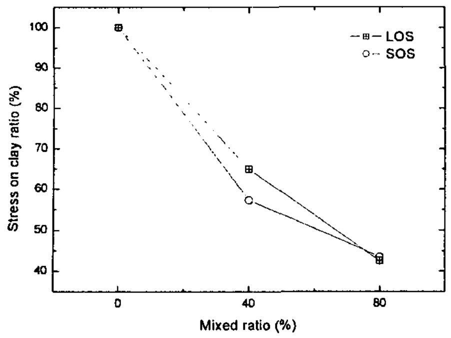

Fig 8 Stress allotment ratio on clay

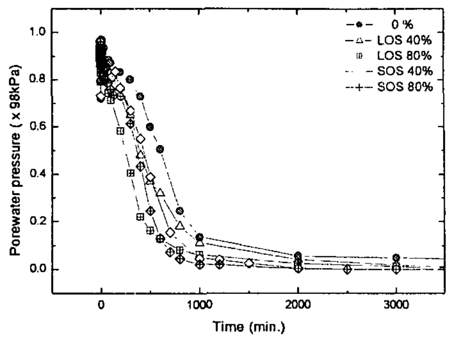

Fig 9 Excess pore water pressure dissipation curve

5.2 The Characteristics of Water Pressure Dissipation

Figure 9 shows the dissipation change of excess pore pressure. The mixed oyster shell ratio increased, and the dissipation velocity increased in early stage. Moreover, compared with the dissipation velocity between pure clay and mixed soil, the dissipation velocity of mixed soil became faster in proportion to the increase of mixed oyster shell ratio. Dissipation closing time of excess pore pressure characteristics show that oyster shells can accelerate the dissipation of pore water pressure. And as the mixed oyster shell ratio increases, the dissipation closing time became faster. However, more investigations are needed in order to find out whether the dissipation of pore water pressure is accelerated in the same mechanism between oyster shell and general sand or not.

6. Conclusions

It was empirically proven through consolidation tests that the volumetric change diminished and final consolidation settlement restrained when mixed oyster shell ratio increased. Because the body structure of oyster shell allotted a part of consolidation load, matrix(clay) part experienced a smaller consolidation stress. In this research, void ratio after consolidation was used to interpret such a decrease in the consolidation load of matrix part.

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