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Granular Forming Treatment Test of Crushed Stone Sludge and Soil Properties of The Granulated Soil

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Synopsis

Crushed stone sludge is an industrial waste by-product of crushed stone and sand manufacture. In this study, granular forming treatment tests of crushed stone sludge by an actual plant were conducted. The sludge mixed to granulate with portland blast-furnace slag cement and polymer stabilizer agent. Sludge of moisture content 25, 50, 70, and 100% were tested. Sludges of moisture content 50 and 70% were possible to granulate, but cement content increased. The granulated soils were tested for density and water absorption, grain size distribution, the California bearing ratio (CBR), and permeability after curing for 63 days. The water absorption was high. Therefore it has water retention capacity. With increasing cement content, the CBR values of compacted specimens decreased, and the coefficient of permeability increased. They are caused by crushing with compaction granulated soils which are low grain strengths.

KEYWORDS: Crushed stone sludge, Granulated soils, Soil properties, Grain strength

1. Introduction

Desiccation of aggregate used for concrete and asphalt mixture is a serious problem. Crushed stone and sand are used instead of natural aggregate positively, and the use will increase year by year. But the production generates crushed stone sludge.

Utilization of the sludge is impossible as is. Special treatments are necessary to utilize it. One of the treatment methods includes granular forming treatment. The granulated soils are easy handling, and they are expected to apply as construction materials. The granular forming treatment techniques of crushing after hardened by cement and calcining by kiln after granular formed have been developed.[1) 2)] But the production process is many, and it costs too much. This study adopted a system that granulates with mixing cement and polymer stabilizer agent to sludges.[3)] The system is quite useful compared with the above system for production time and cost. Granular forming treatment tests of crushed stone sludge by an actual plant and soil properties of the granulated soil are reported.

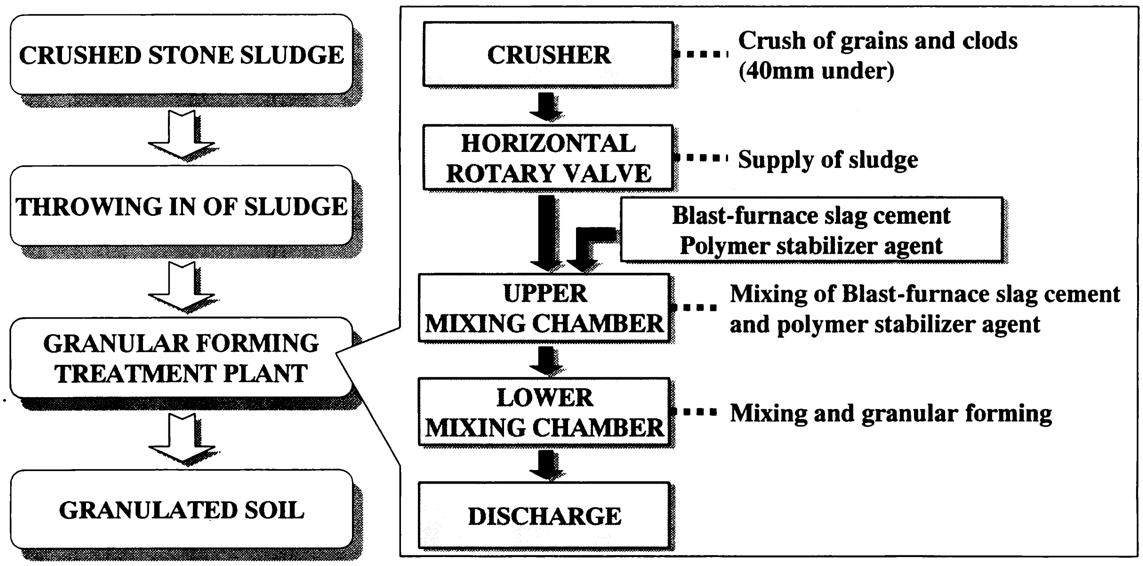

Fig. 1 Production process of the granulated soils

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2. Experimental

Production process of the granulated soils is shown in Fig. 1. The tests were used Portland blast-furnace slag cement and polymer stabilizer agent which polyacryamide coagulant is a main of. Properties of crushed stone sludge are shown in Table 1. Sludges are mixed with cement and polymer stabilizer agent in mixing chamber of the plant. It is granulated with crosslinked by polymer stabilizer agent and sheared by mixing. Mix proportion of the granulated soil is shown in Table 2. The polymer stabilizer agent was added 2% of the cement by weight. The granulated soils were investigated soil properties after curing for 63days.

Table 1 Properties of Crushed Stone Sludge

Particle density (g/cm^3)	2.747
Moisture content (%)	25.0
Liquid limit (%)	33.5
Plastic limit (%)	19.0
Plasticity index	14.5
Grain Size distribution	
Sand	5.5
Silt	43.5
Clay	51.0

Table 2 Mix Proportion of Granulated Soils

Moisture content (%)	Cement content (kg/m^3)
25	80
50	330
	380
	500
70	390
	420
	650
100	300

3. Results and Discussion

3.1 Immediately after granular forming

The cone index of immediately after granular forming is shown in Fig. 2. And the photos are shown in photo1. The cone index of moisture content 25% could not be determined. The cone index increased with increasing cement content.

When the moisture content is 25%, cement stuck to only face of sludges. Because of low moisture content, cement and sludges weren't mixed uniformly (photo 1(a)). In case of the moisture content is 50% and 70%, granulated soils were good shape (photo 1(b)). It seems that the grain size became small with increasing cement content. Sludge of moisture content 100% almost never granulated for too high moisture content and fluidity (photo 1(c)). Fluidities of moisture content 50% and 70% were also high, and cement was abundantly necessary to granulate them.

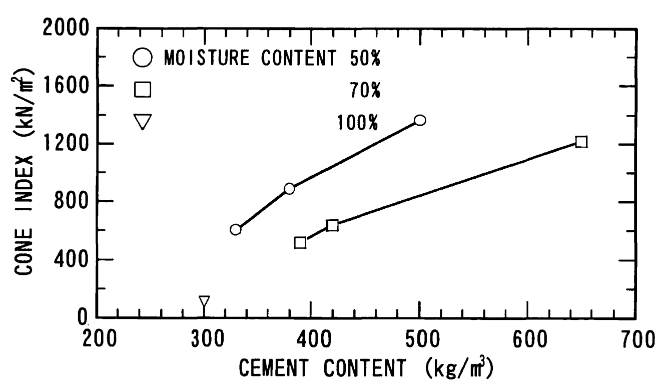
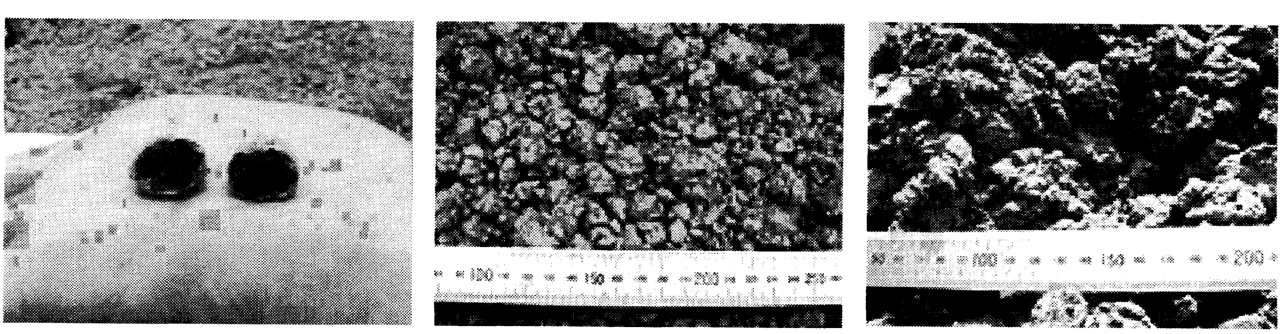


Fig. 2 Cone Index of Immediately after Granular Forming



(a) w=25%, SC=80kg/m^3 (b) w=70%, SC=420kg/m^3 (c) w=100%, SC=300kg/m^3

Photo 1 Granulated Soils of Immediately after Granular Forming

3.2 Soil properties of granulated soils

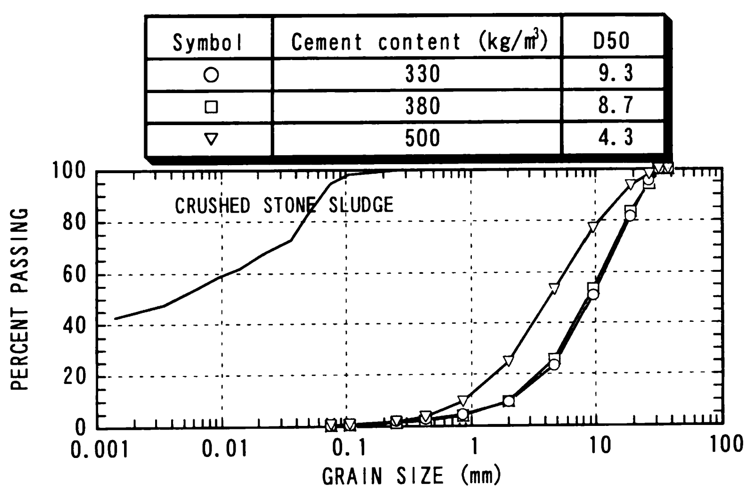
(1) Physical properties

The results of density and water absorption tests are shown in Table 3. The density was about 2.0g/cm^3. The absorption was 25-30%. The granulated soils were material that is lighter and more retentive of water than crusher run and sand.

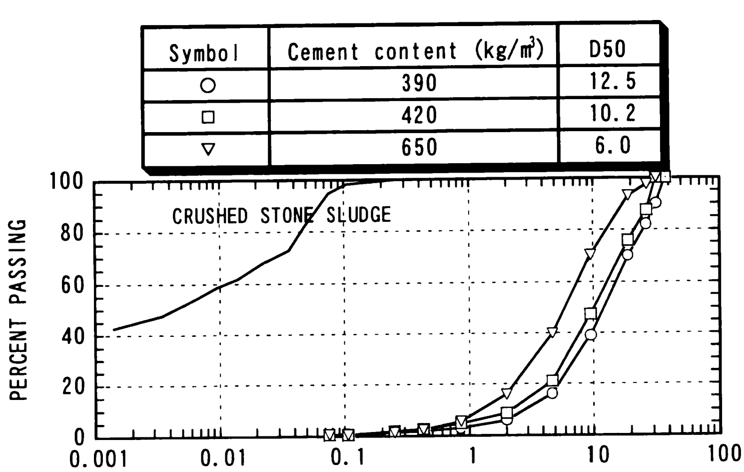
The results of grain size distribution test are shown in Fig. 3. The grain-size accumulation curves moved to the right side of sludge. The D50 decreased with increasing cement content. Cement and polymer stabilizer agent contents vary the grain size distribution. Granular forming by adding low cement may be possible with increasing polymer stabilizer agent.

Table 3 Density and Water Absorption of Granulated Soils

Moisture content (%)	Cement content (kg/m^3)	Density (g/cm^3)	Water absorption (%)
50	330	1.92	28.6
	380	1.95	27.2
	500	1.97	26.4
70	390	1.89	30.1
	420	1.92	29.2
	650	1.97	27.6
Crusher run		2.45~2.70	< 3.0
Sand		2.50~2.65	1.0~5.0



(a) Moisture Content 50%



(b) Moisture Content 70%

Fig. 3 Grain-Size Distribution Curve for Granulated Soils

(2) Compaction

The maximum dry densities and optimum moisture contents of granulated soils cured for 63 days are showed in Table 4. The compaction methods used standard effort (E_C≒550kJ/m^3) and modified effort (E_C≒2500kJ/m^3). The lightweight of granulated soils made maximum dry densities of low value. The optimum moisture contents were showed approximately 30% due to high water absorption. As compactive effort increased, maximum dry densities were up and optimum moisture contents were down, and it showed results similar to general soils. It appeared that granulated soils of low cement content compacted densely with crushing grains. But the results of moisture-density tests did not show recognizable difference.

Table 4 Maximum Dry Densities and Optimum Moisture Contents of Granulated Soils

Moisture content (%)	Cement content (kg/m^3)	Standard effort		Modified effort	
		Maximum dry density (g/cm^3)	Optimum moisture content (%)	Maximum dry density (g/cm^3)	Optimum moisture content (%)
50	330	1.227	34.8	1.411	31.8
	380	1.283	32.7	1.483	29.5
	500	1.250	34.5	1.434	31.2
70	390	1.124	33.0	1.374	32.0
	420	1.115	31.1	1.302	32.0
	650	1.190	33.5	1.405	31.4

(3) California bearing ratio

The CBR values of compacted specimens were measured after curing for three, seven, 28, and 91 days periods with grained condition. The results of moisture content 70% are shown in Fig. 4. The CBR decreased with increasing cement content, and changed by curing time. The CBR of cement content 650kg/m^3 didn't change. The CBR of cement content 390 and 420kg/m^3 increased up to seven days, but decreased beyond it.

The results are presented in Fig. 5, which shows the variations of CBR values versus compactions. The CBR cement content 390kg/m^3 increased markedly with increasing compactions.

The grains of cured for 3 or 7 days and low cement content are easy to crush by compaction, and it compacted moderately. Therefore, it is considered that the CBR was gained high values. A Change of grain-size accumulation curve of cement content 390kg/m^3 was larger than cement content 650kg/m^3 (Fig. 6). The granulated soils of moisture content 70% were tested for modified CBR. The results are shown in Fig. 7. The modified CBR was over 30%. The granulated soils may apply to subbase course as granular materials. But examinations of durability are necessary to utilize as granular base course materials.

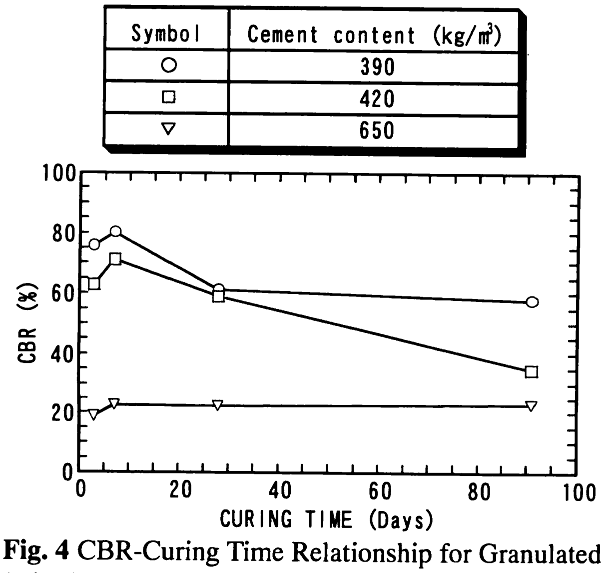


Fig. 4 CBR-Curing Time Relationship for Granulated Soils (Curing with Grained Condition)

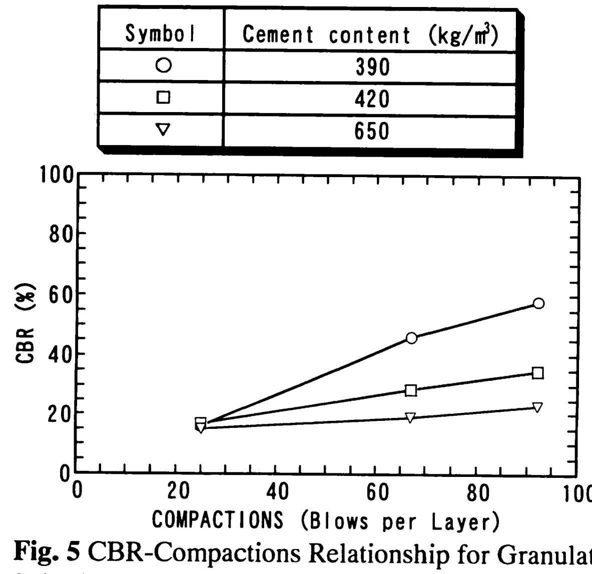


Fig. 5 CBR-Compactions Relationship for Granulated Soils (Compactions after curing for 63days periods)

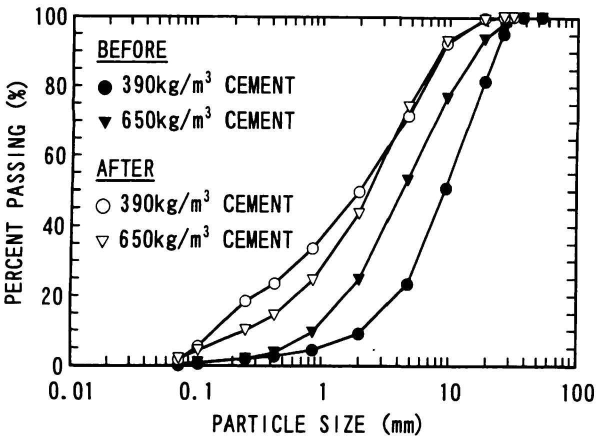


Fig. 6 Grain-Size Accumulation Curve Before and After Compactions

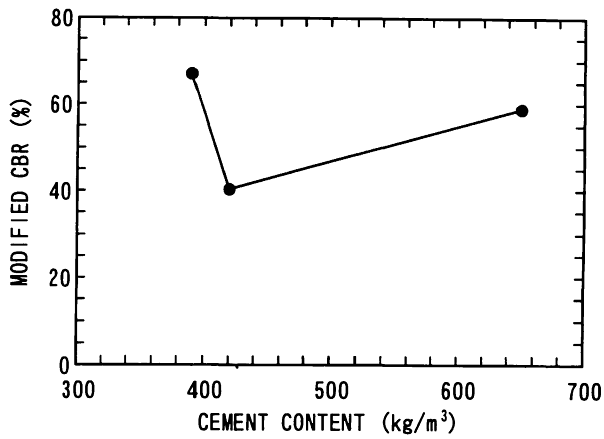


Fig. 7 Modified CBR of Granulated Soils

(4) Permeability

Corresponding coefficients of permeability of cement contents are shown in Fig. 4. The grains were soft immediately after granular forming treatment. The voids between them disappeared by compaction. The results that compacted specimens were tested after curing for 63 days with compacted condition show that it is impermeability most. After curing for 63 days with grained condition, they were compacted and tested for permeability. Some hardened grains were crushed by compaction, but they were 10^{-2}-10^{-3}cm/s orders equal with gravel and sand. When the compactive effort increased to 2500kJ/m^3, grains were crushed more. Therefore, the coefficients of permeability were 10^{-3}-10^{-4} cm/s orders.

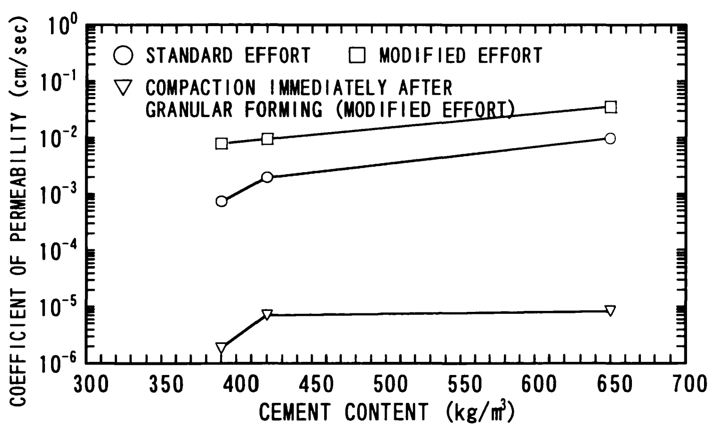


Fig. 8 Coefficient of Permeability of granulated soils

4. Conclusions

This experiment produced the following results:

The moisture contents and the fluidities of sludge affected granular forming, such that sludge of low moisture content was not miscible with cement and high moisture content was not granulated.

The granulated soils were material that is lighter and more retentive of water than crusher run and sand.

The amount used of cement and polymer stabilizer agent affected grain size distribution, such that the D50 decreased with increasing cement content.

The high CBR values were gained because the granulated soils at early ages and with low cement content were compacted moderately with crushing grains.

The grain strengths affected the properties, such that CBR and permeability of compacted specimens.

References

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