Effective Reuse of Coal Ash as Civil Engineering Material

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1. Introduction

Each year in Japan, there is an increase in coal ash generated by thermal power plants. Attempts have been made to use coal ash as landfill or raw material for cement. However, the decline in demand for cement, the increasing difficulty of finding new landfill sites, the increasing generation of coal ash, and the growing social interest in recycling and reuse of natural resources have made it necessary to develop new applications. Toward developing new methods for coal ash use, the Civil Engineering Research Institute of Hokkaido has been studying its use as a civil engineering material. The subject of this study is coal ash discharged from thermal power plants in Hokkaido, which is in northern Japan. To examine its suitability as civil engineering material in applications such as landfill and as stabilizer for improving soil, test were performed on trafficability, box shear, unconfined compression, flow, bleeding, frost heave, and CBR.

The results showed that coal ash can be used as civil engineering material with little or no processing. This paper compiles the methods for using coal ash as a civil engineering material.

2. Properties of Coal Ash

The coal ash used in the tests was discharged from five different combustion furnaces. Therefore, the properties of the ash differ by the characteristics of the coal raw material, the type of furnace, and the firing conditions. The properties of coal ash used in this study are shown in Table 1. Coal ash from furnaces a, b, c, d, and e is here designated Ashes A, B, C, D and E. The particle densities for Ashes A, B, and E are considerably lower than the soil particle density for ordinary soil (2.5 to 2.7). All the coal ash is fine grained, with a natural water content of approximately 0%, consistency limit of N.P., and fine-grained (75 μ m) content exceeding 80%. The uniformity coefficients of Ashes A, B, and D are below 10; therefore, their grain size distribution makes them poor as soil materials. Ignition loss of Ashes B and C is several percent, and of Ashes A, D and E is about 10%, which shows that Ashes A, D and E have more unburned portions than Ashes B and C. Some portions of Ash B are acidic, but most of the ashes are strongly alkaline.

The main components of coal ash are silicon dioxide and aluminum oxide, which together account for 70 to 90% of the ash by weight. Ashes C and D were desulfurized

Table 1. Properties of coal ash

Name of boiler		Ash A	Ash B	Ash C	Ash D	Ash E
Soil particle density (g/cm^3)		2.120-2.334	2.238-2.501	2.70~2.97	2.167	2.522-2.690
Notional water content (%)		0.05-0.30	0.02-0.30	0.00~0.14	0.06	0.00
Grain size distribution	>2mm (%)	0.0	0.0	0.0	0.0	0.0
	2mm-75μm (%)	7.8-19.0	5.5-7.0	12.5~15.0	9.5	4.5-8.1
	75μm<(%)	81.0-92.2	93.0-94.5	85.0~87.5	90.5	91.9-95.5
Consistency limit (%)		N.P.	N.P.	N.P.	N.P.	N.P.
Ground material classification		ML	ML	ML	ML	ML
Ignition loss (%)		8.2-17.3	1.0-3.7	2.1~6.5	16.0	9.3-18.8
pH		12.0-13.0	3.7-13.0	11.6~13.0	12	11.5-12.6
Maximum dry density (t/m^3)		0.923-1.085	1.020-1.592	1.220~1.347	0.956	1.038-1.005
Optimum moisture content (%)		36.1-43.0	17.0-31.2	29.2~31.4	48.1	45.5-46.0
Chemical composition	SiO_2(%)	49.1~53.5	49.1~70.3	40.0~42.2	59.4	37.5~42.5
	Al_2O_3(%)	17.9~21.0	18.2~30.7	9.7~18.0	23.4	22.1~27.1
	Fe_2O_3(%)	3.2~5.9	0.6~11.4	1.33~2.4	5.4	2.9~3.6
	CaO(%)	2.6~9.1	0.0~8.7	26.2~35.0	4.5	8.0~13.9
	MgO(%)	1.0~1.5	0.2~2.5	0.8~1.4	1.7	0.3~1.8

in the furnace during firing by the addition of coal and limestone, and they have high quicklime contents.

3. Scope of Study

Using coal ash without processing is the most economical method. However, this is not always possible; therefore, we processed dry coal ash by hydrating and compaction to study its performance as a civil engineering material. At the same time, when coal ash with zero moisture content is mixed into unsuitable soil with high water content, it makes unusable soil usable by reducing the water content. Therefore, the use of coal ash as stabilizer material is also studied. But in using coal ash as a stabilizer material, the ash disperses when it is mixed into the soil. To counter this problem, coal ash that is wetted with a small amount of water (hereinafter: hydrated coal ash) before mixing is tested for reduction of dispersion. When coal ash is mixed with solidifying materials to increase its strength, the hydration needed for mixing will affect the solidifying strength, so the necessary hydration is surveyed as well.

Since there is less quality variation between one coal ash and the next than between one soil and the next and because coal ash contains no moisture, it can be conveniently improved through stabilization to become a value-added material such as liquefied stabilized soil or granulated coal ash, as well as foam-mixed solidified soil. Use in such materials will be studied here. Liquefied stabilized soil is stabilization-treated soil with improved flowability. It is produced by adding water and solidifying material to the soil, and mixing. All kinds of soil derived from construction work can be used in this material. This material is particularly effective in back filling and filling narrow spaces or places

where compaction is difficult, because of its good flowability and lack of need for compaction. Foam-mixed solidified soil is liquefied stabilized soil mixed with air foam. It is lightweight, which makes it effective as a material to reduce earth pressure at backfilled retaining walls and bridge abutments, and as a material for embankments.

Granulated coal ash is material that is modified by the addition of solidifying material and water, and is granulated by mixing and rotating. The process affords improved work efficiency, and because dispersion is prevented the material is convenient to store. The material can be handled in the same manner as ordinary soil.

These uses are shown in Figure 1. The test methods for each material in this study are mentioned below.

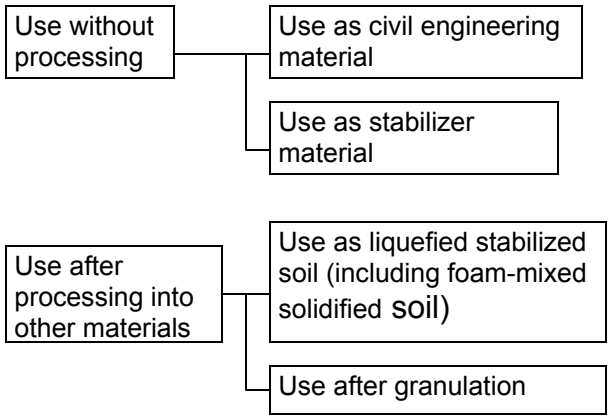

Figure 1. Uses of coal ash

4. Results of Study

1) By taking certain measures, coal ash can be effectively used as a civil engineering material in embankments, antifrost layers, and the like, regardless of the ash properties. Furthermore, the materials can be used to make liquefied solidified soil and granulated coal ash.
2) Coal ash in powder form and granulated coal ash have almost no cohesion. In embankments made from these materials, it is necessary to take measures against slope failure caused by rain or embankment collapse caused by earthquake.
3) Coal ash readily disperses immediately after being generated. Dispersion of the material can be prevented by the addition of water or by granulation.
4) Civil engineering materials made from coal ash are strongly alkaline; therefore, greening is difficult when planting is done directly on earth structures made from these materials. A countermeasure to this problem is to use earth cover that incorporates additional soil.

5. Types of Coal Ash and Their Uses

The appropriate uses for coal ash, according to their properties, are collected in Table 2. As shown in this table, Ashes C and D are suitable for almost any use. Ashes A, B and E can be effectively used when certain measures are taken.

6. Conclusion

The properties of coal ash vary according to the coal and the combustion furnace, but by taking advantage of its various characteristics, the material can be used as a civil engineering material. However, environmental conditions such as variations in

groundwater level, imposed loads and air temperatures may cause changes in the structures. It is expected that a need will arise to clarify the durability of civil engineering materials made from coal ash.

Table 2. Properties and uses of coal ash

Type of coal ash	Use without processing				Use by processing into other materials				
	Embankment	Stabilizer material	Subbase course	Antifrost layer	Liquefied solidified soil	Foam mixed solidified	Granulated coal ash		
							Embankment	Base course	Antifrost layer
Ash A	○	○	○	—	△	△	—	—	—
Ash B	○	○	○	—	○	○	—	—	—
Ash C	◎	◎	◎	—	△	◎	—	—	—
Ash D	◎	—	◎	◎	—	◎	◎	△	◎
Ash E	○	—	—	—	—	—	◎	○	○

◎：Can be effectively used when hydrated
○：Can be effectively used by mixing with solidifying material
△：Can be effectively used when other measures are taken
—：Possibly be effectively used when certain measures are taken

References

[1] The Japanese Geotechnical Society (2000): “Methods and Descriptions of Soil Tests”, p.58

[2] Public Works Research Institute, Ministry of Construction (1997): “Technical Manual for the Use of Liquefied Stabilized Soil”, p.42

[3] Environmental Agency (1991): “Environmental Standard on the Contamination of Soil”, Notice of the Environmental Agency No. 46

[4] The Japanese Geotechnical Society (1998): “The N Value and the Methods for Using c and ϕ”, p.166

[5] Japan Road Association (1988): “Guidelines for Road Earthwork and Drainage”, pp. 238 - 243

[6] Oikawa, K., Matsunaga, Y., Ikegami, K., Adachi, S., Takeuchi, D., Kishida, T. (1996): “Characteristics of Various Cement-Treated Soils Used in Reducing Earth Pressure from the Quay Wall Backfill”, pp. 103 - 110