Outline of “Development of Volcanic Glass Powder for Use in Concrete”

「火山ガラス微粉末の開発」の概要


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1. Introduction

To achieve the United Nations’ Sustainable Development Goals, highly durable low-carbon concrete made with supplementary cementitious materials (SCMs) is required. Volcanic sediments, which have pozzolanic activity, have long been known to improve the durability of concrete, but it has also been noted that using volcanic ash as an SCM can cause the problems of low workability and slow strength development. Also, the chemical composition and physical properties of volcanic ash have high variability. In Japan, a volcanically active region, volcanic ash was used widely as a mineral admixture 100 years ago but is now rarely used because of its low performance.

The reaction of natural pozzolans is due to volcanic glass composed of amorphous silicate, but most natural pozzolans also contain inert minerals such as quartz and feldspar. Furthermore, in their natural state, volcanic ejecta also contain pumice and sometimes weathered clay. However, by focusing on the different densities of these components, volcanic glass can be sorted by dry gravity classification. This technological development has made it possible to manufacture volcanic glass powder (VGP) as a high-performance SCM for use in concrete by dry sorting and pulverizing high-purity volcanic glass.

2. Scope of the Study

(1) Raw Material and Manufacturing Method

The volcanic sediments used in this study are Ito Shirasu, which originated from the Ito pyroclastic flow that erupted from the Aira Caldera in southern Kyushu 29,000 years ago.

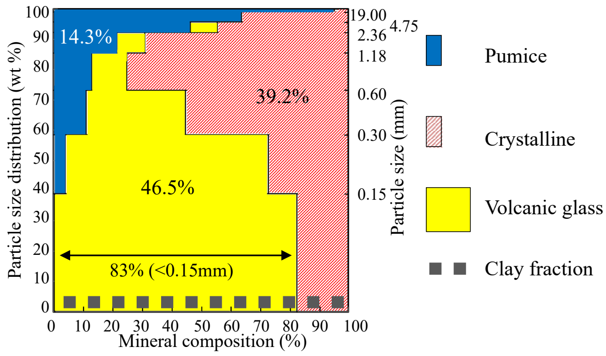

Fig. 1 Mineral composition of Ito Shirasu[1]

Fig. 2 Four types of mineral after sorting[1]

Fig. 1 shows the mineral composition of Ito Shirasu by grain size, with pumice and volcanic glass comprising approximately 60% of the total. The volcanic glass has relatively small grains, but it would be difficult to sort by sieving alone because of the overlap in terms of crystalline material and grain size. Therefore, sorting was performed using an air table, which is a dry specific gravity sorter for the mass processing of grain and industrial waste. **Fig. 2** shows the sorted crystalline, pumice, volcanic glass, and clay fractions. VGP is then manufactured by taking the sorted amorphous silicate with a glass content of approximately 90% and a SiO_2 content of more than 70% and pulverizing and classifying it into powder with a minimum average particle diameter of 1 μm and a maximum BET specific surface area of 18 m^2/g.

(2) Performance of VGP

When VGP is used in concrete, its fineness leads to improvements in flowability, strength development, and resistance to penetration of carbon dioxide and chloride ion. In addition, VGP can be used in both conventional and high-strength concrete. **Fig. 3** shows test results for the compressive strength of concrete made with a water–binder ratio of W/B = 0.2 and a replacement ratio of 10% using silica fume and three grades of VGP. Each grade of VGP exhibited high performance as an SCM equivalent to or higher than that of silica fume from 7 days. **Fig. 4** shows test results for the compressive strength of concrete made with a unit water content of about 185 kg/m^3, a unit cement content of about 300 kg/m^3, W/B = 0.6, and a replacement ratio from 0% to 20% using VGP. The strength of the VGP concrete exceeded that of the control concrete from 7 days, and the higher the replacement ratio, the higher the strength and the higher the performance.

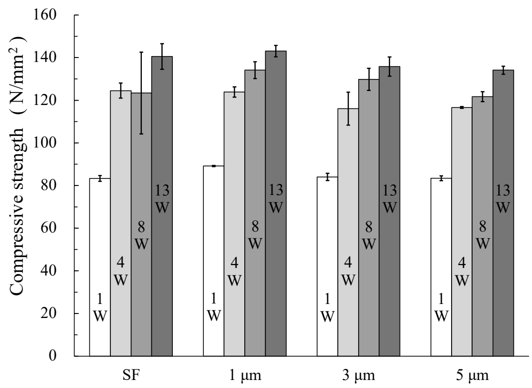

Fig. 3 Compressive strength tests (W/B = 0.2)[1]

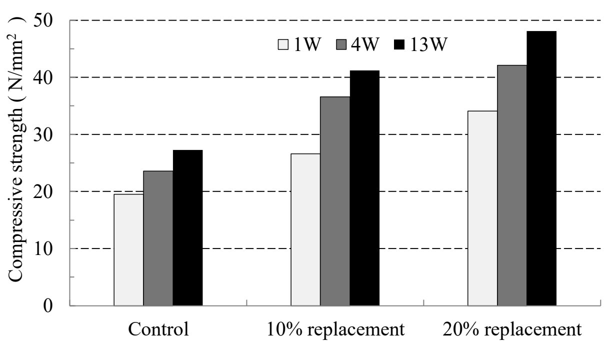

Fig. 4 Compressive strength tests (W/B = 0.61)[1]

(3) Establishment of JIS A 6209

If 10% of the estimated 75 billion cubic meters of Ito Shirasu reserves were to be converted into resources, then that would allow 3.375 billion cubic meters (3.61 billion tons) of VGP to be manufactured, an amount that could replace 30% of the cement used in concrete in western Japan for the next 100 years. Furthermore, the manufacturing process of VGP emits only 10% of the carbon dioxide of cement manufacturing. When used in concrete construction, VGP has been shown to reduce carbon dioxide emissions by more than 20% compared with conventional methods.

This series of technological development and research also led to the establishment of Japanese Industrial Standard (JIS) A 6209 "Volcanic Glass Powder for Concrete," showing that VGP can be classified into three types according to its properties and applications. **Table 1** lists the JIS qualities established in March 2020. The possibility of manufacturing VGP from not only Ito Shirasu but also other volcanic sediments from outside Japan has been noted [2], and future research and development is expected.

Table 1 Properties of VGP (JIS A 6209)

	Type I	Type II	Type III
SiO_2, min, %	70.0		
Al_2O_3, max, %	15.0		
MgO, max, %	5.0		
SO_3, max, %	3.0		
Free CaO, max, %	1.0		
Chloride ions, max, %	0.10		
Loss on ignition, max, %	4.0		
Moisture content, max, %	3.0		
BET surface area, min, cm^2/g	80000	40000	10000
Strength activity index			
at 7 days, min, % of control	100	95	90
at 28 days, min, % of control	105	100	95
Density, min, g/cm^3	2.25		
Density, max, g/ cm^3	2.40		

3. Conclusion

This development work has shown the following.

- High-performance SCMs can be manufactured from volcanic sediments by dry specific gravity classification and pulverization.
- VGP can be applied to a wide range of concrete and performs well in terms of strength, flowability, and durability.
- VGP can be classified into three types according to its fineness, which led to the establishment of JIS A 6209.

References

[1] Tomoyose, A., Noguchi, T., Sodeyama, K., Higashi. K.: *Volcanic Glass for Concrete*, Concrete Journal, Vol.57, Issue 1, JCI, Tokyo, pp.67-70, Jan. 2019 (in Japanese).
doi: https://doi.org/10.3151/coj.57.1_67
[2] Tomoyose, A., Noguchi, T., Sodeyama, K., Higashi. K.: *Concrete with high-purity volcanic glass fine powder manufactured from pyroclastic deposit*, SN Appl. Sci. 2, 851, 2020.
doi: https://doi.org/10.1007/s42452-020-2614-6