Mechanical Properties of Concrete Made of Natural Lightweight Aggregate and Volcanic Ash as Buffer Layer for Check Dam

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1. Introduction

In recent years, many sediment disasters from typhoons or concentrated heavy rain have been reported in mountain regions worldwide. To mitigate these sediment disasters, concrete check dams are widely used. However, the sleeve of a concrete check dam is sometimes destroyed from collision with boulders contained in debris flow[1)]. To expand the service life of these check dams, it is important to alleviate the shock energy of any debris flow. Placing a buffer layer in front of the concrete check dam is an effective solution.

On the other hand, in Miyazaki Prefecture, Japan, a huge eruption of Mt. Shinmoedake occurred in January of 2011. There was increased risk of debris flow due to ejection of material, such as volcanic scoria and ash, then deposited on the mountain surface. Utilization of volcanic ejection as concrete material is effective not only for resource circulation, but also for the mitigation of sediment disaster in a mountain region. It also matches the philosophy of "*local production for local consumption*". In this study, certain basic mechanical properties of concrete as a buffer layer in front of a concrete check dam made of natural lightweight aggregate and volcanic ash are experimentally investigated and analyzed.

2. The Experimental Outline

Volcanic pumice as a coarse aggregate from Miyakonojo City, Miyazaki Pref., Japan (G1, particle size: 10-5mm, saturated-surface-dry density: 1.35 g/cm^3, water absorption rate: 83.3%, solid content: 60.5%, G2, particle size: 15-10mm, saturated-surface-dry density: 1.27 g/cm^3, water absorption rate: 82.8%, solid content: 57.7%), volcanic ash as fine aggregate from Miyakonojo City, Miyazaki Pref., Japan (saturated-surface-dry density: 2.25 g/cm^3, water absorption rate: 10.75%), ordinary portland cement (density: 3.15 g/cm^3), fly ash as fine aggregate (JIS 2 grade, density: 2.28 g/cm^3, specific surface: 4020 cm^2/g), lignin sulfonic acid-based air-entraining water-reducing agent, alkyl benzene sulfonic acid-based air-entraining agent, and tap water were used; Here, JIS means Japanese Industrial Standards.

The mixure proportion of concrete is shown in **Table 1**. The water-to-cement ratios (W/C) were 70% and 65%. Unit water content was 170 kg/m^3 for all of the mix. In the table, "VA100%" means that 100% volume of the fine aggregate was volcanic ash, "VA90%, FA10%" means that 90% volume of the fine aggregate was volcanic ash and 10% of the volume was fly ash.

Cylindrical specimens with a diameter of 75 mm × height of 150 mm were prepared. Specimens were demolded after 24 h of casting, then water cured until the testing time. Dynamic modulus of elasticity, compressive strength, and static modulus of elasticity were measured in accordance with JIS A 1127, JIS A 1108, and JIS A 1149, respectively, at the material ages of 3 d, 7 d, 14 d, and 28 d. Stress-strain curves for each mix were also obtained.

Table 1 Mix proportion of concrete

Mix Proportion	W/C	s/a	W	C	VA	FA	G1	G2	AEWRA	AEA	Slump	Air Content
	%		kg/m^3								cm	%
VA100%	70	43	170	243	693	0	384	155	0.49	0.8	8.5	5.5
VA90%, FA10%					624	70					3.5	5
VA80%, FA20%					554	140					-	4.5
VA100%	65	43	170	262	687	0	381	154	0.52	0.8	1	9
VA90%, FA10%					618	69					5	7.9
VA80%, FA20%					550	139					9.5	7.8

G1: coarse aggregate (10-5 mm) AEWRA: air-entraining and water-reducing agent
G2: coarse aggregate (15-10 mm) AEA: air-entraining agent

3. Experimental Results

Fig. 1 shows the change in the compressive strength of concrete with material age. **Fig. 2** shows the change in the dynamic modulus of elasticity of concrete with material age. **Fig. 3** shows the change in the static modulus of elasticity of concrete with material age. All the plots are the average value for 3 specimens. Compared to "VA100%", "VA90%, FA10%" and "VA 80%, FA20%" had a higher compressive strength and elastic modulus at all material ages. Less bleeding and pozzolanic reactivity resulting from mixing fly ash were considered to be the reason. For W/C=70%, the compressive strength and the elastic modulus were smaller than for W/C=65%, but the differences between them become smaller with the elapsing of material age.

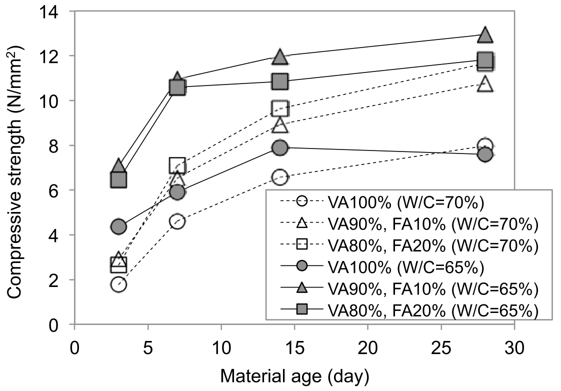

Fig. 1 Change in compressive strength of concrete with material age

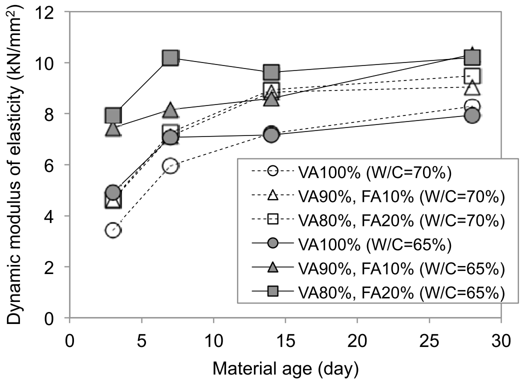

Fig. 2 Change in dynamic modulus of elasticity of concrete with material age

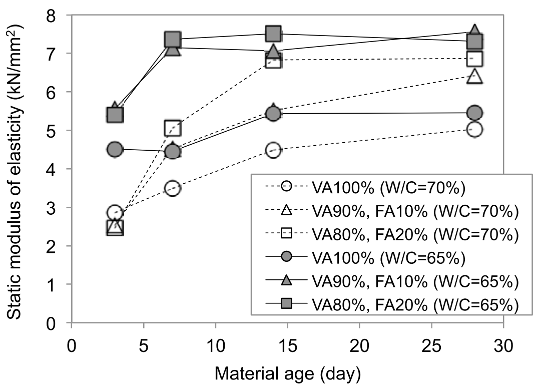

Fig. 3 Change in static modulus of elasticity of concrete with material age

Fig. 4 shows the relationship between the dynamic modulus of elasticity and the static modulus of elasticity. Similar to ordinary concrete, there is a linear relationship between them. It is also indicated that the static modulus of elasticity for the concrete targeted in this study was about 71.3% of the dynamic modulus of elasticity. This percentage is smaller than the value of 83% for plain concrete[2]. It is considered to be resulted from the vulnerability of volcanic pumice as a coarse aggregate.

Fig. 5 shows the relationship between compressive strength and the static modulus of elasticity. There is a linear relationship between them. Therefore using the relational expression, it is possible to predict the static modulus of elasticity to some extent from the compressive strength. This information may be beneficial in the analytical simulation of energy-absorbing properties of concrete such as those targeted in this study.

Fig. 6 shows the stress-strain curves at the material age of 28 d. All the curves were averaged for 3 specimens using Saichi et al.'s method[3]. In the figure, stress-strain curves for polystyrene concrete[4] are also shown. Here, “P-40” means 40% by volume of polystyrene was mixed in the concrete, for example. It is reported that these polystyrene concretes have excellent energy-absorbing properties[4]. A comparison between this study and previous study[4] shows that the stress-strain curves for “VA100%” are similar to that for “P-50”, and the stress-strain curves for “VA90%, FA10%” and “VA80%, FA20%” are similar to that for “P-40”. Therefore, the concretes targeted in this study do have the possibility to function as a buffer layer in front of a check dam.

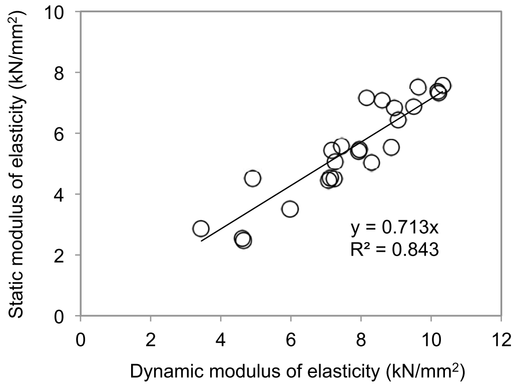

Fig. 4 Relationship between dynamic modulus of elasticity and static modulus of elasticity

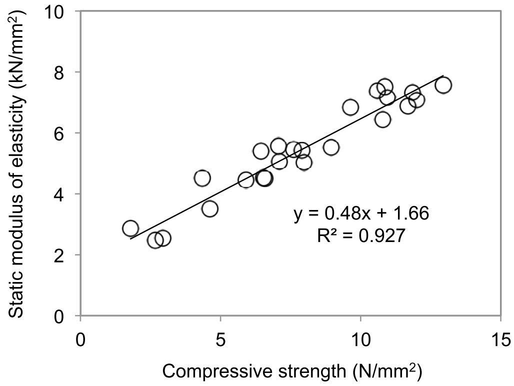

Fig. 5 Relationship between compressive strength and static modulus of elasticity

4. Conclusion

Some of the basic mechanical properties of concrete made of natural lightweight aggregate and volcanic ash are reported here. From the stress-strain curves, concretes targeted in this study were shown to have a possibility to function as a buffer layer in front of a check dam. The authors recognize that it will be vital to clarify the optimum strength and thickness of a buffer layer in a future study by conducting impact tests.

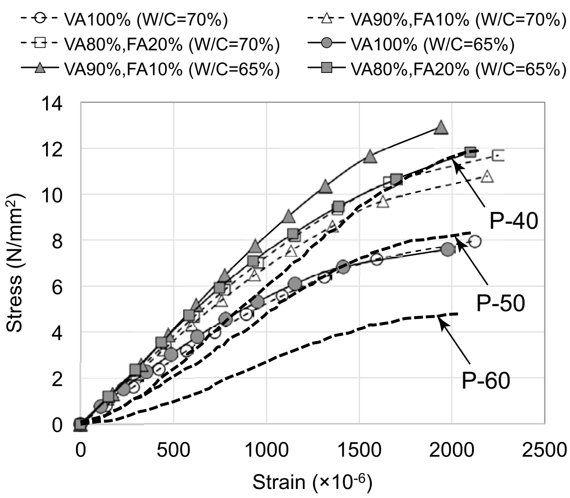

Fig. 6 Stress-strain curves at the material age of 28 d

References

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