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Shock-absorbing capability of lightweight concrete utilizing volcanic pumice aggregate

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HIGHLIGHTS

- Applicability of concrete with volcanic pumice to buffer layer is studied.
- Falling weight impact tester is employed in the impact test.
- Taguchi method is employed in arranging the impact test.
- Using volcanic pumice is statistically significant on reducing impact load.

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ABSTRACT

Sediment disasters from concentrated heavy rains severely damage to civil life. Concrete check dams are widely used to mitigate disasters, however, sometimes such structures are damaged due to collision of boulders or fluid force of debris flow. Placing buffer material in front of concrete structure can be an effective solution. On the other hand, there exist abundantly unused natural resources such as volcanic ash, scoria and pumice in the mountain regions. They sometimes have become risks of debris flow. Utilization of these materials is hence useful for resource circulation as well as disaster prevention.

In this study, shock-absorbing capability of lightweight concrete utilizing volcanic pumice as coarse aggregate was experimentally investigated, for application to buffer material. In the impact test, a falling weight impact tester was employed, with placing buffer layer concrete on base layer concrete. Type of coarse aggregate, water-to-cement ratio, thickness of buffer layer and impact velocity were considered as experimental factors, and the experiments were designed with the Taguchi method. Sizes of specimens and levels of experimental factors were selected based on actual phenomena observed in sediment disasters. As a result, the lightweight concrete is proved to have a superior shock-absorbing capability than control concrete using crushed limestone as coarse aggregate. Statistical analysis results indicated that the lightweight concrete is by averages of 28% and 41% more effective in reducing the maximum impact load than the control concrete, under the impact velocities of 1.5 m/s and 4.5 m/s, respectively.

1. Introduction

Many sediment disasters from concentrated heavy rain have occurred in mountain regions worldwide. To mitigate these sediment disasters, concrete check dams are widely constructed. However, sleeve of concrete check dams sometimes are destroyed from colliding of boulders or fluid force of debris flow [1]. To expand the service life of these structures, it is important to alleviate the shock energy. Perry et al. [2] have reported that low strength lightweight concrete layers proved to be effective in reducing and, in some cases, completely eliminating damage to the structural concrete. Placing buffer layers in front of concrete check dams can thus be an effective solution.

On the other hand, there is an increased risk of debris flow due to depositing volcanic ejections such as volcanic ash, scoria, and volcanic pumice. Application of such volcanic ejections to concrete materials would be effective, not only for resource circulation, but

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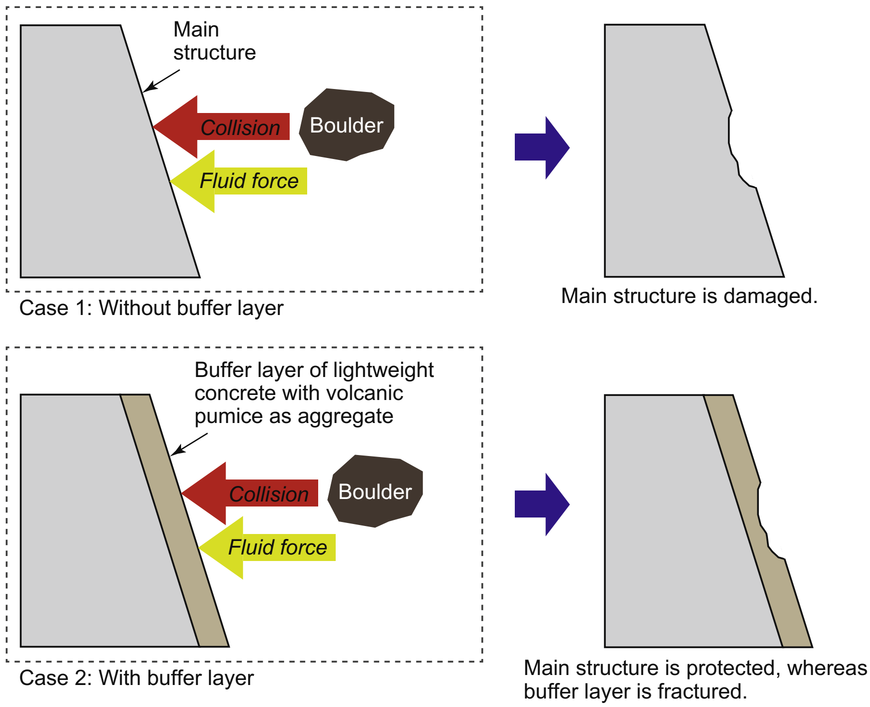

Fig. 1. Schematic concept of the buffer layer targeted in this study.

Table 1
Physical properties of the materials used.

Materials	Symbol	Physical properties
Ordinary Portland cement	C	Density: 3.15 g/cm^3
Sea sand (Kitakyushu city, Fukuoka, Japan)	S	Saturated surface-dry density: 2.59 g/cm^3 Water absorption rate: 1.20%
Crushed stone powder	CSP	Density: 2.58 g/cm^3
Volcanic pumice (Miyakonojo city, Miyazaki, Japan)	G_1	Particle size: 10–5 mm Saturated surface-dry density: 1.35 g/cm^3 Water absorption rate: 83.3%
	G_2	Particle size: 15–10 mm Saturated surface-dry density: 1.27 g/cm^3 Water absorption rate: 82.8%
Crushed limestone (Tsukumi city, Oita, Japan)	G_1	Particle size: 10–5 mm Saturated surface-dry density: 2.70 g/cm^3 Water absorption rate: 0.53%
	G_2	Particle size: 15–10 mm Saturated surface-dry density: 2.70 g/cm^3 Water absorption rate: 0.53%
Air-entraining water-reducing agent	AEWRA	Lignin sulfonic acid-based type
Air-entraining agent	AEA	Alkyl benzene sulfonic acid-based type

also for the mitigation of sediment disasters in the mountain regions. It also matches the philosophy of "local production for local consumption".

Volcanic scoria and pumice are both pyroclastic ejecta [3], which are rock fragments of explosive origin, associated with explosive volcanic eruptions. Volcanic scoria is irregular in form and generally very vesicular, and has the basic composition of basalt. Volcanic pumice is excessively cellular, glassy lava and has the same basic composition of rhyolite. Hossain [3] investigated on the suitability of using volcanic scoria as coarse aggregate in lightweight concrete. He concluded that the lightweight concrete had sufficient strength and adequate density to be accepted as structural lightweight concrete, though it was observed a lower modulus of elasticity, and higher permeability and initial surface absorption than control concrete. Hossain [4] has also reported

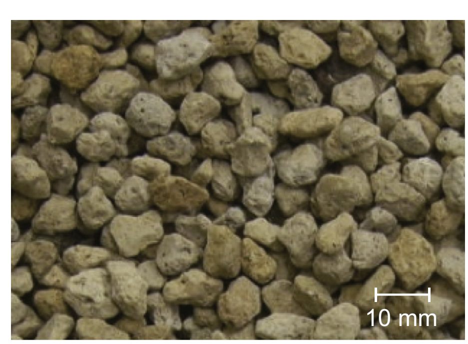

Fig. 2. Appearance of the volcanic pumice used.