Variation of particle grading characteristics of an artificial material mixed by rotary crushing and mixing method

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1. Introduction

Many natural disasters are occurring because of climate change related to global warming. Due to rising temperatures, an increasing number of very strong typhoons are being formed. In East Japan in 2019, the 19th typhoon (Hagibis) caused a lot of damage. 71 river embankments collapsed causing 80,000 households to be flooded. The damage from natural disasters is likely to increase in future and civil engineering structures could suffer more damage. This would mean a greater demand for good quality construction materials. Already, a lot of well-graded soil is required for construction projects and sometimes different materials are also used in combination. In the process, some unwanted (waste) material may be generated. In this study, the rotary crushing and mixing method (twister method) was used to improve the characteristics of the artificial material RC40 which is receiving attention as a recycled material (used in the recovery of collapsed river embankment) without generating by-product or surplus materials.

2. Rotary crushing and mixing machine (Twister machine)

Twister machines are classified according to the size of their cylinders. In this research, Rotary crushing and mixing machine (RCM-Machine) with 500mm cylinder diameter (type TM-500) was used as shown in Figure 1. Materials was put on the conveyor belt for uniform crushing and mixing in the cylinder. Inside the cylinder, there are 3 floors. Each floor consists of 4 flexible chains and the striking force of rotating chains pulverizes the soil into fines. By adjusting the number of rotations up to 1200 rpm (rpm: revolutions per minute), the particles can be crushed in various ways.

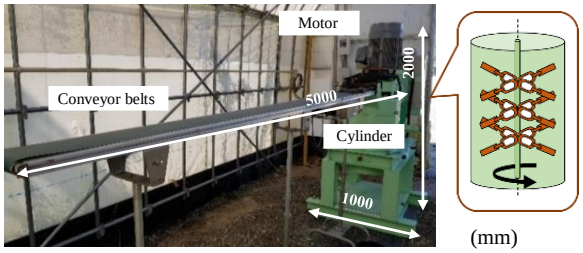

Fig 1. Outline of twister machine

3. Samples and methodology

3-1. Artificial materials RC40

RC40 is a recycled material obtained by crushing asphaltic and cementitious concrete from construction sites. 40 means a grain size of 0 to 40mm. The samples were classified into three categories RC1, RC2, and RC3 according to the 50% diameter of particle (D50). Single particle strength test was carried out for 10 particles of the average particle size. Some index properties for the three samples are given in Table 1.

Table 1. Properties of samples

	Rpm	RC40		
		RC-1	RC-2	RC-3
D_{50} (mm)	0	14.3	22.8	32.0
	400	12.3	21.5	30.5
	800	10.0	11.1	9.9
	1200	5.2	4.2	4.0
U_C	0	1.45	1.19	1.20
	400	1.95	2.07	1.71
	800	5.95	9.27	10.08
	1200	9.43	12.00	11.00
Single particle strength, F_{max} (kN)		2.48	2.09	2.31

3-2. Characteristics of RC40 mixed without twister machine

One of the RC40 was named as the raw material, and the other two samples were mixed at a constant ratio of 10%, 20%, 30%, and 40% respectively to the raw material. In this study, the grain size distribution curve was calculated and not determined from sieve analysis.

3-3. Characteristics of RC40 mixed by twister machine

Firstly, before using RCM-Machine for mixing, 1kg of RC40 was prepared in 1: 1, 3: 7, and 7: 3 ratios. The two types of RC40 materials were then evenly placed on the conveyor belt from 1m before the input for mixing. The number of rotations was set at 400, 800, and 1200rpm.

4. Results and discussion

Figure 2 is a typical graph of RC40 mixed without RCM-Machine. It shows the grain size distribution when RC1 and RC2 are mixed in different ratios. RC40 is an artificial material with a straight grain size distribution curve shape. When other materials are added to the raw material, the curve becomes closer to the added material according to the proportion of the additive. However, when RC1 and RC3 were mixed, a different result was found. The result of the mixed RC1 and RC3 was gap graded because artificial materials RC1 and RC3 do not have particles of 19~26.5mm (Figure 3). The soil with a gap graded grain size distribution is classified as poorly-graded soils.

Therefore, soil mixed with RC1 and RC3 cannot be used as a construction material. However, this problem can be solved if it is

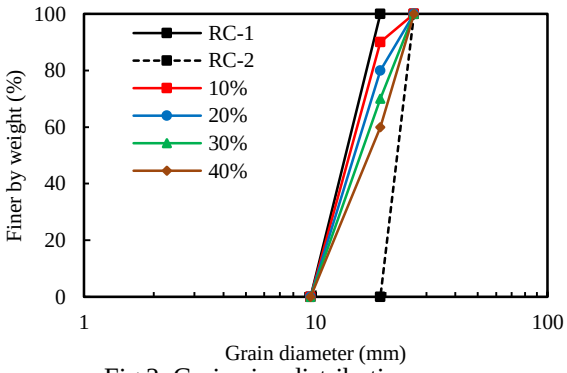

Fig 2. Grain size distribution curve
(Effect of addition of RC-2 to raw material RC-1)

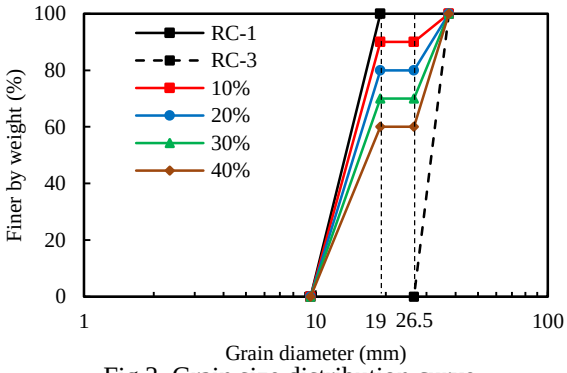

Fig 3. Grain size distribution curve
(Effect of addition of RC-3 to raw material RC-1)

improved with a RCM-Machine. In this study, the gap graded material could be improved using RCM-Machine. Figure 4 shows the results of RC1 and RC3 mixed at a ratio of 1:1 after successive mixing for 400, 800 and 1200 rpm. Samples can be seen to form between the two material grain size distribution curves at 400 rpm, similar to when mixing without the RCM-Machine. As the number of rotations was increased, the changing grain size distribution curve could be identified.

The single particle strength, F_{max} depends on the size of the particles. Data of the mean of $\sigma_C = F_{max}/A$ for each sample against the mean particle size are plotted in Figure 5. A was calculated as $A = (D_{50})^2$ because it is difficult to measure the joint surfaces of particles.

RC40 exhibit near linear decline in strength with increasing particle size in Figure 5. The mixed materials were mixed 1: 1 and the stress was calculated as the average of the stresses of each material. The RC40 was distributed close to one straight line even if two materials were mixed even if one material was crushed. The slope can be calculated to estimate the crushing stress of different size particles.

And, the initial value of D50 and the rate of change of D50 were compared according to the rpm (Figure 6). In the case of crushing test, when the crushed RC40 at 800rpm and 1200rpm, the rate of change of D50 increased as the D50 increased, the rate of change of D50 at 400rpm was decreased. The mixed results of D50 at 800rpm and 1200rpm was lower than a result of crushed material, and the rate of change at 400rpm was higher than a results of crushed materials.

RC40 was crushed according to the rpm to confirm whether it satisfies the requirement for river embankment materials. RC40 satisfied the requirement as river embankment materials when crushed separately at 1200rpm. On the other hand, the results were different when RC40 was mixed at 1200 rpm because the mixed RC40 has a lower rate of change. All results of RC40 mixed at 1200 rpm was closest to the grain size distribution curve required as river embankment. However, with RC40 mixed at 1200rpm of RC40 mixed at 1200 rpm was not satisfied because the requirement for 10% diameter particle size was not satisfied (Figure 7). Thus, the requirements for RC40 to be used as river embankment materials are that they should be crushed separately at 1200rpm and should not be mixed.

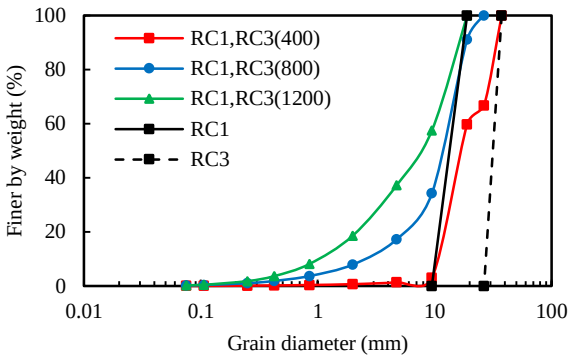

Fig 4. Grain size distribution curve

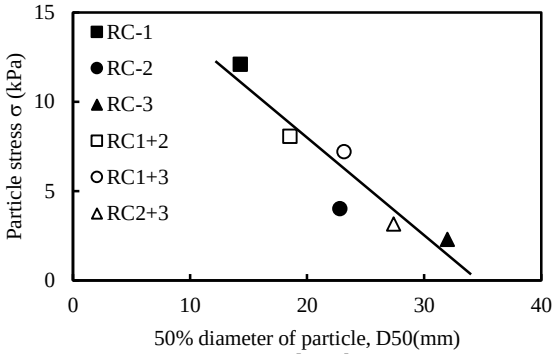

Fig 5. Grain size distribution curve

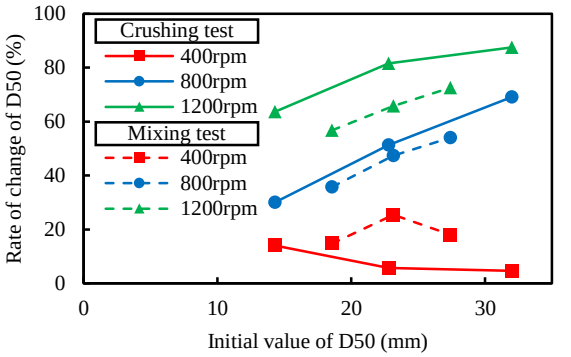

Fig 6. Relationship between the rate of change of D_{50} and initial value of D_{50}

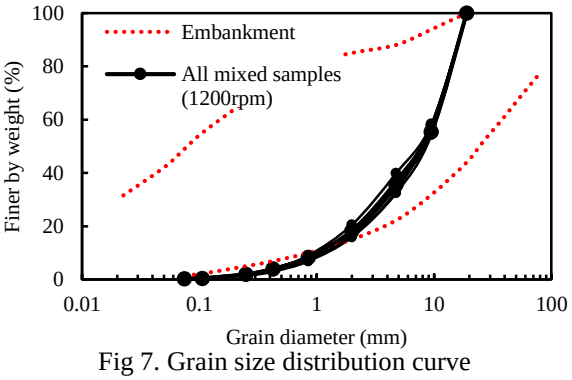

Fig 7. Grain size distribution curve

5. Conclusions

The characteristics of mixing an artificial material in different proportions by RCM-Machine was investigated. The main conclusions are as follows:

(1) The mixing of RC40 with the RCM-Machine at 400rpm was insufficient as geo-materials because of gap grading. From 800rpm, the two materials were determined to be sufficiently mixed.

(2) RC40 has different characteristics depending on the rpm when RC40 is separately crushed and mixed. When RC40 is mixed at 800rpm and 1200rpm, the rate of change in D50 is reduced.

(3) In order to improve the use of RC40 as a ground material of river embankment, each RC40 should be crushed separately at 1200rpm.

Acknowledgement

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Reference

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