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A CONSIDERATION ON MIX-PROPORTION TO UTILIZE LOW-QUALITY FINE AGGREGATES IN AIR-DRY CONDITION

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ABSTRACT: This study aims to investigate the utilization of air-dry recycled fine aggregate and its effects on the fresh and hardened properties of mortar. Low quality Recycled Concrete Fine Aggregates (RCFA) are mainly composed of aggregate and hardened cement paste. Therefore, they induce an enormous water demand, poorer compressive strength, and high variability in mechanical behavior, which makes their application challenging in the production of mortar and concrete. In this study, two types of fine aggregates, gabbro-rock crush sand, and recycled sand are used to produce mortar. Recycled fine aggregate was obtained from waste concrete by pulse power technology. The water absorption of both fine aggregates is comparably calculated by the electrical conductivity method. Cylinder specimens of 50mm in diameter and 100mm in height were prepared and tested for compressive and split tensile strength. The water absorption of fine aggregates progressed rapidly during the first 30 minutes interval of absorption time. Air-dry state of sands was proved promising in affecting the compressive and split tensile strength of mortar. During mixing mortar mixture, the extra-added water was not immediately absorbed by the oven and air-dry RCFA particles. Therefore, the slump flow of mortar increased and it reduced the compressive strength. According to X-ray CT scanned images, the volume of voids were different from each other in RCFA particles. Therefore, the boundary between fine aggregate and water-penetrated areas could not be distinctively observed.

Keywords: Recycled concrete fine aggregate; Water absorption; Air-dry state of moisture; Electrical conductivity; Mechanical properties of fine aggregate

1. INTRODUCTION

Focusing on the conservation of natural resources and to promote a sustainable construction industry, the generated recycled aggregate can be replaced for natural aggregate to manufacture concrete and mortar [1-6].

The influence of using recycled aggregate on the flow properties of concrete was examined based on the assumption that the mix proportioning of concrete must be appropriate. Particularly appropriate proportioning is required when both fine and coarse aggregates are replaced for natural aggregate [7].

Recycled concrete aggregates are typically sourced from construction demolitions and waste. However, due to the attached mortar in RCA, a weaker concrete often resulted when using RCA as partial or full replacement of coarse aggregates [8].

Concrete specimens made from pulsed power recycled aggregate resulted in better strength by 10.0% and 15.8% compared to natural aggregate concrete containing 25% and 50% fly ash, respectively. Moreover, using a Two-Stage Mixing Approach (TSMA) has been applied to improve concrete strength. This method has shown preferable results in strength and can be improved by using the TSMA method in the mixing process [9].

As the replacement of natural aggregate, recycled aggregate was used in air-dry state. It was concluded that the fresh and hardened properties of concrete remained unchanged compared to the concrete prepared with natural aggregate. However, using recycled concrete aggregate after oven-dried or at Saturated Surface Dry (SSD) states, the workability and compressive strength of the concrete were remarkably affected. The fundamental cause of this effect was the high water absorption capacity of the recycled aggregate. Based on the performed study result, aggregate in air-dry condition having only 50% of recycled aggregate should be optimum for normal strength of recycled aggregate concrete manufacture [10].

Mortar produced with Recycled Concrete Fine Aggregate (RCFA) typically presents a lower strength and as a result a lesser durability than similar mortar which is composed of natural fine aggregate [11-13]. When the content of RCFA is increased, the mechanical properties of mortar decreases. Based on the outcome of a few researchers, utilization of RCFA up to a replacement of 30% with natural FA might not make vulnerable the compressive and split tensile strength of mortar [14, 15]. However, according to other authors, the usage of RCFA is not appropriate for the properties of mortar for the high moisture content and adherent cement paste [16-19].

According to previous studies, recycled fine aggregates contain high water absorption capacity. Therefore, the influence of the moisture states related to recycled aggregates on the properties of the fresh and hardened concrete has received some research interest. Pre-wetted and saturated recycled aggregates were used in several studies to prevent a rapid decrease in concrete workability [20, 21].

The mechanical properties of hardened concrete, made from dry and saturated recycled aggregates, were slightly lower than the reference concrete made from natural aggregates.
The decrease was especially obvious in the flexural strength of the concrete prepared with the saturated aggregates. Moreover, the concrete prepared with saturated and dry recycled aggregates showed inferior freeze-thaw resistance, whereas better results were obtained from the concrete made with the semi saturated aggregates [22].

The properties of fine aggregate strongly influence the rheological properties and workability of mortars [23]. Mortars, which are manufactured with 50% of recycled sand along with adding super-plasticizer, showed a reduction in compressive, flexural strength and fracture energy. However, their elastic modulus increased by about 10% concerning standard sand mortar specimens [24].

To prevent the depletion of natural aggregate resources and reduce the environmental burden as well as to consider sustainability and concrete waste management, it is necessary to promote the recycling of concrete. In addition to recycled aggregates, gabbro-rock crush sand and other artificial aggregates are a better substitute for natural aggregate. However, the properties of concrete strictly depends on the nature of aggregate particles. These properties are density, water absorption, and reactivity along with particle size distribution.

It has been reported that the utilization of artificial aggregate such as recycled sand causes a decrease in mortar strength. The attached mortar in recycled sand particles and the moisture content greatly affect the fresh and harden properties of mortar. However, the mechanism of mortar strength reduction has remained unclear.

The main objective of this experimental work is to analyze the influence of moisture content of recycled sand and other fine aggregates that were utilized in the production of mortar. Besides, the work seeks to propose a mixture design for producing mortar containing recycled sand and other fine aggregates.

The recycled fine aggregate was generated from demolished concrete by pulse power technology. This study aims to increase the comprehension of different moisture state effects related to recycled sand on the fresh and hardened mortar properties. Consequently, it could assist in promoting the practical application of low-quality RCFA in mortar production. A test program was carried out to determine the properties of the fresh and hardened mortar prepared with two types of Fine Aggregate (FA) containing different moisture states.

The workability of the fresh mortar was measured by utilizing slump flow, while the compressive and split tensile strength tests were conducted on the hardened mortar specimens. Furthermore, the acoustic emission test was performed during loading the mortar cylinder specimens.

2. EXPERIMENTS

2.1 Materials

2.1.1 Cement and fine aggregate

The cement used in this study was a locally produced ordinary Portland cement equivalent to ASTM Type I Portland cement. The density of the cement was 3.16 gr/cm^3 and the specific surface was 3.5 cm^2/g. No chemical and mineral admixture was used in this study. The fine aggregate used was gabbro-rock crush sand and recycled sand that were reclaimed from recycled coarse aggregate by using electric pulse power technology.

The particle size distribution greatly affects the unit volume of fine aggregate, therefore to reduce this effect and the difference in the actual production rate of mortar, the grain size of the fine aggregate was adjusted to a single grain size. It is from 1.2mm to 2.5mm.

Gabbro-rock crush sand particles are hard and usually dark-black or dark-gray. The shape is angular as it is produced by crushing gabbro block.

The physical properties of the above-mentioned aggregates are summarized in Table 1. It can be seen that recycled sand is one of the low-quality fine aggregates, which has a higher water absorption coefficient than gabbro-rock crush sand. Also, the water demand of fine recycled aggregate is higher, which is explained by the presence of a porous old mortar adhered to the natural aggregates. Moreover, if fine aggregates are reclaimed by the crushing process, a network of cracks could be observed around the particle. The higher porosity and the old paste present in RCFA lead consequently to a lower density of recycled fine aggregates compared to gabbro-rock crush sand.

2.2 Preparation and Design of mortar mixture

Before mixing mortar mixture, four moisture states of the above fine aggregates; humid, saturated surface dry, air-dry (partially-dry), and oven-dry were considered.

Table 1 Physical properties of fine aggregate

Physical Property	Recycled Sand	Gabbro-rock crush sand
Surface dry density (gr/cm^3)	2.53	2.93
Dry density (gr/cm^3)	2.35	2.88
Water absorption (%)	7.62	1.84
Solid content (%)	60.8	57.7
Unit weight(gr/cm^3)	1.43	1.66

Table 2 shows the water content for mentioned moisture states. To make an air-dry state of FA, two techniques such as incubator for recycled sand and ball mill for gabbro-rock crush sand were used to make them partially dried. Time to time their weight was checked until achieving the target weight, which is almost 50% of saturated surface dry state. Electrical conductivity and ASTM C128 methods were used to make a saturated surface dry state of the fine aggregate. Fig.1 shows the various moistures states of FA particles. Fig.2 shows the weight loss of recycled sand in an incubator. The temperature in the incubator was 55 ˚C and remained constant.

The weight loss of gabbro-rock crush sand is presented in Fig.3. It was put in a glass bottle and placed the bottle on two vibrating rods. (Ball mill). After repetitive rolling of the bottle, the gabbro-rock crush sand got partially dried.

Table 2 Water content of FA with different moisture states

Moisture State	Water Content (%)	
	Gabbro-Rock Crush Sand	Recycled Sand
Air-Dry	0.92	3.81
Saturated Surface Dry	1.84	7.62
Oven-Dry	0.00	0.00

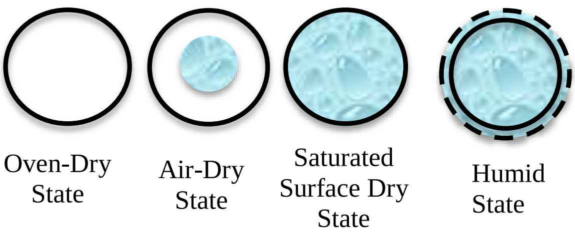

Fig.1 Different moisture states of FA particles

Referring to Table 1, the water absorption of fine aggregates is given at a saturated surface dry state Fig.2 and Fig.3 show various weights of recycled and gabbro-rock crush sand, respectively. The target weight 3363 gr and 3964 gr are both 50% of saturated surface dry state water content which is called here air-dry (partial-dry). The fine aggregates were oven-dried in a 105 ˚C oven for 24 hours. They were cooled down to room temperature before mixing in the mixture.

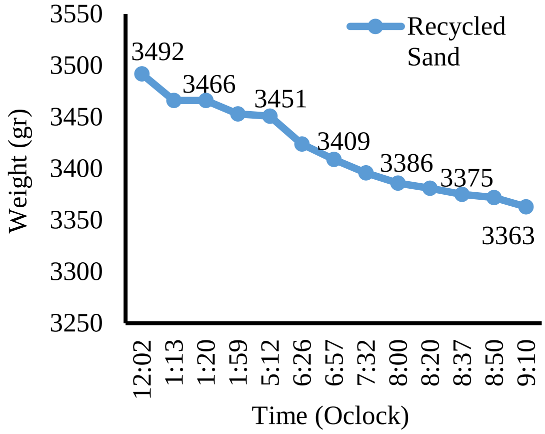

Fig.2 Weight loss of recycled sand in an incubator under 55 ˚C constant.

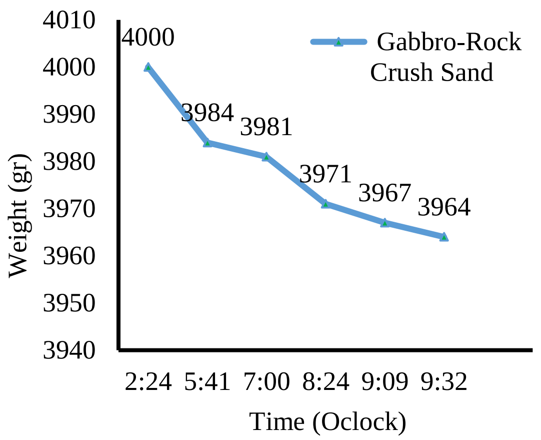

Fig.3 Weight loss of gabbro-rock crush sand in ball mill method

After 24 hours immersed in water, the FA was made saturated surface dry by removing the surface moisture through a dryer mechanical device. ASTM C128 standard device was used to determine the saturated surface dry state.

The mortar mixes were prepared in two stages with the use of fine recycled aggregate and gabbro-rock crush sand considering four different combination mix design. Gabbro-rock crush sand humid state (CHS), saturated surface dry state (CSSD), air-dry or partial dry state (CPD), and oven-dry state (CODS). In the case of recycled sand humid state (RHS), saturated surface dry state (RSSD), air-dry or partial dry state (RPD), an oven-dry state (RODS). These proportions of the mortar mixes were designed using the absolute

weight method. Adjustments were made according to the moisture contents and water absorption capacity of the respective fine aggregates.
Cement to sand ratio was considered 1:4 and a free water-to-cement (w/c) ratio was 0.55.
Total 8 mortar mixes and 48 cylinders were prepared with different combinations of water at different moisture states. The cement amount was kept constant in all mixes.

To maintain the designed mix proportioning unchanged, the amount of water and aggregates were adjusted according to the actual moisture contents. An additional amount of water was needed to saturate the aggregates in air-dry and oven-dry states. Table 3 shows a basic mixture design for mortar while Table 4 shows the adjusted mortar mixture design.
The mortar mixture was mixed for 4 minutes in a small mortar mixer before casting into molds (cylinders) and compaction on a vibrating table. The cylinders were kept at standard room temperature and de-molded after 28 days.

Table 3 Basic mixture design of mortar

Type of FA	W/C	Cement (gr)	Water (gr)	Sand (gr)
CHS	55	2263	1244	10366
CSSD	55	2263	1355	9854
CPD	55	2263	1355	9764
CODS	55	2263	1244	10189
RHS	55	2263	1244	8951
RSSD	55	2263	1355	8811
RPDS	55	2263	1355	8516
RODS	55	2263	1244	8314

Table 4 Modified mixture design of mortar

Type of FA	W/C	Cement (gr)	Water (gr)	Sand (gr)
CHS	55	2263	1244	10366
CSSD	55	2263	1355	9854
CPD	**58**	2263	**1445**	9764
CODS	**63**	2263	**1431**	10189
RHS	55	2263	1244	8951
RSSD	55	2263	1355	8811
RPDS	**67**	2263	**1650**	8516
RODS	**83**	2263	**1878**	8314

2.3 Electrical Resistance Test of Fine Aggregate

The density and water absorption of fine aggregate (Recycled sand and gabbro-rock crush sand) were calculated by the electrical resistance method. The adjusted size of particles was between 1.2mm to 2.5mm. Table 1 shows the measurement results of different physical properties. The saturated surface dry density and oven-dry density were the average values of the experimental results obtained from the operations of four testers.

Regarding water absorption, the relationship between the electrical resistance value and the water content of the sample with surface water and without surface water is given by a straight line. They were divided into two groups (a group of fine aggregate with 12 samples having surface water and the second group with 12 samples having no surface water).

Fig.4 and Fig.5 illustrate the relationship between electrical resistance value and moisture content at different moisture states.

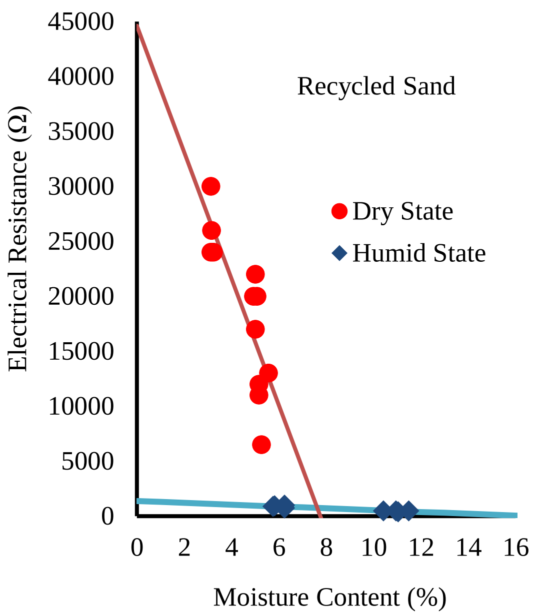

Fig.4 Electrical conductivity test result for recycled sand

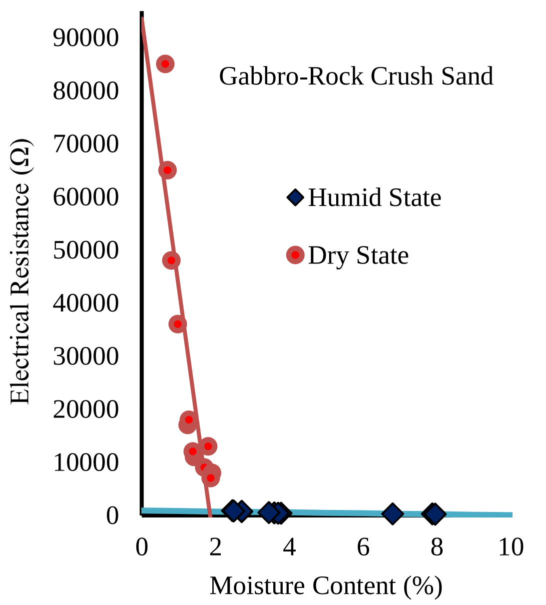

Fig.5 Electrical conductivity test result for gabbro-rock crush sand.

Gabbro-rock crush sand has a dense structure and higher quality. One of the key factors which determine the water absorption of aggregates is the large number of voids inside the particles. From the test result, it is assumed that the space for water absorption was limited as the voids inside the gabbro rock crush sand were small. Consequently, the water absorption is low and density is high.

The structure of recycled sand is not dense and accordingly, the water absorption is higher than gabbro- rock crush sand. The unevenness of the hardened cement paste ratio, which is attached to fine aggregate, causes the high water absorption and density reduction. Meanwhile, the shape of the recycled aggregate is not stable and distorted.

2.4 Analysis of X-ray CT Scan Method

To clarify the internal structure and water absorption of various fine aggregates, a micro-focus X-ray CT scanner was used to photograph the cross-section of fine aggregate.

An X-ray detector was used to visualize the contrast as a photograph which is called the X-ray transmission method. The image gets enlarged by bringing the subject closer to the X-ray source, and a wide range of imaging is possible by bringing the subject closer to the detector. Therefore, to observe the subject at high magnification, the focal size is about a few micron meters.

In this study, various samples were considered like oven-dried, immersed in water for 30 minutes and 24 hours, respectively. In the last two cases, the surface water was rubbed off. The samples were placed in a cylindrical acrylic container and an absorbent cotton was placed at the boundary between each sample to prevent them from drying.

Fig.6 shows the relationship between the water absorption time and the mass of water absorbed for 500 grams of air-dry fine aggregate. This relationship clearly describes that all fine aggregate after they were soaked in water, rapidly absorbed water in the initial stage. The reason behinds this phenomenon is that water easily penetrates the surface layer of FA, while the water penetrating process to the internal structure took place longer and slower. It is concluded that more time is required to get water absorbed into the deeper part of particles.

Fig.7, Fig.8 and Fig.9, show cross-sectional images of gabbro-rock crush sand by X-ray CT scanner. According to these images, gabbro-rock crush sand particles had a square shape, because the rock surface was mechanically crushed during the process of forming crushed sand and the fracture surface became sharp.

The absorbed water in the internal structure (middle part) of gabbro-rock crush sand was difficult to determine. Because of the low water absorption (1.84%) and the boundary between aggregate and water was not thicker as well.

Looking at the cross-sectional image of the recycled fine aggregate, it can be seen that the shape of the particles was round. The fact behind this phenomenon was the pulse power discharge method which caused the tensile stresses to act on the concrete specimens.

The hardened mortar and the aggregate were peeled off. As recycled aggregate contained various densities and voids were varied widely in the internal structure of particles, it was not possible to identify a clear boundary line between water and the aggregate. Fig.10, Fig.11, and Fig.12 show the cross-sectional images of recycled sand by an X-ray CT scanner.

The water absorption process of gabbro-rock crush sand and recycled sand were studied over time. Generally, before making mortar or concrete, the aggregate is put in water to absorb water for 24 hours. However, during this research the recycled sand was made air-dry state by putting it in an incubator for a specific time. To gradually dry the sand particles the temperature of the incubator was set to 55°C. The weight loss was monitored from time to time and mixed the particles so that they could be dried homogeneously.

Gabbro-rock crush sand is very sensitive to absorb and lose water.

The water absorption of fine aggregate is a very significant process, especially at the time of mixing mortar.

To measure the water absorption of air-dry fine aggregate over time, the water absorption was determined per JIS A 1109 “Test method for density and water absorption of fine aggregate”.

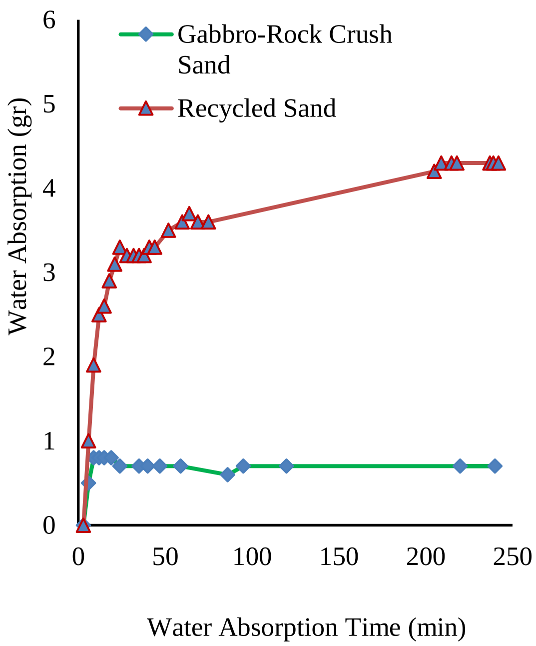

Fig.6 Water absorption of fine aggregates immersed in water.

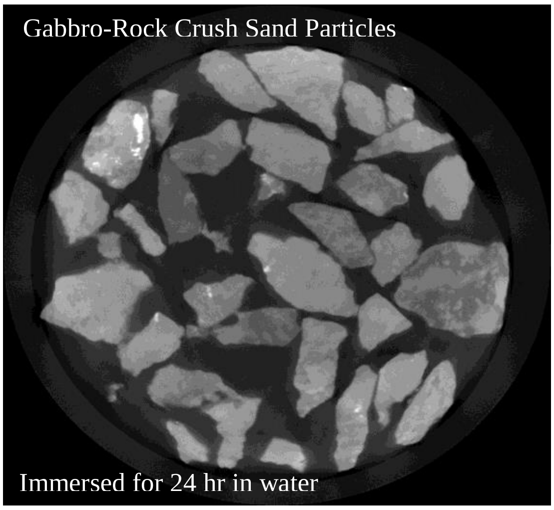

Fig.7 X-ray CT scanned image of gabbro-rock crush sand immersed in water for 24 hours

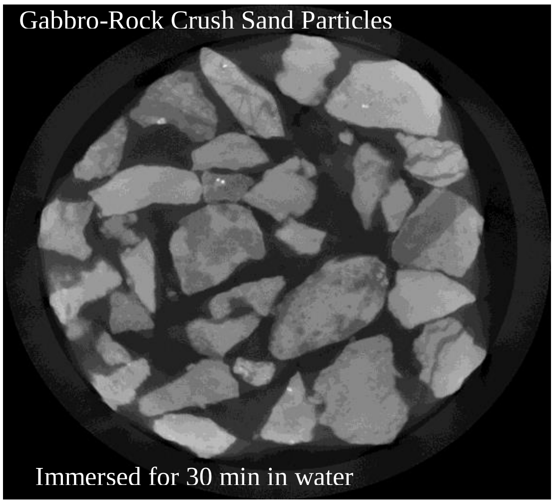

Fig.8 X-ray CT scanned image of gabbro-rock crush sand immersed in water for 30 minutes

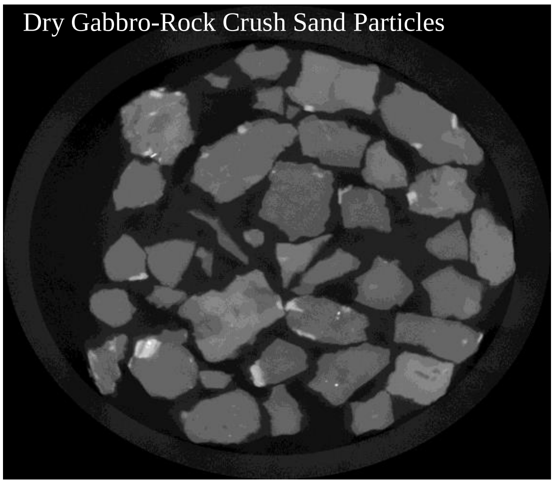

Fig.9 X-ray CT scanned image for the dry state of gabbro-rock crush sand.

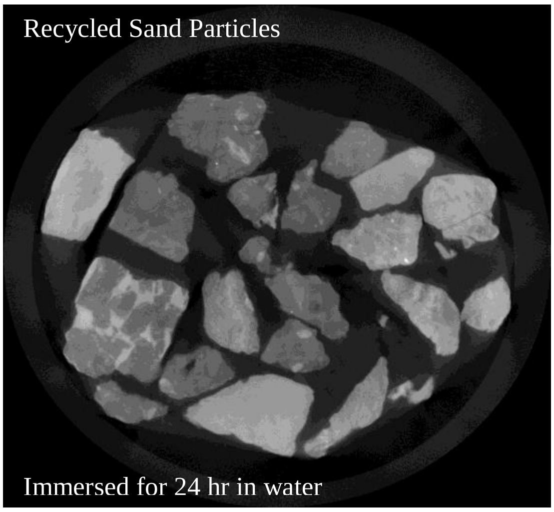

Fig.10 X-ray CT scanned image of recycled sand immersed in water for 24 hours

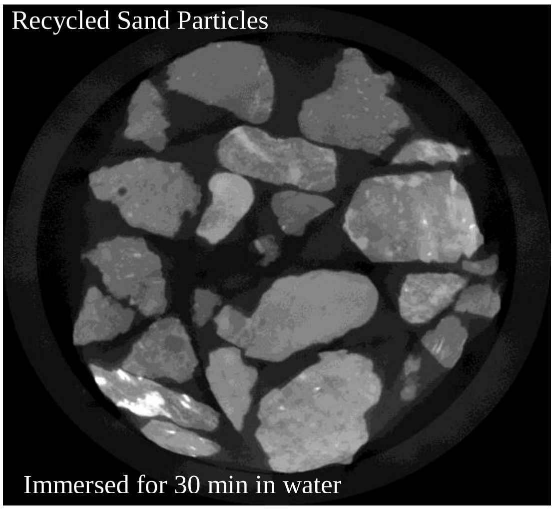

Fig.11 X-ray CT scanned image of recycled sand immersed in water for 30 minutes

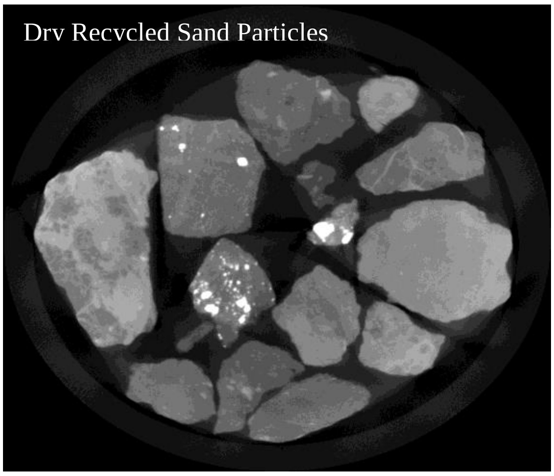

Fig.12 X-ray CT scanned image for the dry state of recycled sand

2.5 Slump Flow Test

The preparation of mortar, flow test, and molding cylinders were performed at a constant room temperature (20±2 ℃, relative humidity 50%). The mortar was prepared according to JIS R 5201. A desk-type paddle mixer SK-10 containing 10-liter capacity was used to make mortar.

The mixed mortar was put into the flow cone device in two layers. Each layer was compacted by penetrating the rod into about half of layer depth for 15 times. Adding extra mortar to adjust the shortage and then smoothed the surface. The flow cone was removed in a vertical direction immediately. The paddle of the flow table was rotated 15 times in 15 seconds. Consequently, after the mortar has spread to the maximum direction and the direction perpendicular the diameter was measured.

Table 5 shows the slump flow test value for all mixes. For each mixture and each curing time three specimens were tested for a given experimental condition. Specimens were cured in water at room temperature and the mechanical properties were evaluated on the 28th day.

Table 5 shows the slump flow test value for all mixes

Slump Flow Test	
Type of Mortar	Slump flow (mm)
CHS	116.1
CODS	107.5
CSSD	113
CPDS	120
RHS	158
RODS	171
RSS	157
RPD	162

2.6 Compressive and Split Tensile Strength Test

The compressive strength of the hardened mortar was determined according to JIS R 5201 standard.

The split tensile strength of the hardened mortar was determined by JIS A 1113 standard. All the specimens (cylindrical specimens of 50mm in diameter and 100mm in height) were cured in a constant room temperature (20 ± 2 ℃, relative humidity 50%).

3. RESULT AND DISCUSSION

3.1 Initial slump flow

The difference in moisture states significantly affected the slump flow of the mortar. Referring to Table 5 the highest value is represented by ROD mortar. The higher initial slump flow value for the mortar with the oven dry and air-dry aggregates was due to the higher initial free water content in the mix (see Table 3). However, as the absorption capacity of the gabbro-rock crush sand was only 1.84%, the adjusted amount of water was small, thus resulted in a small change in the initial slump value.

The present study shows that in the case of oven-dry and air-dry states of fine aggregates compared to SSD state, the mortar slump flow value is increased. This means the extra-added water in the mix was not immediately absorbed by aggregates. Air-dry fine aggregate compared to oven-dried, easily absorbed water over time.

3.2 Compressive and Split Tensile Strength

In the cases of CPD, COD, RPD and RODS states mortars the extra-added water was absorbed by the mortar FA particles. However, it was possible that in the case of CHS, CSSD, RHS, and RSSD states mortar, the absorbed water of FA seeped into cement paste. Therefore, the air-dry states showed the highest compressive strength compared to the SSD state.

The compressive strength of RCFA mortars was less compared to gabbro-rock crush sand mortars.

Compressive strength depends on the water-cement ratio and water absorption of FA. Particularly the water absorption process of air-dry fine aggregate until the mortar gets hardened. It can be suggested that when the fine aggregates containing high water absorption such as RCFA are used, the compressive strength might be increased by designing the mixture with a small water cement-ratio.

For various combinations of mortar mixes, the effects of the moisture states related to RCFA and gabbro-rock crush sand had different results. The compressive strength of oven-dry recycled sand state mortar was lower. However, the oven-dry gabbro-rock crush sand state mortar had the highest compressive strength.

The internal structure of gabbro-rock crush sand particles was extremely dense, and therefore water absorption was much less. In contrast, the recycled fine aggregate structure was porous. During mixing, the absorbing process and seeping out of water was not stable.

According to the result of the compressive strength test, the fine aggregates, which were used in humid and saturated surface dry states, decreased the compressive strength of the mortar. It could be suggested that water inside fine aggregate might have seeped to cement paste, and as a result, the water-cement ratio increased. Besides, the bond between the cement paste and aggregate is considered weak. Therefore, to evaluate more clearly the strength of the bond between the aggregate and the cement paste, the strength was

examined by generating tensile stress on the mortar specimens.
The split tensile strength of mortars made of gabbro-rock crush sand with different moisture states had small differences. This is probably because the water absorption value of gabbro-rock crush sand was low (1.84%).

The air-dry state recycled fine aggregate was able to absorb the added water of the mortar mixture over time. However, the split tensile strength of the mortar did not decrease.
The compressive and split tensile strength of mortar mixes are shown in Fig.13 and Fig.14
Mortar specimens that were made of oven-dry gabbro-rock crush sand had the highest split tensile strength compared to recycled sand specimens.

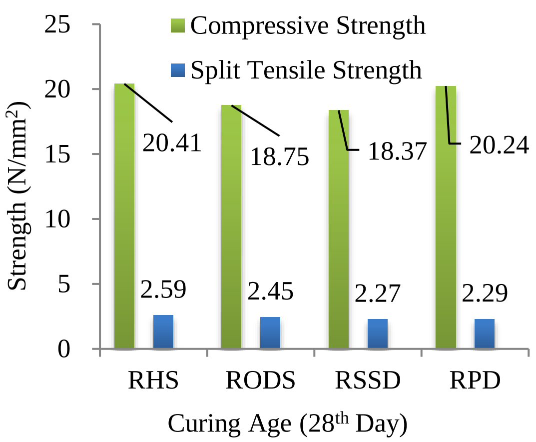

Fig.13 Compressive and split tensile strength of recycled sand mortar specimens

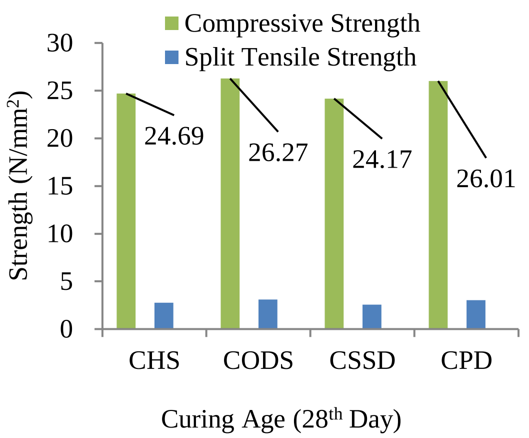

Fig.14 Compressive and split tensile strength of gabbro-rock crush sand mortar specimens

To compare the moisture states' effects, oven dry and air-dry states had better results than humid and saturated surface dry states. In this study SSD state of gabbro-rock crush sand had the lowest strength compared to other moisture states.
As far recycled sand is concerned, a humid state of it showed the highest strength.

4. CONCLUSIONS

Based on the results obtained from experimental data in this research, the following conclusions could be drawn.

1. The electrical conductivity method‘s measurement result for fine aggregate depends on the shape and homogeneity of particles. As RCFA contained a non-homogeneous structure, the accuracy of the test results was limited and had low reliability.
2. The different moisture states of fine aggregates had particular effects on slump flow. ROD state mortar had the highest initial slump flow value in comparison to other moisture states.
3. The initial slump flow of the mortar was strongly dependent on the initial free water content and immediate water absorption of the FA used in mortar mixes.
4. As gabbro-rock crush sand is very dense, therefore, CPD state mortar had higher compressive strength compared to CHS and CSSD states mortar.
5. Using a humid state of FA, with low water absorption property, caused the water to seep out from the particles to mortar paste. Thus the water-cement ratio increased and the compressive strength decreased accordingly.
6. ROD and RPD states of mortar revealed the highest compressive and split tensile strength. The RSSD and CSSD states FA seemed to impose the negative effects on the mortar strength, which might be attributed to ‘‘bleeding’’ of excess water in the mixing process of fresh mortar.
7. Based on X-ray CT scan results, the boundary between RCFA and water-penetrated areas cannot be observed and the volumes of voids were different with each other. There were almost no voids containing water inside the gabbro-crush, fine aggregate particles.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Huda S.B., Alam M.S., Mechanical behavior of three generations of 100% repeated recycled coarse aggregate concrete, Constr. Build. Mat. Vol. 65, 2014, pp.574-582.

[2] Pedro D., Brito de J., and Evangelista L., Influence of the use of recycled concrete aggregates from different sources on structural concrete, Constr. Build. Mat. Vol.71, 2014, pp.141-51.

[3] Soares D., Brito J. de, Ferreira J., and Pacheco J., Use of coarse recycled aggregates from precast concrete rejects: mechanical and durability performance, Constr. Build. Mat. Vol.71, 2014, pp.263-272.

[4] Thomas C., Setién J., Polanco J.A., Lombillo I., and Cimentada A., Fatigue limit of recycled aggregate concrete, Constr. Build. Mat. Vol.52, 2014, pp.146-154.

[5] Brand A.S., Roesler J.R., and Salas A., Initial moisture and mixing effects on higher-quality recycled coarse aggregate concrete, Constr. Build. Mat. Vol.79, 2015, pp.83-89.

[6] Huda S.B., and Alam Shahria M., Mechanical and freeze-thaw durability properties of recycled aggregate concrete made with recycled coarse aggregate, J. Mat. Civ. Eng. 2015, 04015003. Concrete Structures and Materials, Vol. 4, No. 2, 2010, pp.113-118

[7] Buyle-Bodin F., and Zaharieva R.H., Influence of industrially produced recycled aggregates on flow properties of concrete. Materials and Structures, Vol 35, No. 504e509, 2002.

[8] Anthony J.T., Richard D.J., and Alvin C., Microstructure and mechanical properties of Concrete with treated recycled concrete Aggregates. International Journal of GEOMATE, Vol.16, Issue 57, 2019, pp.21-27

[9] Arifi E., Zacoeb A., and Shigeishi M., Effects of Fly Ash on the Sstrength of Concrete made from Recycled Aggregate by Pulse Power. International journal of GEOMATE, Vol. 7, Issue 1, 2014, pp.1009-1016.

[10] Poon C.S., Shui Z.H., Lam L., Fok H., and Kou S.C., Influence of moisture states of natural and recycled aggregates on the slump and compressive strength of concrete. Cement and Concrete Research, Vol, 34, No.31e36, 2004.

[11] Lee C.H., Du J.C., and Shen D.H., Evaluation of pre-coated recycled concrete aggregate for hot mix asphalt. Constr Build Mat, Vol.28, Issue 1, 2012, pp.66-71.

[12] Choi Y.W., Moon D.J., and Kim Y.J., Characteristics of mortar and concrete containing fine aggregate manufactured from recycled waste polyethylene terephthalate bottles. Constr Build Mat, Vol.23, Issue 8, 2009, pp.2829-2835.

[13] Dapena E., Alaejos P., Lobet A., and Pérez D., Effect of recycled sand content on characteristics of mortars and concretes. J Mater Civ Eng, Vol. 23, 2011, p.414.

[14] Braga M., Brito de J., and Veiga R., Incorporation of fine concrete aggregates in mortars. Constr Build Mat, Vol.36, 2012, pp.960-968.

[15] Vegas I., Azkarate I., Juarrero A., and Frías M., Design and performance of masonry mortars made with recycled concrete aggregates. Mater Constr, Vol.59, 2009.

[16] Corinaldesi V., Giuggiolini M., and Moriconi G., Use of rubble from building demolition in mortars. Waste Manage, vol 22, issue 8, 2002, pp.893-899.

[17] Corinaldesi V., Mechanical behavior of masonry assemblages manufactured with recycled-aggregate mortars. Cement Concr Compos, Vol.31, Issue 7, 2009, pp.505-510.

[18] Corinaldesi V., and Moriconi G., Influence of mineral additions on the performance of 100% recycled aggregate concrete. Constr. Build. Mat. Vol.23, Issue 8, 2009, pp.2869-2876.

[19] Lee S.T., Influence of recycled fine aggregates on the resistance of mortars to magnesium sulfate attack. Waste Manage, Vol.29, Issue 8, 2009, pp.2385-2391.

[20] Lucy F.N., Mukaddes D.M., and Tewodros G., Comparative Investigation of the Effect of Recycled Fine Aggregate from New and Old Construction Wastes in C-25 Concrete in Ethiopia. Sustainability, Vol 11, No. 7116, 2019.

[21] Sagoe-Crentsil K.K., Brown T., and Taylor A.H., Performance of concrete made with commercially produced coarse recycled concrete aggregate. Cem. Concr. Res. Vol. 31, 2001, pp.707-712.

[22] De Oliveira M.B., and Vazquez E., The influence of retained moisture in aggregate from recycling on the properties of new hardened concrete. Waste Manag. Vol. 16, 1996, pp.113-117.

[23] Westerholm M., Lagerblad B., Silfwerbrand, J., and Forssberg E., Influence of fine aggregate characteristics on the rheological properties of mortars. Cement and Concrete Composites. Vol. 30, 2008, pp.274–282.

[24] Luciana R., Consuelo S., Giuseppe Andrea F., and Jean-Marc T., Recycled Mortars with C&D Waste, 21st European Conference on Fracture, ECF21, 20-24 June 2016, Catania, Italy.