

STUDY ON REDUCTION OF UNIT WATER AMOUNT OF CONCRETE WITH WASTE GYPSUM

ATSUSHI SHIMABUKURO and KEIJI KUWAJIMA

Dept of Civil Engineering and Architecture, NIT, Tokuyama College, Shunan, Japan

This study discovered that the combination of waste gypsum and fly ash was capable of being used as fine aggregate in concrete. However, results showed that the unit water amount of the concrete with waste gypsum had to be increased to assure the designated workability. In general, if the unit water amount of concrete increases, hardened concrete will have various issues. Therefore, in this study, we try to reduce the unit water amount of this concrete by the high-performance AE (Air Entraining) water reducing agent containing viscosity improver. In order to investigate the effect of the above AE water reducing agent for the reduction of the unit water amount of the concrete with waste gypsum, the workability of above concrete with this agent from slump test and air containing test was examined. Also, compression, tension, and bending, of the concrete with waste gypsum from each strength test was measured. On the basis of the test results, it showed that we are able to assure the workability of fresh concrete with waste gypsum by the above agent used in this study, even if the unit water amount is reduced. Also, it was confirmed that the compressive strength of concrete with waste gypsum is equivalent to the strength of concrete without waste gypsum.

Keywords: High-performance, Air entraining water reducing agent containing viscosity improver, Trial mixing, Workability, Strength test, Strength ratio.

1 INTRODUCTION

The sea sand is used as a fine aggregate of concrete. To protect marine resources, the mining of sea sand is prohibited and the Japanese government limits the expansion of mining regions in the coastal regions of Setouchi of Japan. In recent years, the use of crushed sand as a fine aggregate in concrete has increased, and crushed sand is widely used to take the place of sea sand. However, the rocks which are the raw material of crushed sand are used as a fine aggregate of concrete as well as a material for asphalt concrete. The supply of rocks will be more and more difficult in future years. Therefore, we use waste gypsum to replace a part of sand as the fine aggregate of concrete. The amount of waste gypsum generated in Japan is next to concrete waste, construction sludge and wood waste. It is expected that the amount of waste gypsum will keep increasing in the future. Hence, it is necessary to find a good method for the practical use of waste gypsum.

In a previous study, we verified that the combination of waste gypsum and fly ash was able to be used as a fine aggregate of concrete (Shimabukuro and Kuwajima 2017). However, it shows that the unit water amount of the concrete with waste gypsum increased in order to secure the designated workability. In general, if the unit water amount of concrete increases, there will be various problems with hardened concrete. Therefore, in this study, we try to reduce the unit water amount of concrete by high-performance air entraining (AE) water reducing agent containing viscosity improver, which is named as AEV in this paper.

In order to investigate the effect of AEV on reducing the unit water amount of concrete containing waste gypsum, we make and test trial mixes for the concrete with waste gypsum and AEV until the target values of the slump and the air content are satisfied. Then, the appropriate mix proportion of each material for the concrete with waste gypsum and AEV is determined, based on the results of trial mixing. In addition, we conduct the strength tests on the concrete specimens that are made with this mix proportion. According to these above tests, the effect of AEV on the concrete with waste gypsum for (i) fresh concrete characteristics, and (ii) strength characteristic of the hardened concrete are evaluated.



Figure 1. The result of the sieving test.

2 ABOUT WASTE GYPSUM

Gypsum board is widely used as a building material because it has a low price and some useful properties, such as fire resistance, adiabaticity, and sound insulation. The waste gypsum is produced when dismantling buildings having gypsum board. According to the extent of crystallization of water, the gypsum is classified into the gypsum dihydrate, the gypsum hemihydrate and the anhydrous gypsum (Kanto Branch of Japanese Geotechnical Society 2013). The waste gypsum used in this study is the gypsum hemihydrate. The property of the gypsum hemihydrate is to react with the water and to solidify. The results of the sieving test of the waste gypsum used in this study are shown in Figure 1 (Shimabukuro and Kuwajima 2017). From this result, we consider that the waste gypsum can be applied to substitute the sand as a fine aggregate, because the particle size distribution of the waste gypsum is within the standard particle size range of fine aggregate.

3 ABOUT AEV

AEV used in this study is a kind of an air entraining and high-range water reducing agent that integrates viscosity improvement into a high-performance AE water reducing agent. The properties of AEV are described as follows:

- It is classified as a high-performance AE water reducing agent in Japanese Industrial Standards (JIS).
- We can upgrade ordinary concrete with a relatively small cement amount to high flowing concrete.
- We can improve the workability of the fresh concrete and reduce the amount of compaction required.

From these properties, it is considered that workability can be assured by applying AEV to concrete with waste gypsum, even if the unit water amount in concrete is reduced.

4 EXPERIMENTAL OVERVIEW

4.1 Mix Design

We conducted the mix design of the concrete in which a part of the fine aggregate is replaced with waste gypsum. For each design condition of the concrete, the design strength is 18 N/mm², the targeted slump value is 8 cm, and the targeted air content is 4.5%. And, the water-cement ratio is 0.64 because we use this value when we set the concrete strength to 18 N/mm² in our laboratory. The maximum size of crushed stone used as coarse aggregate is 20 mm in this study. On the other hand, the sea sand with the fineness modulus of 2.70 is used as the fine aggregate. Each density of the coarse aggregate and the fine aggregate is 2.66 g/cm³ and 2.60 g/cm³, respectively. Also, the density of waste gypsum used in this study is 2.63 g/cm³. The replacement ratio of waste gypsum to the fine aggregate is 10% of the volume ratio. AEV is mixed depending on the ratio of the weight to the cement amount.

4.2 Slump Test and Air Content Test

In this study, we made trial mixes to find the required amount of each material in the concrete until the slump and the air content satisfy the targeted value. The slump and the air content are measured by the method standardized by JIS. The tolerances of the slump value and the air content are ± 2.5 cm and ± 1.5 %, respectively.

4.3 Curing Method and Curing Period

The curing method in this study uses water curing for a week, four weeks, and 12 weeks for the compressive strength test.

4.4 Strength Test

The compressive strength test is carried out according to the method standardized by JIS. The shape of the specimen is a cylinder with 100 mm diameter and 200 mm height. The compressive load is sustained until the specimen fractures entirely. We calculate the compressive strength from the maximum load. And we carry out the tensile strength test and the bending strength test to confirm their relationship with compressive strength. The tensile strength specimens are the same shape as the compressive strength test specimens, and the bending strength specimens are

the prismatic shape with width of 150 mm, height of 150 mm, and length of 530 mm. These strength tests are also performed under the method standardized by JIS.

Mixing Case	W (kg/m ³)	C (kg/m ³)	Wg (kg/m ³)	S (kg/m ³)	G (kg/m ³)	AE (kg/m ³)	Note	Slump (cm)	Air (%)	Evaluation (Satisfying target values)
OC	169	264	0	816	1036	0.911	Our	8	4.1	0
PC	192	300	79	700	985	0.912	study	7	5	0

Table 1. Mix proportion quantity and the results of our previous study.

W: Water, C: Cement, Wg: Waste gypsum, S: Fine aggregate (sea sand), G: Coarse aggregate, AE: AE water reducing agent

Table 2. Mix proportion quantity in this study and the results of the slump tests and air content tests.

Mixing Case	W (kg/m ³)	C (kg/m ³)	Wg (kg/m ³)	S (kg/m ³)	G (kg/m ³)	AEV (kg/m ³)	Addition amount of AEV	Slump (cm)	Air (%)	Evaluation (Satisfying target values)
Trial 1	168	264	83	735	1036	2.64	1%	4.5	-	×
Trial 2	173	275	84	749	989	2.75	1%	4.5	-	×
Trial 3	175	283	83	742	976	5.66	2%	7.5	4.4	0

AEV: Air Entraining water reducing agent containing viscosity improver

5 RESULT AND CONSIDERATION OF TRIAL MIXING

We performed trial mixes on the basis of OC and PC in Table 1, which were shown in our previous study (Shimabukuro and Kuwajima 2017). OC is ordinary concrete without waste gypsum and PC is the concrete with waste gypsum, which replaces 10% of the fine aggregate volume with waste gypsum volume. From this table, we find that the unit water amount increases by containing waste gypsum to satisfy the targeted values of the slump and the air content values. Therefore, we try to reduce the unit water amount by AEV after some trial mixing. The results are shown in Table 2 and the detail of the modified method is as follows.

First, we changed the air entraining water reducing agent to AEV based on the values of OC in Table 1. We set AEV amount as 1% to the cement weight in Trial 1 shown in Table 2. From the results of Trial 1, the slump value was 4.5 cm at Trial 1 even if AEV was contained in the concrete with waste gypsum. Because the target value of the slump was not satisfied, we had to perform the next trial mixing.

Secondly, the unit water amount in Trial 2 was corrected based on the result of Trial 1. However, the targeted slump was not satisfied even in Trial 2.

Based on these results, we modified the unit water amount slightly and changed AEV amount from 1% to 2% in Trial 3. As a result, both the target values of the slump value and the air content were satisfied. Therefore, we consider that Trial 3 was the most appropriate mixing for the concrete with waste gypsum and AEV. Comparing Trial 3 with PC, unit water amount of the concrete with waste gypsum was reduced by containing AEV. Hence, AEV is considered to be an effective agent for reducing the unit water amount of the concrete with waste gypsum.



Figure 2. Results of compressive strength test.

Figure 3. The average compressive strength of the concrete with waste gypsum and curing period relation.

Table 3. Each strength ratio when the compressive strength ratio is 1.0.

Strength ratio	Replacement ratio 10%				
Compressive strength ratio	1.0				
Tensile strength ratio	1/11				
Bending strength ratio	1/6				

6 RESULT AND CONSIDERATION OF STRENGTH TESTS

6.1 Compressive Strength Characteristic of Concrete with Waste Gypsum and AEV

The strength tests using the mixing result of Trial 3 were carried out to investigate and confirm the strength characteristic of the concrete with waste gypsum and AEV.

Figure 2 shows the result of the compressive test after curing for four weeks. According to this figure, the compressive strength of the concrete with waste gypsum is equivalent to that of the ordinary concrete without waste gypsum. Figure 3 shows the relationship between the compressive strength and the curing period. The values of Figure 3 are the average values of 3 specimens. From this figure, the compressive strength of the specimen with curing for a week does not reach the design strength which is 18 N/mm², and the strength of the specimen with curing for four weeks satisfies the design strength. Besides, the compressive strength of the specimen with curing for 12 weeks is almost equivalent to the strength of four weeks and does not also decrease from four weeks of strength.

From these, it is concluded that the concrete with waste gypsum and AEV can be used as same as the ordinary concrete.

6.2 Relationship between Compressive Strength and Each Strength for Concrete with Waste Gypsum and AEV

Table 3 shows the ratios of each strength to the compressive strength of the concrete with waste gypsum and AEV. From this table, for each strength ratio of ordinary concrete, the tensile strength ratio is 1/10 to 1/13 and the bending strength ratio is 1/5 to 1/7 (Kobayashi 2006). The values of the concrete with waste gypsum and AEV show almost the same tendency of the ordinary concrete. Therefore, in conjunction with the above consideration, it is considered that the concrete with waste gypsum and AEV can be applied as construction material, regarding the compressive strength characteristic.

7 CONCLUSIONS

We examined the workability of the fresh concrete with waste gypsum and AEV and measured various strengths of this hardened concrete. As a result, the knowledge obtained in this study is shown as follows:

- (1) From the trial mixing results, it is possible to reduce the unit water amount of the concrete with waste gypsum by containing AEV. Therefore, AEV is considered to be an effective agent for reducing the unit water amount of the concrete with waste gypsum.
- (2) From the strength tests results, the compressive strength of the concrete with waste gypsum and AEV was equivalent to that of ordinary concrete, and the tendency of each strength ratio to the compressive strength showed the same tendency as that of the ordinary concrete. Hence, it is considered that the concrete with waste gypsum and AEV can be used as a construction material like ordinary concrete, in relation to the compressive strength characteristic.

References

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