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An experimental study on development of construction concrete products using wastepaper

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Concrete had the biggest proportion of structure material today. It has caused a lots of environmental problems such as emission of carbon dioxide, dust by cement production. For this reason, many study was actively progressed to develop the environment-friendly concrete. Also, it was performed to reduce the cement usage by replacing industrial waste to cement. Specially, wastepaper was contained the wood-fiber. It was known that wood-fiber could combined with cement. For this reason, this study was looking for the way of recycling wastepaper by replacing for the cement. Wastepaper had a low fiber strength and contains a lots of impurities. It was caused that the mechanical performance will be reduced by interruption of bond in cement composite. So, this study analyzed the possibility of recycling wastepaper for replacing cement and carried out experiment about optimum mixing ratio, physical and mechanical properties of concrete to develop environment-friendly concrete products with wastepaper. First of all, the optimum replacement ratio of wastepaper can be obtained from the mortar test using wastepaper. Secondary, was make the concrete product and perform the test to evaluate the application of concrete using wastepaper. This study will be presented with basic data for using wastepaper to structural material economically by making and analyzing concrete product with wastepaper.

Key word: Mortar, Wastepaper, Concrete product, Mechanical property.

Introduction

Concrete had the biggest proportion of structure material today. It has caused a lots of environmental problems such as emission of carbon dioxide, dust in production of cement. For this reason, environment-friendly concrete has been developed to reduce the amount of cement. The development of concrete by using recycled materials like waste tires, waste plastics, waste oil and waste glass and was progressed actively by many researchers. [1-8]

In particular, wastepaper is generated mostly of the waste now. In the case of Korea, the total annual raw materials is 1,216 million tons and the annual consumption of waste paper is about 865 million tons. It represents a recycle rate about 71.1%. It can be expected to promote recycling rate by using waste paper as construction materials. Wastepaper has similar properties of wood-fiber, but it has a low fiber strength and contains a lots of impurities. Accordingly, if a large amount of wastepaper are mixed in the cement composite, the mechanical performance will be reduced by interruption of bond in cement composite. [9-13] However, if the concrete contained appropriate amount of waste paper exceeds certain level of mechanical performance, it will be possible to develop a lightweight and environment-friendly construction materials.

To develop environment-friendly concrete products with wastepaper, this study analyzed the possibility of recycling wastepaper for replacing cement and carried out experiment about optimum mixing ratio, physical and mechanical properties of concrete to develop environment-friendly concrete products with wastepaper. First of all, the optimum replacement ratio of wastepaper can be obtained from the mortar test using wastepaper. Secondary, was make the concrete product and perform the test to evaluate the application of concrete using wastepaper. This study will be presented with basic data for using wastepaper to structural material economically by making and analyzing concrete product with wastepaper.

Mortar Test using Wastepaper

Mixing and test method

To find the appropriate wastepaper for this study, newspaper, advertisement flyer and copying paper, which are discarded largely, are selected for mix material. The waste paper cut finely from crusher in dry conditions is used. Table 1 was showed type and property of wastepaper for this test. Ordinary Portland Cement (Type 1) produced in Korea was used for mix according to KS L 5201. And, fine aggregate was using a river sand of Korea. The properties of cement and

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Table 1. Type of wastepaper.

Type	Newspaper	Advertisement flyer	Copying Paper
Before shredder			
After shredder			
Specific gravity	0.71	0.88	0.75

Table 2. Properties of cement.

Type	Specific gravity	Fineness (cm^2/g)	Setting time	
			Initial	Final
OPC	3.15	3,468	194 min	5.5 hour

Table 3. Properties of fine aggregate.

Type	Specific gravity	Absorption (%)	Fineness modulus	Weight of unit volume (Kg/m3)
River sand	2.65	3,468	2.65	1,606

sand was represented with Table 2 and Table 3. Mixing method was as following; A certain amount of waste paper is shredded by paper crushers. Cement, fine aggregate and shredded wastepaper are performed dry mixing for 30 seconds in concrete pan type mixer, and then it was mixed for 60 seconds with water by mixing ratio.

The cement mortar experiments with wastepaper are carried out to find an optimum mixing ratio according to change of water to cement (W/C) ratio and an influence of compressive and flexural strength according to wastepaper replacement ratio. In order to find physical and mechanical properties of mortar with change of W/C ratio, replacement rate of wastepaper and type of waste paper, the experiments are divided into 45%, 60%, 75% of W/C ratios. Also, the experiment specimens are made with 0%, 5%, 10%, 15% of replacement ratio against weight of cement to evaluate reasonable wastepaper ratio. It is used the equivalent proportion of newspaper, advertisement flyer and copying paper to evaluate an influence of wastepaper type. Mix proportion of cement mortar with wastepaper is represented by Table 4.

The produced specimens were cured in laboratory and relative humidity about 60% until they were removed from their molds. The molds were removed from specimens after 7 days from casting. The process of making specimens followed KS L IS0 679 for

Table 4. Mix proportion of cement mortar.

Type	W/C (%)	P/C (%)	Weight of unit volume (Kg/m^3)			
			W	C	P	A
PL.	45	0	306	680	0	1,267
	60		408	680	0	997
	75		578	680	0	546
N.P	45	5	306	646	34	1,169
		10	306	612	68	1,070
		15	306	578	102	972
	60	5	408	646	34	898
		10	408	612	68	800
		15	408	578	102	702
	75	5	578	646	34	448
		10	578	612	68	350
		15	578	578	102	251
A.F	45	5	306	646	34	1,193
		10	306	612	68	1,119
		15	306	578	102	1,046
	60	5	408	646	34	923
		10	408	612	68	849
		15	408	578	102	775
	75	5	578	646	34	472
		10	578	612	68	399
		15	578	578	102	325
C.P	45	5	306	646	34	1,176
		10	306	612	68	1,084
		15	306	578	102	992
	60	5	408	646	34	905
		10	408	612	68	814
		15	408	578	102	722
	75	5	578	646	34	455
		10	578	612	68	363
		15	578	578	102	272

*PL.: Plain mortar, N.P: Newspaper,
A.F: Advertisement flyer, C.P: Copying paper,
W/C: Water-cement ratio,
P/C: Wastepaper-cement ratio,
W: water, C: Cement,
P: Wastepaper, A: Aggregate.

method of making concrete specimens, compressive strength test and flexural strength test. [14]

Test result of mortar

To find the appropriate wastepaper for this study, it was compared with equivalent water-cement ratio and replacement rate. Like Fig. 1, mortar using waste newspaper was showed higher compressive strength than other specimens. This was caused that newspaper was

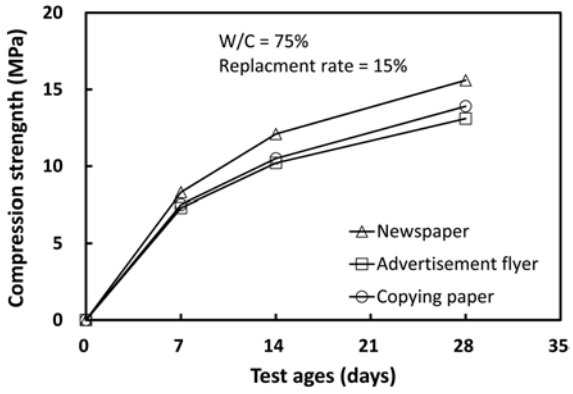

Fig. 1. Compression strength on wastepaper type.

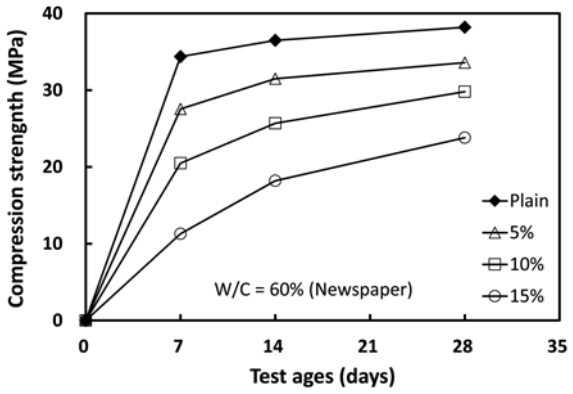

Fig. 2. Compression strength on 60% of W/C.

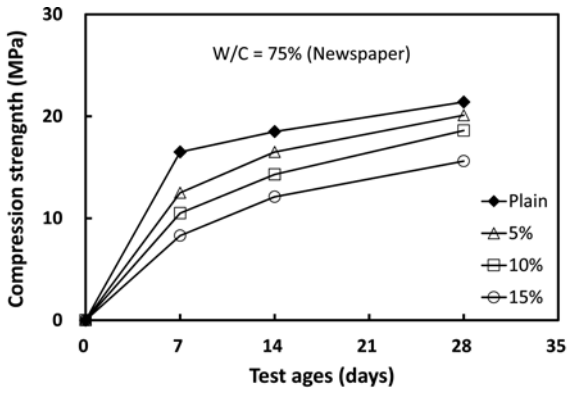

Fig. 3. Compression strength on 75% of W/C.

thinner and had higher absorption than other wastepaper. It help for combining with cement composite.

The mortar test results of compressive strength are shown in Fig 2 and Fig 3. At all W/C ratios, there are a better strength when plain state than replacement state. When the replacement ratio of wastepaper increases to 5%, 10% and 15%, the compressive strength tends to decrease 7 ~ 40%. The specific results of test are given in Table 5. The result showed that the compressive strength was reduced when more replacement ratio of the waste paper.

As the result of the flexural strength in mortar test, the flexural strength with plain state is appeared to

Table 5. Test result of cement mortar.

Type	W/C (%)	P/C (%)	Compressive strength (MPa)	Flexural strength (MPa)
PL.	45	0	48.6	12.5
	60		38.2	10.8
	75		21.4	6.7
N.P	45	5	46.7	11.6
		10	–	–
		15	–	–
	60	5	34.8	10.4
		10	31.3	9.9
		15	21.8	8.8
	75	5	20.1	6.4
		10	18.6	6.0
		15	15.6	5.9
A.F	45	5	35.3	10.1
		10	–	–
		15	–	–
	60	5	33.6	9.8
		10	29.8	8.6
		15	19.9	7.9
	75	5	19.5	6.2
		10	18.2	5.8
		15	13.1	5.1
C.P	45	5	38.1	10.8
		10	–	–
		15	–	–
	60	5	33.2	9.6
		10	30.6	8.7
		15	20.6	8.1
	75	5	19.0	5.9
		10	17.8	5.3
		15	13.9	4.9

mostly excellent result at 60%, 75% of W/C ratio and 28-days curing. Fig 4 and Fig 5 show the change of flexural strength according to wastepaper replacement rate of each W/C ratio in 28-days curing. In two graphs, the flexure strength is reduced to 5% ~ 30% in accordance with the 5% ~ 15% increases of replacement rate of wastepaper. The specific results of test are given in Table 5.

In 45% of water-cement ratio, specimens using waste advertisement flyer was not mixing by lack of mixing water all case of replacement rate. In other wastepaper, it was not mixing that specimens of 45% of water-cement ratio.

As the result of mortar basic test, a newspaper is the most excellent material to replace cement of the wastepaper. And, the compressive strength is appeared to the best results when wastepaper replacement rate is 5%. This is why the results are derived that hydrate formations are actively occurred when wastepaper replaced by small amount. It was considered that the strength is

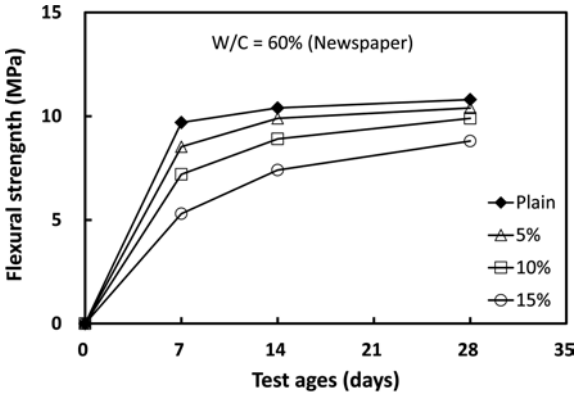

Fig. 4. Flexural strength on 60% of W/C.

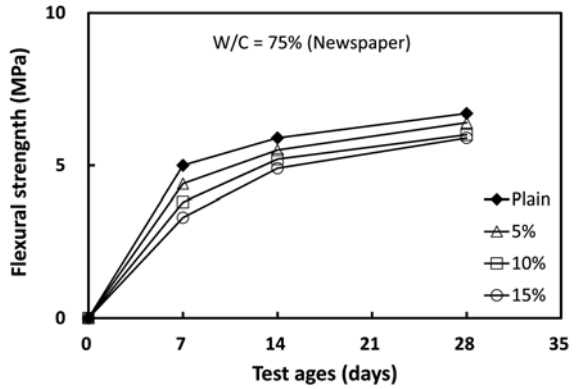

Fig. 5. Flexural strength on 75% of W/C.

increased by the effect that wastepaper fills gap.

Concrete Brick Test using Wastepaper

Mixing and test method

By using the mixing ratio and test results derived from cement mortar test with wastepaper, the concrete brick test was carried out for evaluating the application of concrete product. Mix proportion of concrete brick with wastepaper is represented by Table 6. The tests about compressive strength, absorption and specific gravity were performed by using possible mixing ratio in cement mortar test, making bricks with the size proposed in KS F 4004 [15]. This experiment set importance on the interaction between graphs of strength changes in mortar test and test values of concrete brick test. And it was reviewed an absorption that have an importance in concrete product.

Considering to results from the preliminary test and standard mixture of the concrete brick(190 × 90 × 57 mm), which is mostly used in Korea, it was planned. The each of compressive strength, absorption and specific gravity was measured with W/C ratios set 60, 70, 80%. Also, it were reviewed the compressive strength, absorption and specific gravity of concrete brick that wastepaper replaced 10, 15, 20% of cement weight. The mixture of concrete brick is shown in Table 6.

Table 6. Mix proportion of concrete brick.

W/C (%)	P/C (%)	Weight of unit volume (Kg/m^3)				
		W	C	P	A	S
60	0	300	500	0	717	717
	10	300	450	50	645	645
	15	300	425	75	609	609
	20	300	400	100	573	573
70	0	350	500	0	651	651
	10	350	450	50	579	579
	15	350	425	75	543	543
	20	350	400	100	506	506
80	0	400	500	0	585	585
	10	400	450	50	512	512
	15	400	425	75	476	476
	20	400	400	100	440	440

*W/C: Water-cement ratio,
P/C: Wastepaper-cement ratio,
W: water, C: Cement, P: Wastepaper,
A: Aggregate, S: Stone dust.

Table 7. Test result of concrete brick.

W/C (%)	P/C (%)	Comp. strength (MPa)	Absor. (%)	Specific gravity
60	0	25.9	8.9	1.97
	10	21.6	9.3	1.83
	15	17.1	12.5	1.76
	20	–	–	–
70	0	21.5	9.1	1.86
	10	18.9	9.7	1.72
	15	16.8	12.9	1.65
	20	15.1	18.1	1.58
80	0	15.3	8.4	1.74
	10	12.9	10.1	1.60
	15	12.2	13.4	1.53
	20	11.5	17.1	1.46

*Comp. strength: Compressive strength,
Absor.: Absorption.

Test result of concrete brick

When a W/C ratio is 60%, the result of compressive strength appeared in Table 7, shows the highest strength 21.6 MPa with ages-28day and wastepaper replacement ratio 5%. The highest strength were appeared in case of plain state when tests are carried out with 60%, 70% and 80% of W/C. Like Fig 7, the minimum limit of compressive strength of brick proposed in KS F 4002 is over 8MPa. The actual existing concrete bricks produced in factory show the compressive strength approximately 15 ~ 20 MPa. As the result of the test, it can be determined that the best W/C ratio is 70% and the optimum wastepaper replacement rate is 15%. But optimum mixing ratio was determined according to type of brick, like Fig 7.

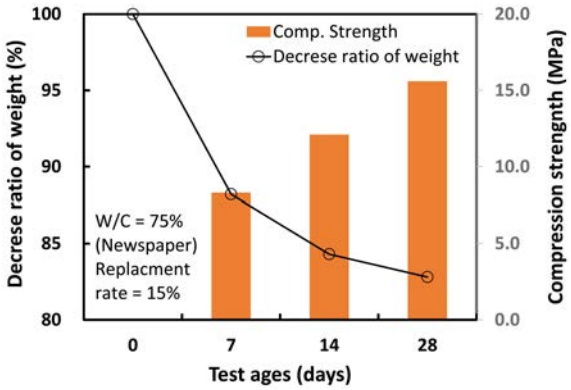

Fig. 6. Decrease ratio of weight.

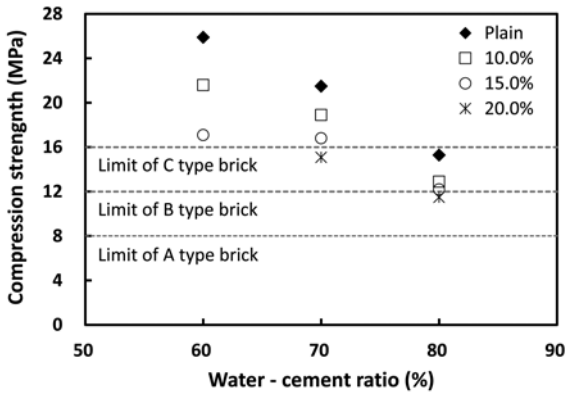

Fig. 7. Compression strength of concrete brick.

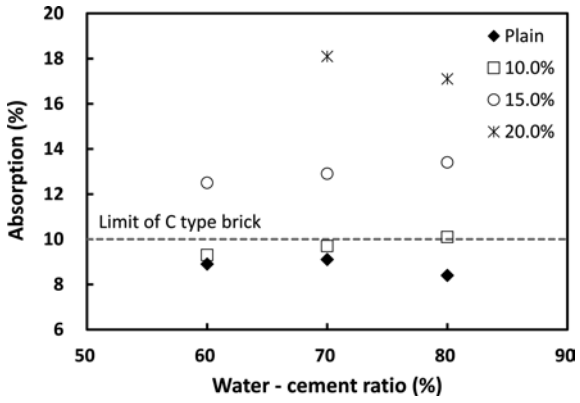

Fig. 8. Absorption of concrete brick.

The test of concrete brick absorption was carried out about all case of W/C ratio. The result show that when replacement rate was 10%, the absorption of concrete brick has a range of 8 ~ 10%. It was similar with concrete brick of plain state. Also, Fig 8. showed that when replacement rate was increased, the absorption of brick was rapidly increased. The reason why the graph shows that an absorption grows by increase of wastepaper proportion in concrete brick was caused that the higher absorptive force of wastepaper. It can be determined that the bond strength between wastepaper and cement paste is decreased by a more amount of replaced wastepaper. This increases an absorption by growing air-gaps. Also, this is a reason for decrease of compressive strength. The specific results of test are given in Table 7.

As shown Table.7 and Fig 9., the replacement ratio of wastepaper was correlated to their specific gravity. The specific gravity of brick in wastepaper replacement ratio of 10% was about 1.7. These brick was able to separate on light-weight brick. And it was reduced form 8% and 17%, respectively, when replacement ratio of waste paper was increased to 10% and 20%. The specific gravity of brick has trend of decreases as a higher wastepaper was included. It was caused that the low density of wastepaper was replaced with high density of cement.

As test results of compressive strength, absorption and specific gravity of concrete brick, it shows that replacement ratio was lower than 10% to satisfy with absorption under 10% in accordance with KS code. All of results are satisfied that the compressive strength is over 8MPa in accordance with KS standard. Also, the brick using wastepaper was separated on light-weight concrete brick

Conclusions

In this study, the basic test of mortar replaced by wastepaper is conducted to develop technology of recycling wastepaper. Through test, the conclusions can be derived to present basic data of application possibility of concrete brick.

(1) As the result of basic test of mortar replaced by wastepaper, the plain state shows higher value when measuring compressive and flexural strength. The state that replacement rate is 5% shows higher value when measuring compressive strength. The result showed that the compressive strength was reduced when more replacement ratio of the waste paper.

(2) As the result of concrete brick test, replacement ratio was lower than 10% to satisfy with absorption under 10% in accordance with KS code. All of results are satisfied that the compressive strength is over 8 MPa in accordance with KS standard. Also, the brick using wastepaper was separated on light-weight concrete brick. In aspect of the replacement rate that satisfies the strength criteria, it is satisfied until replacement rate reaches 20%.

(3) In the future, it is happened to evaluate performance between concrete products by making several concrete products like concrete block, interlocking block, and cement board, etc. It can be predicted to analyze the more proper concrete product.

Acknowledgments

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