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A Study on strength of self-disintegration vegetation base mixing unused resource and expansive admixture

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ABSTRACT

From the viewpoint on consideration of landscape, it is effective to give the self-disintegration ability to the vegetation base. This ability, self-disintegration, mean the artificial materials such as concrete decompose into the composition element such as aggregate and calcium under the controlled speed. In this research, the strength characteristic for self-disintegration of porous concrete was examined using low quality aggregate and expansive admixture as materials of vegetation base. As a result, the specimen using waste roof-tile as aggregates satisfied higher than 10N/mm^2 as initial strength, and that strength decreased with the advance of ages. It was confirmed that amount of expansion continued with the advance of ages by means of adjusting the additional amount of expansive admixture. From these results, it was considered that the self-disintegration vegetation base is possible to produce arranging the type of aggregates and adjusting the additional amount of expansive admixture.

Keywords. Vegetation base (porous concrete), Self-disintegration, Waste roof-tile, Compressive strength, Expansive admixture

INTRODUCTION

The Basic Law for Establishing the Recycling-based Society was established in 2000, and it was decided how to treat and recycle in each division. As a result, high level of recycling rate has achieved due to the reduction of waste output, reducing of illegal waste dumping and promotion of appropriate processing. However, there are many unused resources at each region. For example, SEKISYU roof-tile is one of the three major great roof-tiles in Japan. Lots of these roof-tiles have been wasted while their production as defective product, also discarded when the old houses were disassembled. A part of this waste roof-tile is used for roof-tile material again and sub-base material, but most of waste roof-tile have been treated as the waste.

Other unused resource in the region is the sewage sludge. Recycle rate is about 70% as national average, but in some regions the ratio was less than 50%. Then, the new usage is searched for the area. Also there is a demolished concrete which occurred from all over the country. The amount of demolished concrete generated in a year reached to 31.3 million tons (Fiscal 2008), and 98.1% of it was recycled [The committee, 2008]. However, the application of recycling has been limited; most of them were utilized as the sub-base material for road constructions. In the future, quantity of demolished concrete will increase and the demand for road materials will decrease. Besides, it is predicted that the demanded area of road material and supplied area of demolished concrete will not match. Therefore it is necessary to establish new reuse or recycle method instead of sub-base material. In recent years, it has been promoted the use of a recycled aggregate (high quality), however it is not effective way to reuse attributively as a recycled aggregate. This is because there is a problem such as stabilization of cost and quality. In other words, in order to use demolished concrete effectively, it is required to clarify the characteristics of the recycled aggregate (low quality) and suggest the appropriate utilization method for its performance.

On the other hand, Law Concerning Special Measures for Conservation of Lake Water Quality was revised in 2010, and water quality management was intensified. An effective measure for improving the self-purification capacity is to create spaces for biodiversity in the water area. That is, catching the species living in the water area contributes indirectly to removal of nutrient salts from the system as the organisms consume the nutrients [Nakamura, 2005]. Therefore, planting of reed is a popular measure to create spaces for biodiversity in these water areas. Reed is well known to play an important role. It will be biodiversity space for shellfish and bird, in addition to absorbing the nutrient salts by itself [Nakatsuji. et al, 2006] . However, many cases have been reported in which the planted reed was run off by the waves at steep revetment of lakes and ponds which were established in the past for reasons of disaster safety. In present, the counter measures using coconut fiber mat and bamboo pot have been studied. Meanwhile, there were some problems. For example, coconut fiber mat is washed away by wave and bamboo pot plants reed inside of bamboo pot, so that satisfactory growth have been identified inside, not outside of the pot. Then, the authors have been studying about vegetation base for reed which was made of a porous concrete (**Photo 1**). As a result, it was appeared that the vegetation base could prevent the run off of reed by its weight and root of reed take to the porous part. However, after taking root to the vegetation base sufficiently, the vegetation base also prevented the reed growth and landscape was deteriorated. Therefore, it was considered that the shape of the vegetation base should not maintain for long period.

Photo 1 Soaked vegetation base near the steep revetment

From these backgrounds, it was considered that the vegetation base maintains the shape after vegetation because it prevent run off by its weight. Furthermore, vegetation base disintegrates after rooting because it prevents the growth and landscape. In this research, vegetation base which satisfied these abilities was investigated. The materials were recycled aggregate (crushed aggregate, waste roof-tile aggregate and sludge aggregate) which considered low quality materials usually, however it was considered to be a suitable material from the viewpoint of strength in order to solve this theme. In addition, expansive admixture was also added to impart expansive-destruction multiply. This research examined the following three considerations. First consideration is the strength characteristics using low-quality aggregate. Second consideration is the strength characteristics using expansive admixture. Third consideration is the strength characteristics using low-quality aggregate and expansive admixture at the same time. In order to evaluate the compressive strength, all vegetation base used in this experiment was cylindrical specimens of ϕ 10 × 20cm and the target void of the specimens was about 30%. Besides, from the results of vegetation base up to now, strength of initial strength was decided to 10 N/mm^2 from the view point of workability.

EXPERIMENTAL PROCEDURE

The strength characteristics of the vegetation base mixing recycled aggregate

3 species of aggregate were used for the test. Firstly, natural aggregate was collected in Shimane prefecture (Natural Aggregate: NA, Using NA specimen: NAs). Secondly, test specimen for measuring the compressive strength was crushed for aggregate (Crushed Aggregate: CA, Using CA specimen: CAs). Thirdly, the disposal product at the time of tile manufacture was used for aggregate (Waste roof-tile Aggregate: WA, Using WA specimen: WAs). The strength characteristics of the test specimen using these aggregates were evaluated. Mix proportions of specimen are shown in **Table 1**. Basic physical property of aggregate is shown in **Table 2**. These specimens were cured in water until age 28 day. After curing, specimens were soaked into Lake Shinji. There is enclosed water area and the eutrophication is progressing. Specimens were settled near the steep revetment where is strongly affected by the wave force. The strength characteristic of the test specimen was evaluated from compressive strength. Compressive strength was measured at soaking 0day (0 month), soaking 28day (1 month) and soaking 84day (3 month). In addition, number of specimens prepared in this experiment was three at each and measurement result was taken as an average of three specimens.

Table 1 Mix proportion of specimen

	W/C (%)	Target Void (%)	Unit (kg/m³)					
			W	C※1	G1※2	G2※3	G3※4
NAs	25	30	59	237	1527	0	0
CAs			71	284	0	1310	0
WAs			59	237	0	0	1261

C※1: ordinary portland cement, G1※2: natural aggregate, G2※3: crushed aggregate, G3※4: waste roof-tile aggregate

Table 2 Basic physical property of aggregate

	aggregate size（mm）		Density in saturated surface-dry condition（g/cm^3）	Water absorption (%)	Solid volume percentage (%)
	maximum	minimum			
NA	20	5	2.70	0.78	57.7
CA			2.43	5.91	55.0
WA			2.23	6.94	57.7

The strength characteristics of the vegetation base mixing expansive admixture

In order to give disintegration performance, this consideration tried to mixed cement with expansive admixture. In general, the expansive admixture is used to reduce the drying shrinkage and cracking due to temperature changes. Using this expansive effect of this material, this study aimed to evaluate the possibility on the generation of intentional expansive-destruction of cement. The component of this expansive admixture is lime which is made of calcium oxide (CaO) mainly, and it has the characteristics of expansion phenomenon when it reacts with water because of producing calcium hydroxide (Ca $(OH)_2$). Standard addition of expansive admixture is 20kg/m^3, mix proportions of specimen are shown in **Table 3**. The name of the specimen using expansive admixture are expressed as EX (numbers) and the numbers in parentheses indicate the amount of expansive admixture. Natural aggregate (NA) size is 5 to 13mm and they were produced in Shimane prefecture. Physical properties of NA are described as follows: density in saturated surface-dry condition is 2.73g/cm^3, Water absorption is 0.36% and solid volume percentage is 56.6%. These specimens were cured in air until age 14 days. After 14 day, they were soaked into test tank in experimental room (**Photo 2**) and compressive strength is measured with fixed age. The ages are soaking 0 day (1 month), soaking 28 day (2 month) and soaking 56 day (3 month). In addition, each one specimen was examined in this experiment.

Table 3 Mix proportions of specimen

Specimen	P/G（vol%）	W/C（%）	W/B（%）	Target Voids（%）	Unit（kg/m^3）				
					W	C※1	G※2	EX※3	AD※4
EXs(0)	26.2	20.5	20.5	30	57.1	279	1513	0	C×0.5 %
EXs(14)	27.0	20.0	19.1		55.9	279	1504	14	
EXs(30)	28.7	21.0	18.9		58.5	279	1485	30	
EXs(80)	33.7	22.5	17.5		62.9	279	1429	80	

C※1 : ordinary portland cement, G※2 : natural aggregate, EX※3 : expansive admixture, AD※4 : admixture

Photo 2 Specimens which soaked into test tank

The strength characteristics of the vegetation base mixing recycled aggregate and expansive admixture

In order to evaluate the influence of mixed expansive admixture and composite aggregate at the same time, the strength characteristics of the specimen were studied experimentally. 2 species of aggregates were used for the test. Firstly, the disposal product at the time of tile manufacture was used for aggregate (Waste roof-tile Aggregate: WA, Using WA specimen: WAs). Secondly, industrial waste of inorganic sludge and coal ash was used for aggregate (Sludge Aggregate: SA, Using SA specimen: SAs). Mixing quantities of expansive admixture were 0kg/m^3, 14kg/m^3 and 30kg/m^3. Mix proportions are shown in **Table 4**, and basic physical properties of aggregate are shown in **Table 5**. These specimens were cured in air until age 14 day. After that, they were soaked into test tank in experimental room, and the compressive strength and dimensions (diameter and height) were measured. The measurement dates were soaking 0 day (0 month), soaking 28 day (1 month) and soaking 56 day (2 month). In addition, each one specimen was examined in this experiment.

Table 4   Mix proportion of specimen

Specimen	P/G (vol%)	W/C (%)	W/B (%)	Target Voids (%)	Unit (kg/m^3)					
					W	C※1	EX※2	G1※3	G2※4	AD※5
SAs(0)	16.4	17.0	17.0	30	34.4	202	0	1220	0	C×0.5 %
SAs(14)	19.5	19.2	18.0		41.4	216	14	1189	0	
SAs(30)	18.5	18.1	15.8		36.4	201	30	1199	0	
WAs(0)	31.2	17.5	17.5		59.2	339	0	0	1211	
WAs(14)	33.3	17.2	16.5		59.9	349	14	0	1191	
WAs(30)	34.5	17.1	15.8		59.7	349	30	0	1181	

C※1: ordinary portland cement, EX※2: expansive admixture,
G1※3: waste roof-tile aggregate, G2※4: sludge aggregate, AD※5: admixture

Table 5　Basic physical property of aggregate

Aggregate	Aggregate size (mm)		Density in saturated surface-dry condition (g/cm^3)	Water adsorption (%)	Solid volume percentage (%)
	maximum	minimum			
WA	15	5	2.23	7.45	53.8
SA	15	7	2.03	21.70	60.6

RESULTS and DISCUSSION

The compressive strength characteristics of the vegetation base mixing recycled aggregate

The compressive strength characteristics of specimens (NAs, CAs and WAs) were shown in **Figure 1**. In initial strength, WAs was the highest (10.2N/mm^2), and the order became NAs (8.65N/mm^2) and CAs (7.18N/mm^2) continuously. This reason was considered that the bonding area between aggregate and cement paste in WAs have been widened due to the destruction of aggregate while they were mixing. In case of CAs, compressive strength was considered to be lower because of influence of mortar adhesion to the aggregate. Anyhow, the initial strength of specimens with each aggregate did not reach the required performance of 10N/mm^2. Moreover, the change with time of compressive strength showed different tendencies; WAs and NAs were on the decline and CAs was constant. Initial strength of WAs satisfied 10 N/mm^2 at 0 day (0 month), and reduced to 6N/mm^2 after 28 day (1 month) of soaking. The reasons were considered as follows. Carbon film was formed on the surface of roof-tile during the process of firing with high temperature and the surface had a water resistance by coating of glaze. In other words, in case of using waste roof-tile, adhesion of the cement reduced because a part of tile had hydrophobicity. For that reason, there was no significant influence for specimen before soaking. However adhesion of the cement and

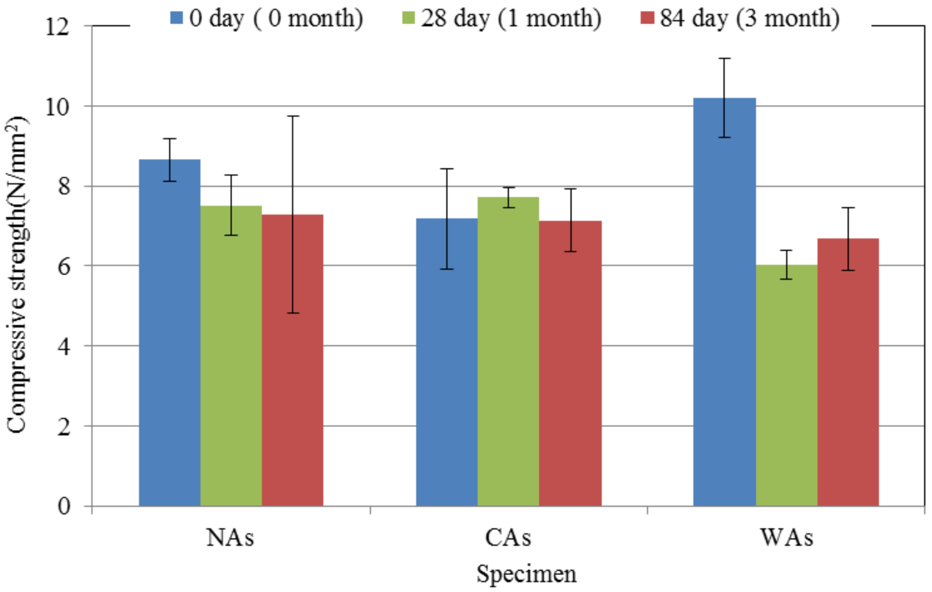

Figure 1　Change with time of compressive strength on NAs, CAs and WAs

aggregate was decrease because wave force and leaching make strength of specimen weak. As for the results of NAs, it was considered that the strength reduced under the influence of waves and the leaching of the cement. As for the results of CAs, it was considered that the surface of aggregate was improved by mortar contained in the crushed aggregate has hydrophobicity. As a result, change with time of the compressive strength was not confirmed. From the results above, in case of using a NA, it was possible to expect small effect of reducing the strength, but it was difficult to expect large effect of it. In case of using a CA, it was confirmed that the initial strength was low, but it could keep the strength. In the case of using a WA, it was confirmed that the initial strength was high and strength decreased with time. Therefore, it was considered that the WA was appropriate aggregate for self-disintegration vegetation base.

The compressive strength characteristics of the vegetation base mixing expansive admixture

Change in the compressive strength due to the difference of the amount of expansive admixture is shown in **Figure 2**. Comparing the compressive strength of soaking 0 day (0 month) on each specimen, EXs(14) was the highest (11.5N/mm^2), and the order became EXs(0) (12.9N/mm^2) and EXs (8.99N/mm^2) continuously. Change of compressive strength, EXs (0) and EXs (14) were increasing and EXs (30) was decreasing. The following factors were considered. Standard addition of expansive admixture is 20kg/m^3 in this experiment, so that strength of specimen increased because expansion was within an allowance in case of less than 20kg/m^3. Therefore, strength of EXs (0) and EXs (14) were increased. However excessive expansion occurred in case of over standard addition, therefore EXs (30) was decreased. As a result, it was considered that expansive admixture could manage the strength of specimen by controlling the additional amount.

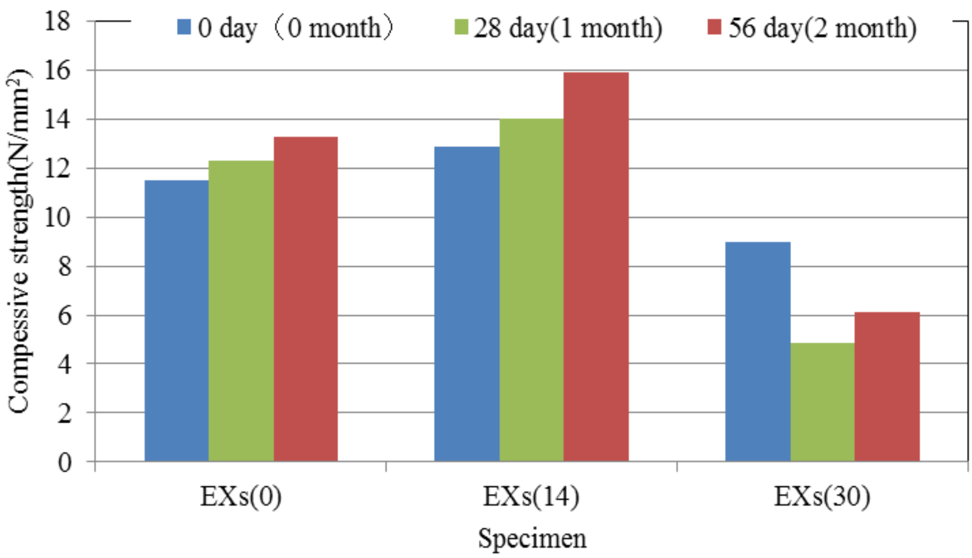

Figure 2 Change in the compressive strength due to the difference of the amount of expanding material

The compressive strength characteristics of the vegetation base mixing recycled aggregate and expansive admixture

Compressive strength change due to aggregates and addition of expansive admixture is shown in **Figure 3**. Comparing the compressive strength of soaking 0 day (0 month) on each specimen, all SAs were about 4N/mm^2 and all WAs were about 10N/mm^2. The Factor of this lower initial strength of SAs was considered as follows. SA was granulated material which used cement, but more than 60% weight volume of SA was composed of sludge and fine demolished concrete, so that strength was low. WAs satisfied the target strength because WA was strong aggregate [Takada.2005]. On soaking 28 day (1 month), it was confirmed that the compressive strength of all specimen decreased comparing with soaking 0 day (0 month). This influence was especially clear on SAs (30). From these results, it was confirmed that SA which had a low strength had small effect of expansive admixture due to the high controlling factors in the aggregate. WA which had a high strength could decrease intentionally by mixing the expansive admixture more than standard addition. On soaking 56 day (2 month), it was confirmed that the compressive strength increased with or without the addition of the expansive admixture compared with soaking 28 day (1 month). From these results, the influence of expansive admixture decreased compressive strength up to soaking 28 day (1 month). Then, strength was increased after soaking 28 day (1 month), because soaking played a role of water curing. As a result, it was confirmed that multiple using of recycled aggregate and expansive admixture could decrease the strength more than they were used alone. Therefore, it was suggested that other aggregate could be used for self-disintegration vegetation base.

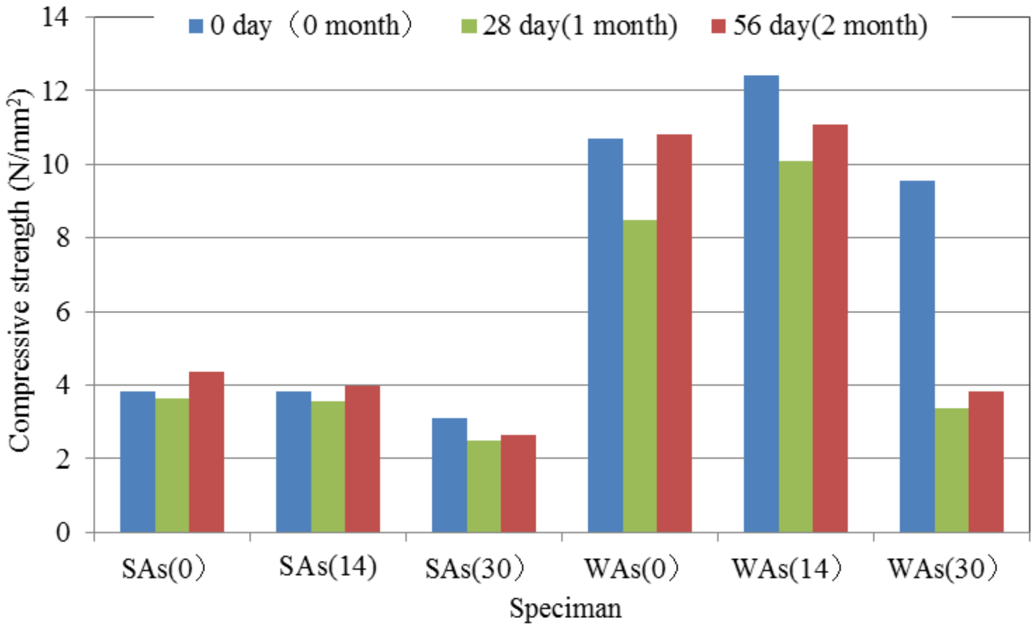

Figure 3 Change with time of compressive strength on SAs and WAs

Table 6 Change with time of dimension

	Height（mm）			Diameter（mm）		
	0 day （0 month）	28 day (1 month)	56 day (2 month)	0 day （0 month）	28 day (1 month)	56 day (2 month)
SAs（0）	200.0	200.0	200.1	100.0	99.9	100.0
SAs(14)	200.1	199.5	199.4	100.0	100.1	100.3
SAs(30)	200.0	200.5	201.0	100.0	100.8	100.6
WAs(0)	200.0	200.0	200.1	100.0	100.2	100.2
WAs(14)	198.9	199.4	199.5	99.7	100.1	100.1
WAs(30)	199.0	201.9	201.0	100.1	100.6	100.7

The dimensional change of the specimen is shown in **Table 6**. It was not confirmed that the dimensional change of both specimens at addition amount of the expansive admixture 10kg/m^3 and 14kg/m^3. However, it was confirmed that the dimensional change of both specimens at addition amount of the expansive admixture 30kg/m^3 , height was 2.0mm (compare with 0 day and 56 day of WAs(30)) and diameter was 0.6mm increment (compare with 0 day and 56 day of WAs(30)). From this result, it was appeared that the expansive admixture which mixed more than standard addition could expand specimen and it could decrease the compressive strength with time.

SUMMARY and CONCLUSION

In this research, it was considered to disintegration performance against performance of general concrete; safety performance, stability behaviour, serviceability performance and durability performance. The vegetation base maintains the shape after vegetation because it prevent run off by its weight. Furthermore, vegetation base disintegrates after rooting because it prevents the growth and landscape. The vegetation base which satisfied these abilities was investigated. The aggregate used for vegetation base was WA which ensured 10N/mm^2 of initial target strength. Moreover, it was confirmed that effect of decreasing strength was higher using expansive admixture. The remaining issue is long-term change with time of strength in the actual water area. In addition, it is expected that appropriate material for vegetation base would be selected from the unused resources in various region of the country.

The results obtained in this research were summarized to below.

(1) Using waste roof-tile as an aggregate for specimen, it has higher strength comparing with other specimens which used natural aggregate and crushed aggregate. Furthermore, it was considered that waste roof- tile could give the disintegration to the vegetation base because change with time of strength was higher than other materials.

(2) In case of mixing the expansive admixture less than standard addition, strength of specimen increased with time. Meanwhile, more than standard addition, strength decreases with time because excess expansion of volume was generating to specimen. From the results above, it was considered that the expansive admixture could manage the strength of specimen by controlling the additional amount of it.

(3) In order to examine multiple effect mixing both aggregate and binder, specimen was made using waste roof-tile and expansive admixture. As a result, it was appeared that the all WAs satisfied required performance ($10N/mm^2$) and decrease further degree due to expansive-destruction effect of both aggregate and binder. From the result above, it was considered that multiple utilization could be applicable at various water areas such as influence of wave force.

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