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Fundamental Study on Ecosystem Support Canal using Porous Concrete

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ABSTRACT: This research aimed to enhance the compressive strength of porous concrete as well as to develop the porous concrete that can support and improve the ecosystem preservation by itself. Several porous concrete specimens were prepared for the measurement of mechanical properties. As a result, it was confirmed that the radius of coarse aggregate affected significantly to mechanical properties of porous concrete under the same unit weight of cement. It was also revealed that strengths at age 28 days were stable despite of different sizes of coarse aggregate. The bio-adhesive ability of porous concrete specimen was evaluated against water bugs and adhesive algae. Every porous concrete specimen was soaked in same environmental condition at the bottom of actual concrete canal. From this experiment, it was confirmed that preference environment for some specific species of water bugs are possible to be supplied when the porosity and the size of coarse aggregate would be adjusted.

Keywords: Porous Concrete, Ecosystem Support, Biodiversity, Bio-adhesive

1. INTRODUCTION

In Japan, previous improvement programs on agricultural facilities were mostly executed focused to the functions of water use and structural safety, and they were not considered enough against nature and ecosystem. As a result, various ecosystems were lost or damaged seriously, it is necessary to make actions for conservation and recovery of ecosystem now a day.

From such background, Land Improvement Act was revised in 2001 in Japan. In the law above, “consideration to make the harmony with environment” was provided as the principle of every project. However, existing technology that has such consideration against environment is not established completely including the evaluation of its effect yet. It is necessary to analysis from the viewpoint of general judgment containing the quantitative evaluation on the influence to ecosystem.

Concrete materials are mainly used for the agricultural hydraulic structures such as canal and head works due to their low permeability and structural safety. On the other hand, there are a lot of studies concerns to porous concrete that gives newly function such as environmental consideration. Up to now, porous concrete becomes to be famous material for revetment of river bank in order to support the recovery of vegetation at the river embankment. However, this material has not used frequently because of its low strength and durability.

This research aimed to expand the utilization of porous concrete that has both high strength as well as the special function that is called as “bio-adhesive ability”. The former point, to improve the compressive strength of porous concrete as high as structural material, was examined from the viewpoint of strengthening. The latter point, to observe the relationship between the different types of porous concrete and inhabited creatures, was examined from the viewpoint of colonized living things.

2. METHOD AND PROCEDURE

2.1 Evaluation on Compressive Strength of Porous Concrete

Cylindrical porous concrete specimens were placed using different grain size of coarse aggregate; No.5 (13 – 20mm), No.6 (5 – 13mm) and No.7 (2.5 – 5mm). Fundamental mixture proportions of porous concrete are shown in Table I. Amount of mortar was adjusted to be constant in order to examine the influence of grain size of coarse aggregate to compressive strength. Using the biaxial forcing mixer, concrete was mixed under dry condition for 1 minute and additional 3 minutes after adding the water. Water amount was finely adjusted with confirming the adhered mortar condition around the aggregate particles. Porosity of porous concrete were varied with changing the packing amount into mold, and 6 types of porous concrete were placed in this experiment. Three numbers of cylindrical specimens for each type were tested for measuring the compressive strength. Handy vibrator was used for the compaction. Standard curing, sunk in 20℃ water, was applied and measured the compressive strength at age 14 and 28 days.

Here describes the measurement method on porosity of porous concrete as follows. Firstly, volume of specimen (V_1) was measured. The specimen was soaked into water for 24 hours in order to absorb the water, measure the weight in water (W_1). Secondly, the specimen was put out to atmosphere where the temperature and relative humidity were controlled into constant condition of 20℃ and 60%, respectively. Wait until the weight into stable. Furthermore, set the same specimen for 24 hours in atmosphere under the same temperature and relative humidity condition was measured as W_2. Total porosity was calculated using (1) is shown below;

Total porosity At (%) $= (1-((W_2-W_1) / \rho)/V_1) \times 100$ (1)

where ρ is the density of water.

2.2 Summary on Bio-adhesive Characteristic Experiment of Porous Concrete

Porous concrete specimens sizing of 230mm length × 230mm width × 60mm height for bio-adhesive characteristic experiment were made by same process described at previous section. Details of the specimens are shown in Table II. All the specimens were set in actual open channel for agricultural placed in Kochi University, and were studied for the evaluation of bio-adhesive ability such as number of water bugs and amount of attached algae. Concrete specimens were mentioned to be sunk in the water all the time. Water bugs settled in porous concrete specimen were collected on the tray fulfilled with water. Gathered water bugs were investigated as follows; identify the species using technical book of water creatures [1]-[4], divided into each species and counted their number. However, bugs less than 1mm of body length were excluded to count.
Algae were gathered with shaving from one surface (downstream side) of specimen. Suspensions were collected, filtrated with glass filter and measured the wet weight, dry weight and chlorophyll a (call "chl.a" here after). Dry weight was measured after the treatment of drying 24 hours with 60℃. Absorptiometer was utilized for the measurement of chl.a.

3 RESULTS AND DISCUSSION

3.1 Compressive Strength of Porous Concrete

Relation between compressive strength and porosity was shown in Fig.1. Under the same porosity condition, compressive strength was higher as the larger particle diameter of coarse aggregate. It was considered that specific surface of coarse aggregate was decreased when using the larger sizes of coarse aggregate, and the thickness of mortar binder surrounding the coarse aggregate particle in unit volume became increased. Moreover, relationship between compressive strength and porosity made with coarse aggregate No.5 and No.6 showed similar value and tendency despite the thickness of mortar between coarse aggregate No.5 and No.6 were different. It was revealed that developed compressive strength would be stable and enough when the thickness of mortar was insured to be standardized.

On the contrary, compressive strength was declined as the increment of porosity of porous concrete. The main cause of this result was occurred due to the reduction of cement amount in unit weight. Comparing the strength development of age from 14 to 28 days, each increment of compressive strength were evaluated as 7.9% in No.5, 10.0% in No.6, and 2.5% in No.7. From this result, it was clarified that strength development of No.7 was smaller than those of No.5 and No.6. It meant that strength of No.7 was close to stable condition while it was age 14 days.

All the porous concrete could gain higher than 20 N/mm^2, as high and stable as normal concrete. It meant that porous concrete could be useful for the member of structure if the relationship between compressive strength and porosity was clarified enough.

Table I Fundamental Mixture Proportions of Porous Concrete

Grain size	No.5	No.6	No.7
Particle diameter (mm)	13 - 20	5 - 13	2.5 - 5
Cement (kg/m^3)	221	221	221
Admixture (kg/m^3)	39	39	39
Sand (kg/m^3)	233	233	233
Gravel (kg/m^3)	1548	1540	1537
Water (kg/m^3)	57	57	57
Porous diameter (mm)	2.0 - 14.6	0.8 - 9.5	0.4 - 3.7

Table II Porous Concrete Specimens detail

Crashed stone size	Particle diameter (mm)	At (%)
No.5	13~20	22.3
		29.4
No.6	5~13	22.2
		25.7
No.7	2.5~5	18.9
		20.5
		22.7

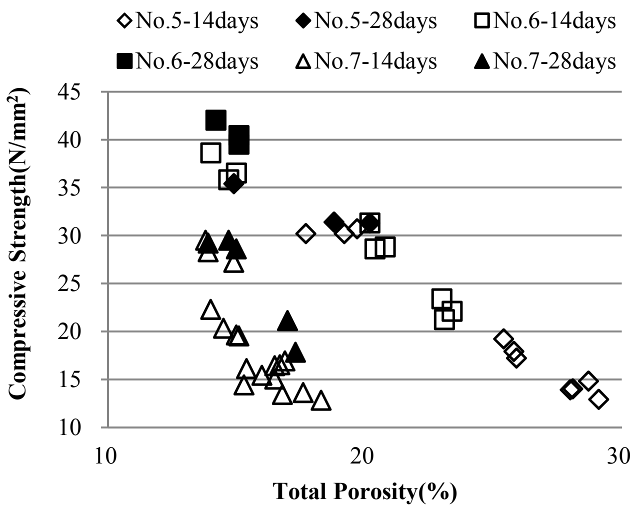

Fig.1 Relation of Compressive Strength and Porosity

3.2 Bio-adhesive Characteristic Experiment of Porous Concrete

3.2.1 Species Number and Population Size of Water Bugs

Generic names and species gathered from porous concrete specimen were shown in Table III. Twenty three of generic names and twenty six of species were confirmed, and the dominant species was *Asellus hilgendorfi*. Second, third and fourth dominants were *Ectopria*, *Stenelmis* and *Ephemeroptera*, respectively. The change with time of population size gathered from the specimen was shown in Fig.2 a). The larger population size was confirmed when size of coarse aggregate was bigger. It was considered that various lengths of body of water bugs were easy to enter to the void of porous concrete surface when the diameter of porosity was large enough. On the other hand, there was a sharp drop in population size of water bugs during May 21st of 2010 to July 18th of 2010. Several times of torrential rainfall were generated before July 18th of 2010, the water bugs were estimated to be washed away or evaded due to violent water flow and muddy water.

Change with time of species number in each specimen was shown in Fig. 2 b). Lots of species were confirmed and variation of population sizes was larger at the beginning of the experiment. However, species number was getting stable as the time went on. It meant that water bugs suited to the environment established with porous concrete were selected with the time passage, and particular species were becoming to be the dominant. Judging from the investigation result in 2011 and 2010, different species were confirmed. Then it was suggested that observed species in the past data would be happened to reach to the specimen from upstream. Further observation will be necessary whether existing species as a dominant were climax species or not. Much population of *Ephemeroptera* and *Ptilodactylidae* were confirmed in the porous concrete of No.5 and No.7, respectively. Moreover, specimen of lower porosity showed highly number of each species. Therefore, it was suggested that coarse aggregate of No.5 and No.7 might create the preference environment for *Ephemeroptera* and *Ptilodactylidae*, respectively.

Diversity index for each types of specimen was calculated. Simposon's formula shown at (2) was chosen to get the diversity index. This formula aims to see the balance between the species number and population size of biotic community, shown as follows;

$$D = 1 - \sum_{i=1}^{S} P_i^2 \quad (2)$$

where P_i is proportion of individual number of species (i) to all individual number of communities, and S is the species number of objective community. If one species was extremely superior to other species, diversity index would be very small. In this study, the population size of *Asellus hilgendorfi* was too much, therefore, this dominant was excluded from the calculation of this index. Change with time of diversity index was shown in Fig. 2 c). Diversity indexes were varied in all specimens during the initial period of this experiment. However, they came to be stable and similar value in all specimens since May of 2011. We confirmed in 2011 that some newly species were colonized that made permanent resident. That could be one reason of stabilization of that index described above.

Table III Species List of Water Bugs

Order	Scientific Name
Ephemeroptera	*Baetis* sp.
	Ecdyonurus sp.
	Cinygmula sp.
	Ephacerella longicaudata
	Uracanthella punctisetae
	Caenis sp.
Trichoptera	*Leptocerus* sp.
	Hydroptila sp.
	Molanna moesta
	Ecnomidae sp.
	Nippoberaea gracilis
	Goerodes sp.
	Goera japonica
Plecoptera	*Nemoura* sp.
Diptera	*Conchapelopia japonica*
	Psychodidae sp.
	Chironomus samoensis
Hemiptera	*Aphelocheirus vittatus*
	Aphelocheirus nawae
Coleoptera	*Ectopria opaca*
	Ectopria opaca
	stenelmis sp.
	stenelmis sp.
Odonata	*Calopterygidae* sp.
	Gomphidae sp.
Isopoda	*Asellus hilgendorfi*

3.2.2Bio-adhesion of Algae Grew on the Porous Concrete

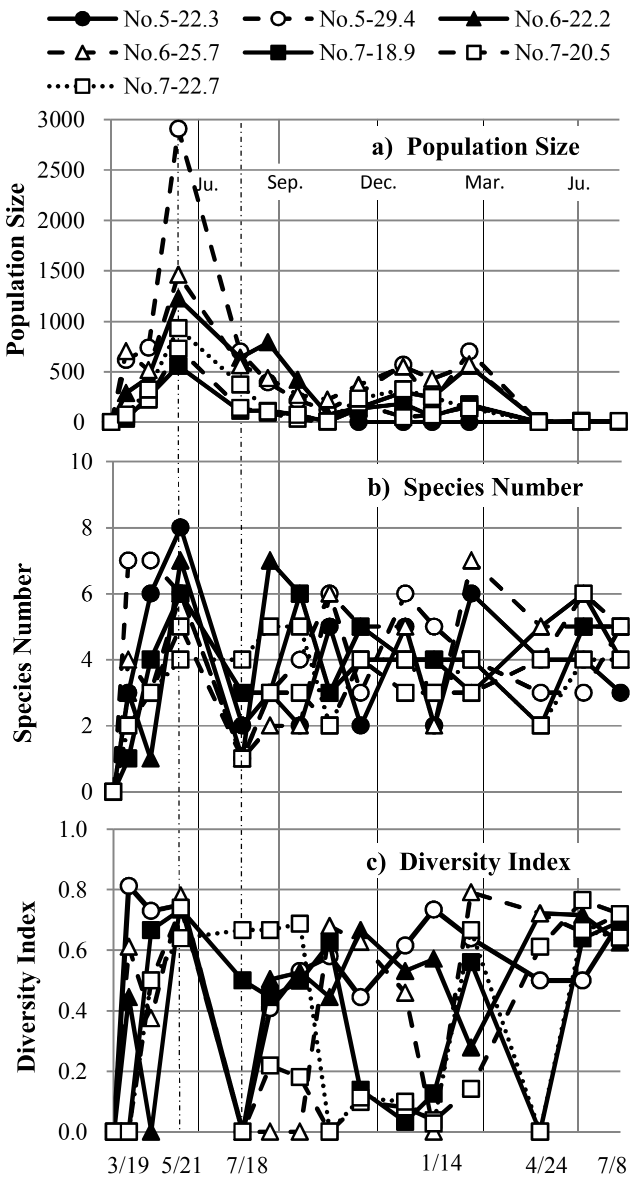

Fig.2 Change with Time of Result for Water Bugs

Adhesion of algae was confirmed in all porous concrete specimens, the name of species was shown in Table IV. Identified algae were mostly the same kind of diatom (*Bacillariophyceae*), maximum species number was obtained at 22.7% porosity of porous concrete using coarse aggregate No.7. Change with time of quantity variation of chl.a and dry weight was shown in Fig. 3 a) and b), respectively. Quantity of chl.a and dry weight showed same tendency with the results of water bugs, these values came to be stable as time passing by. There was no relationship between the quantity of chl.a and dry weight; calculated correlation coefficient was almost zero. Here showed the result of relationship between time and ratio (quantity of chl.a / dry weight) in Fig. 3 c). Assuming that quantity of chl.a was an indicator of living algae as well as dry weight was that of both living and dead algae, variation of this ratio was very large in most of all specimens. However, in 18.9% porosity of porous concrete specimen using coarse aggregate No.7, this ratio was stable comparatively. It was suggested that this type of porous concrete would be good adhesion ability against diatom. The reason was considered that smaller particles of aggregate gave larger specific surface and possible to give better condition for the growth of this algae.

4 CONCLUSION

The results in this study were concluded as follows;

1) Larger particle lead higher compressive strength when each porous concrete was used same amount of cement.
2) Higher porosity of porous concrete generated its compressive strength to be lower when each porous concrete was used same amount of cement.
3) Strength of porous concrete was close to stable condition while it was age 28 days.
4) Possibility that coarse aggregate of No.5 and No.7 might create the preference environment for *Ephemeroptera* and *Ptilodactylidae*, respectively.
5) Possibility that 18.9% porosity of porous concrete using coarse aggregate No.7 would be good adhesion ability against diatom.

Therefore, porous concrete was appeared to be possible using structure that has enough strength, various pores and holes of pores. In addition to, it is considered that the preference environment for specific creatures is able to be created for adjustment of aggregate size and porosity. However, benthos was main target at this experiment. So, this study will be necessary to pay attention to higher order stage of creature for evaluating ecosystem support.

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Table IV Species List of Algae

class	Scientific Name
Bacillariophyceae	*Coscinodiscus* sp.
	Melosira sp.
	Cyclotella meneghiniana
	Hysrosera whampoensis
	synedra sp.
	Fragilaria sp.
	Naviculaceae sp.
	Cymbella tumida
	Gomphonema sphaerophorum
	Rhoicosphenia abbreviata
	Surirella sp.
	Nitzschia trybionella
	Bacillaria paradoxa
	Cocconeis placentula
Chlorophyceae	*Cladophora* sp.

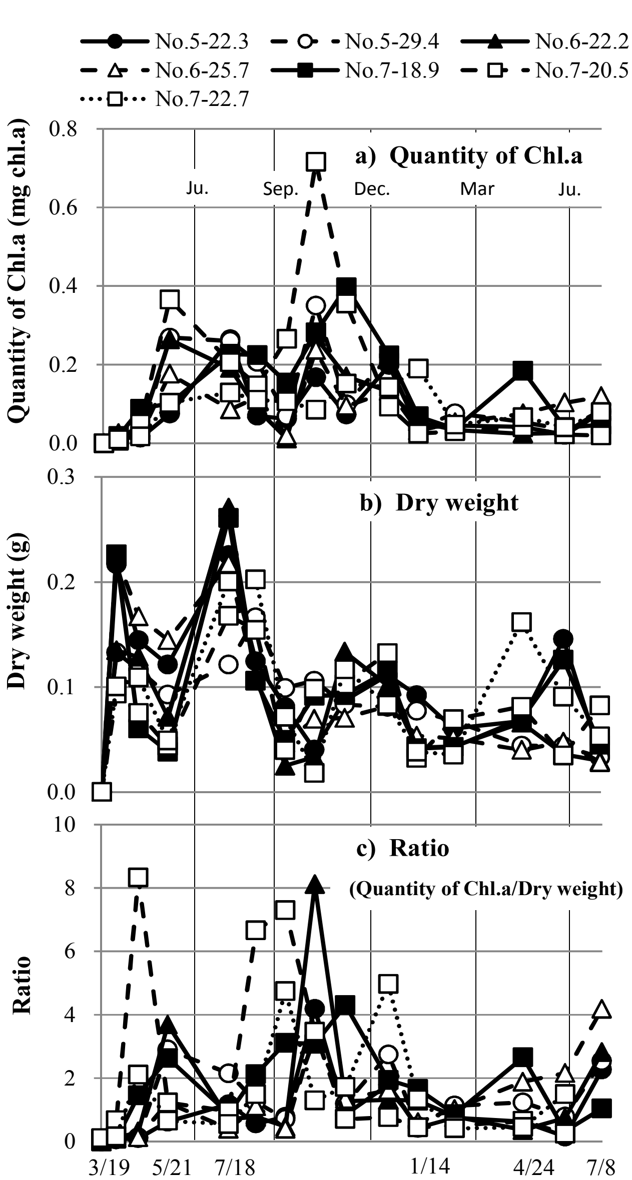

Fig.3 Change with Time of Result for Algae

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