Fundamental Study On CO_2 Fixation Of Existing Concrete Structures

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Introduction

- Decarbonization technologies are attracting attention as we move toward Net Zero 2050.
- Many technologies have been developed for fixing CO_2 in concrete in the manufacturing process.
- However, there are few technologies available to fix CO_2 in existing concrete.

⇒**We conducted basic research to develop technology to fix CO_2 in existing concrete.**

Conventional Technology

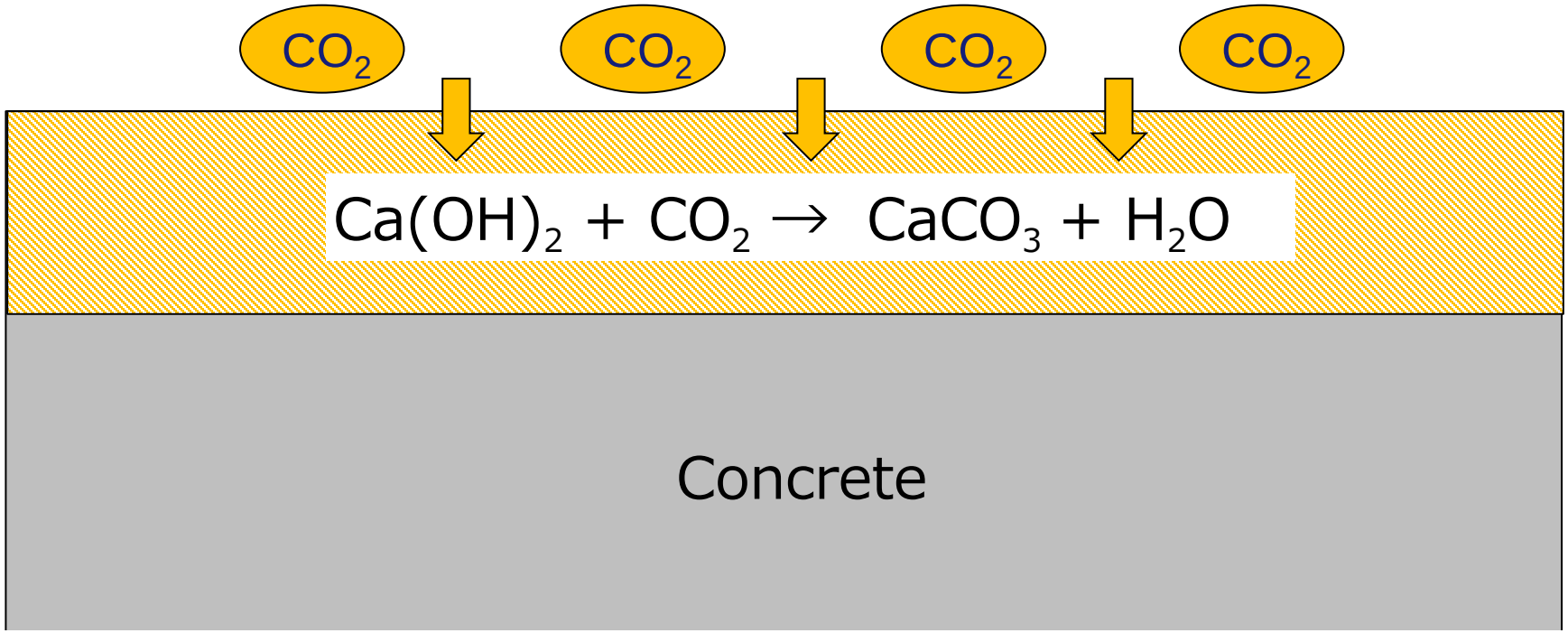
CO_2-fixed precast concrete
(e.g. CO_2-SUICOM)

This Study

Fixing CO_2 in existing concrete

Carbonation of concrete

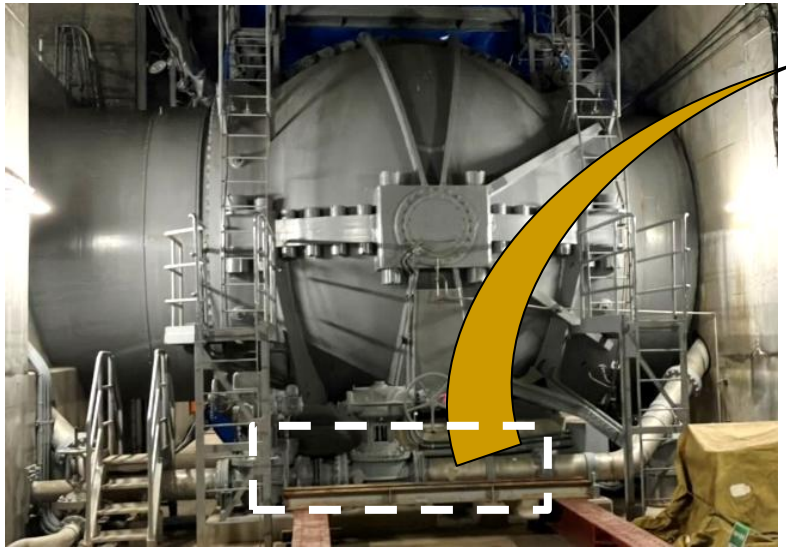
- CO_2 from the air penetrates the concrete and reacts with calcium-containing compounds in the concrete to form $CaCO_3$.
- This reaction allows CO_2 to be fixed in concrete.



Purpose

- The purpose of this study is to confirm the extent to which existing concrete has the capacity to fix CO_2.
- Specimens taken from existing old concrete were forcibly carbonated.
  - −Measuring the amount of CO_2 fixed
  - −Compressive strength test
  - −XRD/Rietveld analysis

Existing concrete※



Specimens

※Structure：Stand for the penstock of a hydroelectric power plant
Age : 39 (since 1985)
Location : inside the tunnel

Overview of concrete

- The mix proportion of that concrete has less water and cement, and more aggregate.
- Maximum aggregate size may be 40mm.
- Natural carbonation depth is 8.0-16.0mm（1.3～2.6mm/√year）.

Cutting surface of structure

Mix proportions of concrete (Estimated value)

Aggregate（kg/m^3）	2026
Cement（kg/m^3）	219
Water（kg/m^3）	120
W/C（%）	55

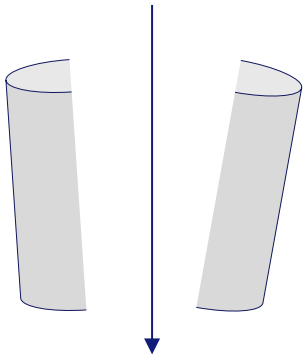
Existing concrete

Specimens
Φ120×240mm

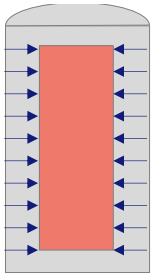
Accelerated carbonation

Compressive Strength

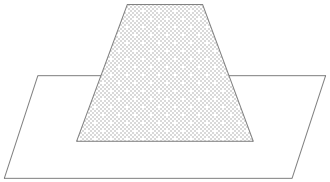
Cutting



Carbonation depth



CO_2 measurement・XRD



Accelerated carbonation

- Specimens were subjected to accelerated carbonation.

CO_2 concentration : 90%
Temperature : 20℃
Humidity : 50%RH

Period
0（No carbonation）
1day
7days
14days
28days

specimens

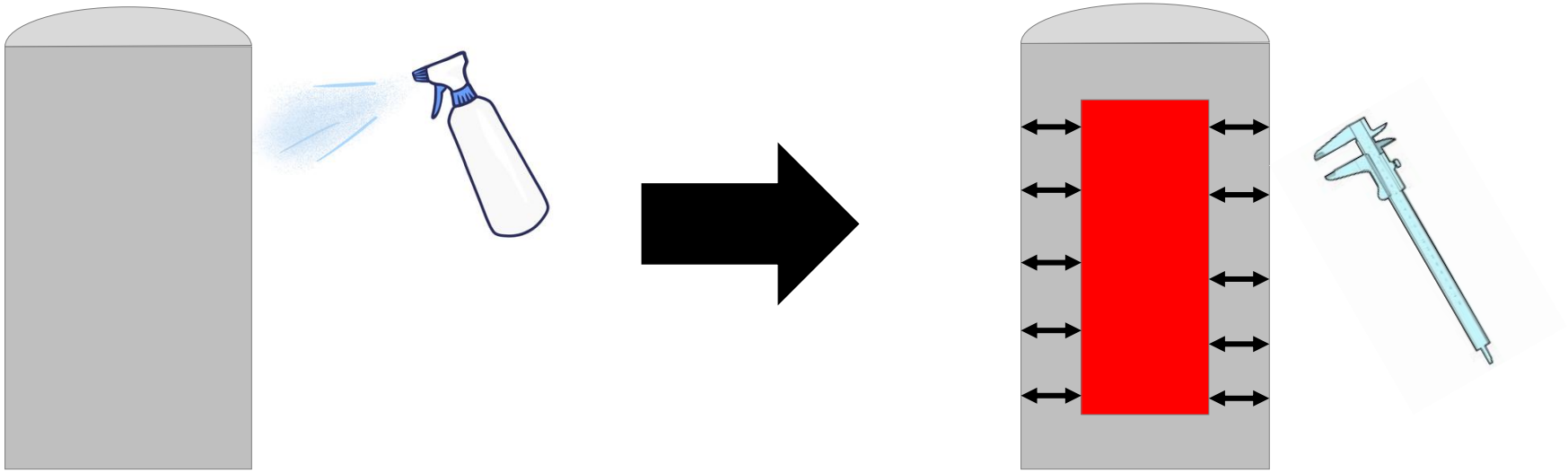
Concrete carbonation acceleration test equipment

Method of carbonation depth measurement

- Concrete is usually alkaline, so it will turn pink when sprayed with a phenolphthalein solution.
- The carbonated part is neutral, so it will not discolor even if sprayed with phenolphthalein solution.
- The degree of carbonation can be evaluated by measuring the distance to the pink colored part.

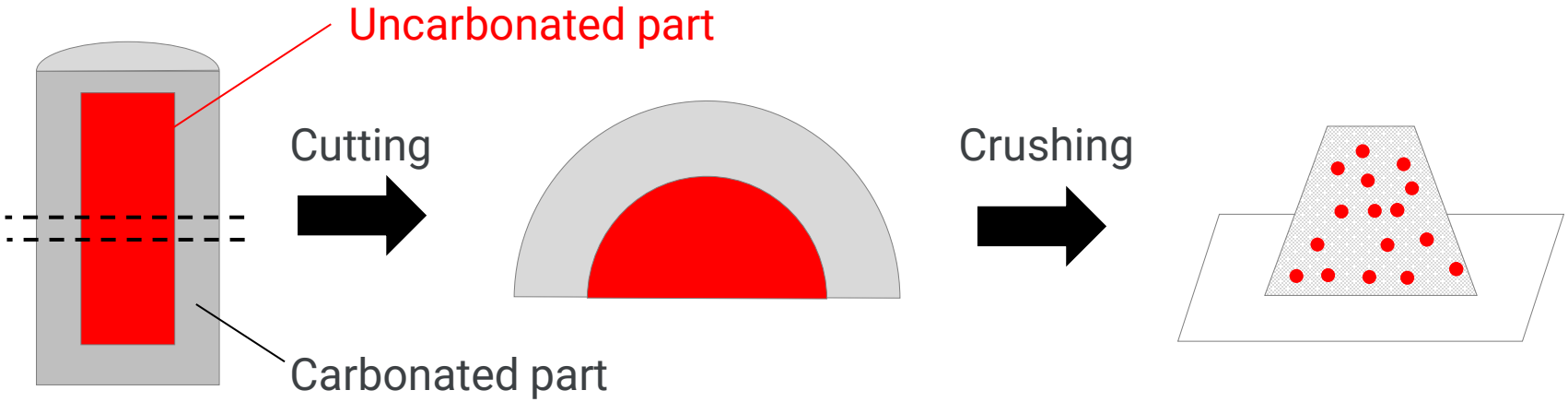
Spraying with phenolphthalein solution

Measuring the distance to the pink colored part



Method of CO_2 fixation measurement

Sample preparation



Measurement（Inorganic carbon）

・Detection method

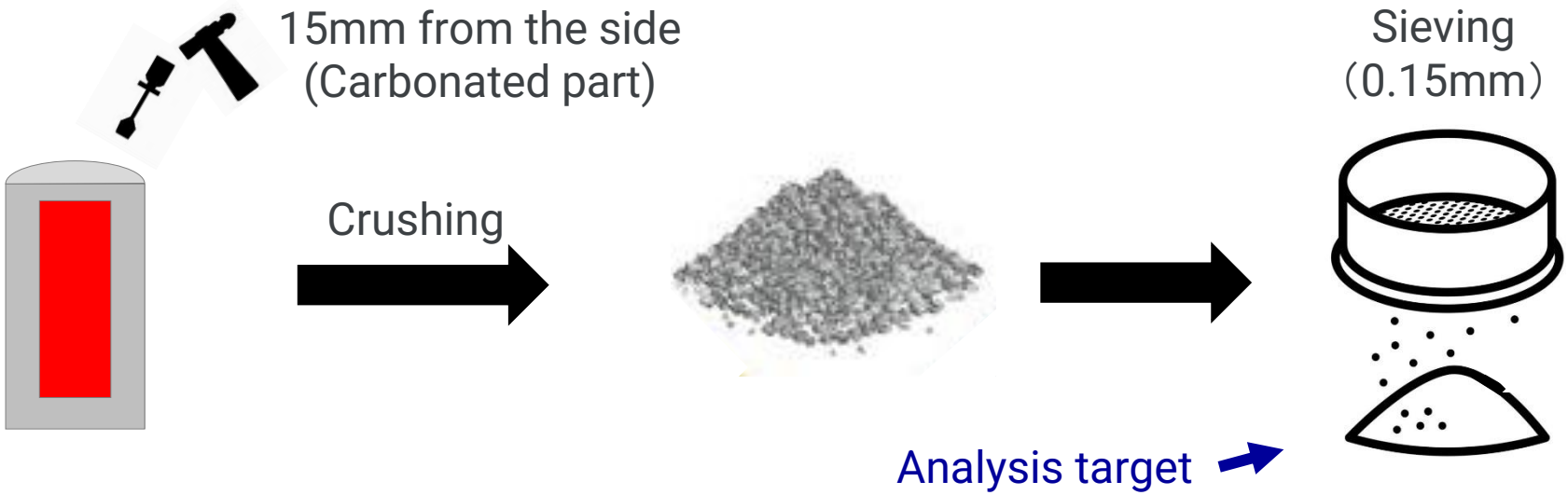
-NDIR（Non Dispersive InfraRed）

・Decomposition temperature of inorganic carbon

-450～900℃

Method of X-ray diffraction (XRD)

Sample preparation



Measurement specifications

Tube voltage : 45kV
Tube current : 40mA
Measurement range : 5～70°
Measurement pitch : 0.008°
Scanning speed : 0.1°/s

Results of carbonation depth measurement

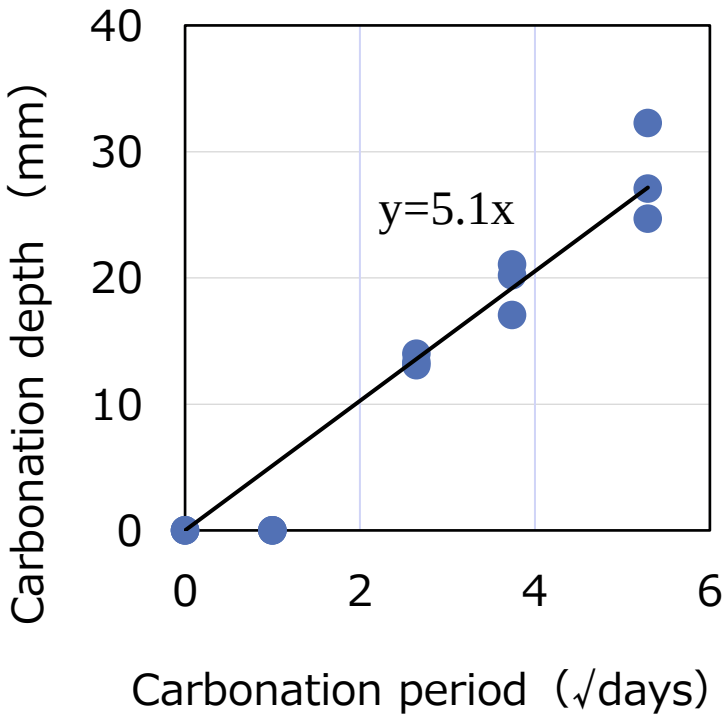
- Carbonation depth increased in proportion to the square root of the carbonation period.
  ⇒Existing concrete which passed after the construction for several decades had ability to fix CO_2.

Photo of the specimens

0days

7days

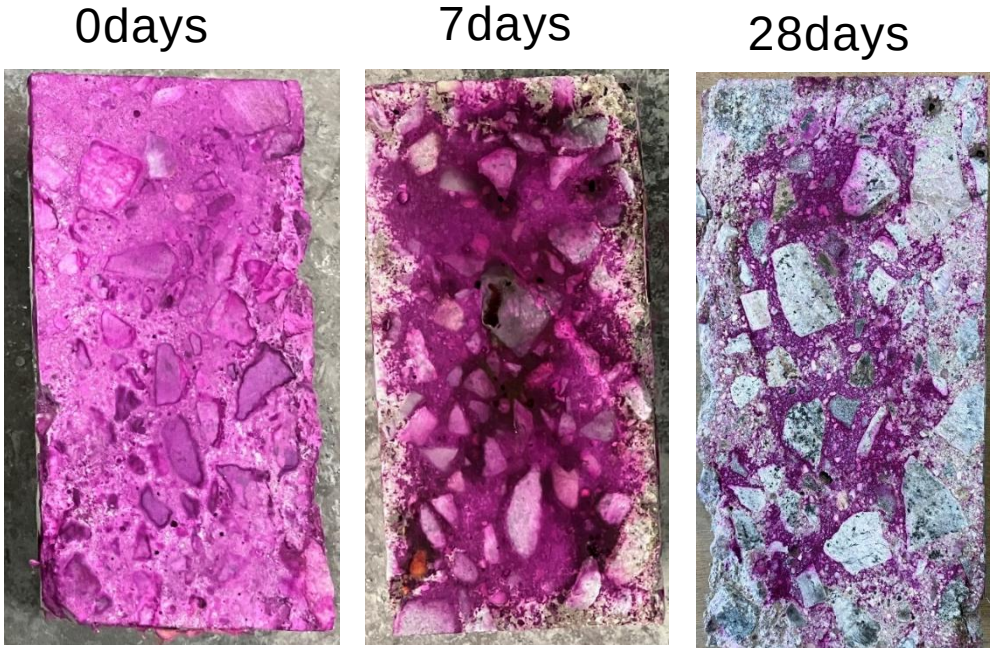
28days

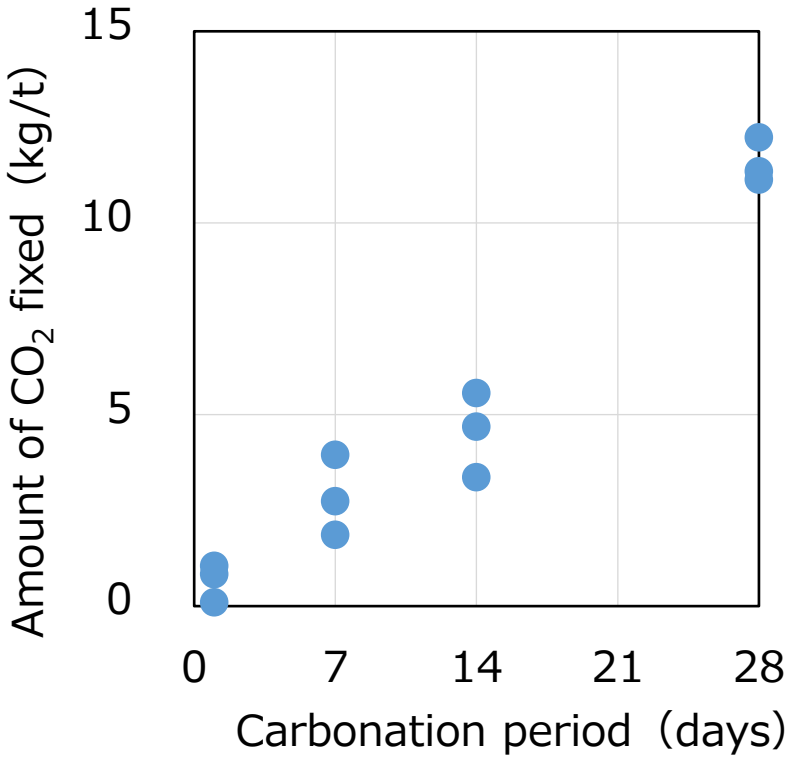


Results of CO_2 fixation measurement

- The amount of CO_2 fixed increased with increasing carbonation period.
- 12 kg/t of CO_2 was fixed in 28 days.

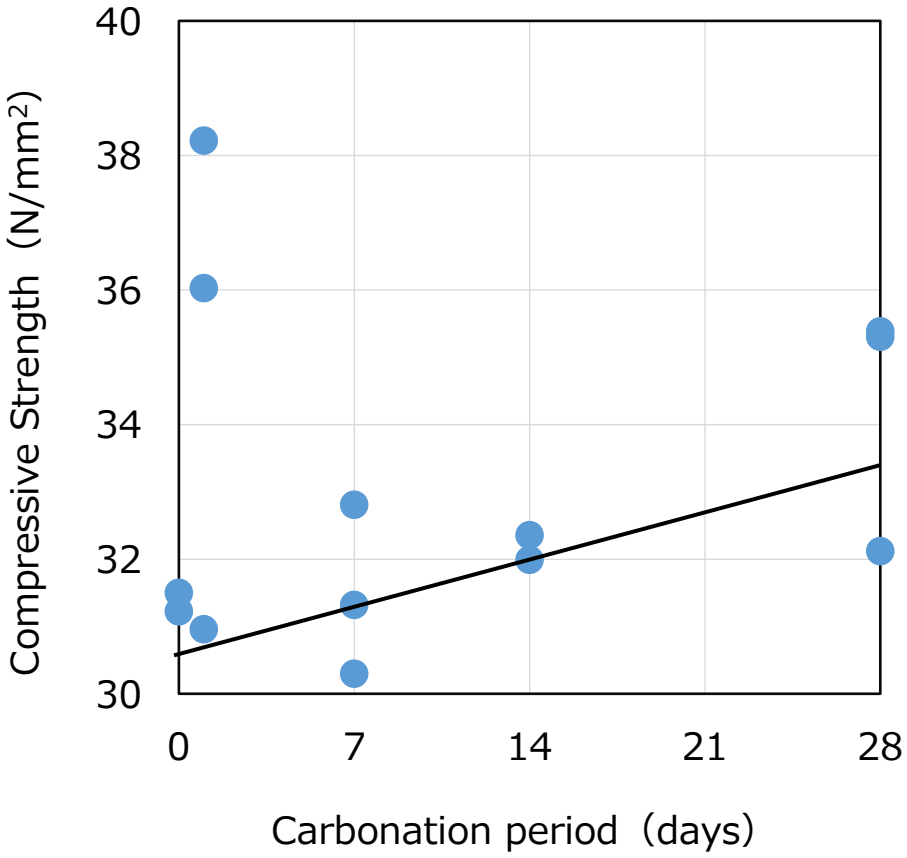
Photo of the specimens

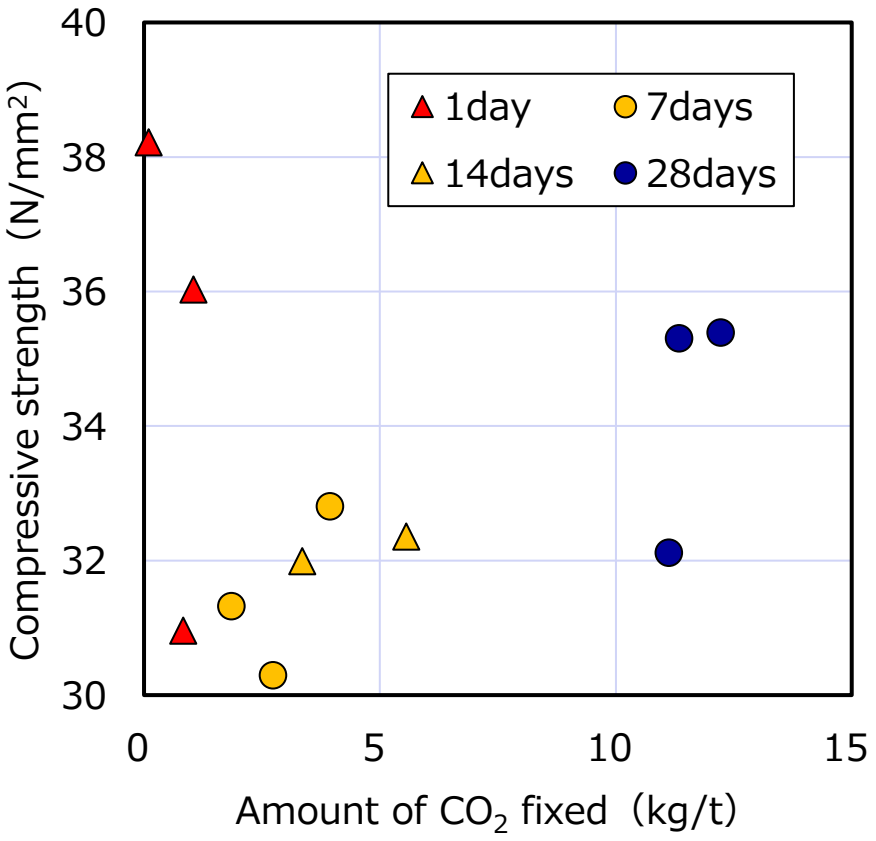




Results of compressive strength test

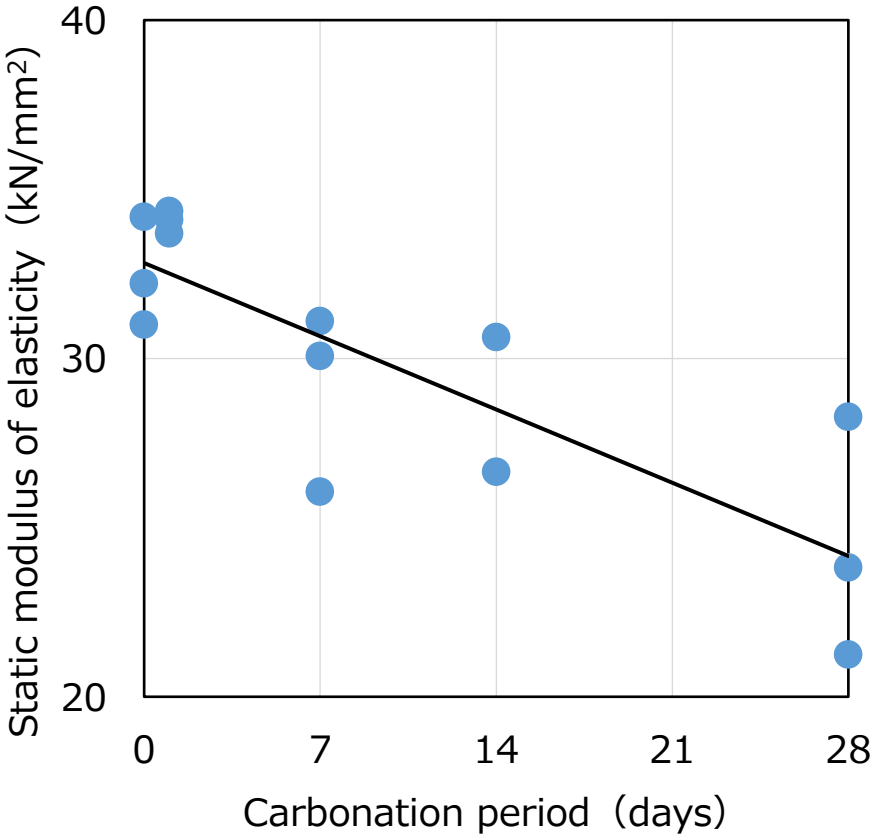
- The Compressive strength increased with increasing carbonation period and the amount of CO_2 fixed.
- As for the reason, we thought that generated calcium carbonate filled in voids of the concrete.

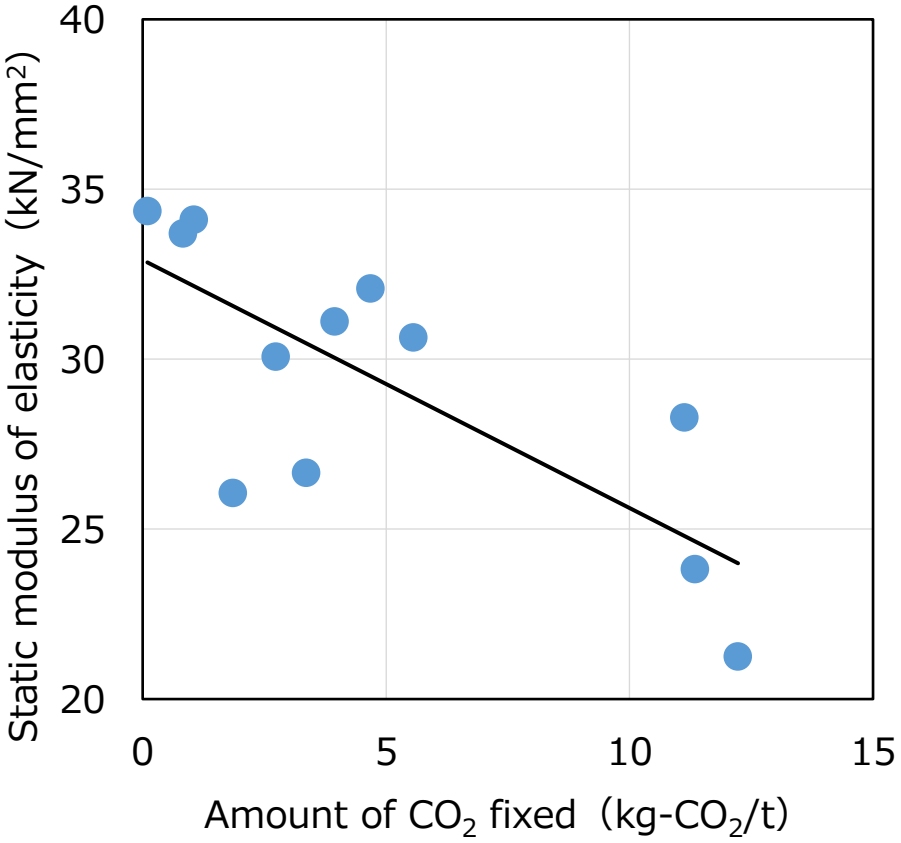




Results of compressive strength test

- The static modulus of elasticity decreased with increasing carbonation period and the amount of CO_2 fixed.





Results of XRD/Rietveld analysis

- Carbonation reduced amorphous and increased $CaCO_3$ (vaterite) .
  →Calcium in the amorphous substance was carbonated and became calcium carbonate.
- The amount of calcite was almost unchanged, but the amount of vaterite increased.
  →The predominant crystal form of calcium carbonate produced in the high CO_2 concentration was vaterite.

Percentage of minerals, wt% (Excluding aggregates)

Mineral	0days (Uncarbonated)	14days
C_2S	5.4	-
$CaCO_3$ (Calcite)	7.6	8.7
$CaCO_3$ (vaterite)	-	45.2
Calcium hydroxide	3.1	0.4
Monosulfate	1.9	-
Amorphous	82.0	45.6

Conclusions

・Carbonation depth increased in proportion to the square root of the carbonation period.

・The amount of CO_2 fixed increased with increasing carbonation period, and 12 kg/t of CO_2 was fixed in 28 days.

・The compressive strength increased with increasing carbonation period and the amount of CO_2 fixed.

・The static modulus of elasticity decreased with increasing carbonation period and the amount of CO_2 fixed.

・The predominant crystal form of calcium carbonate produced in the high CO_2 concentration was vaterite.

Thank you for your attention.