Sea Water Utilization in Concrete Production in Future Water Stressed World: From the View Point of Corrosion Prevention of Steel in Concrete

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Sea Water Utilization in Concrete Production in Future Water Stressed World

-- From the View Point of Corrosion Prevention of Steel in Concrete --

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ACKNOWLEDGEMENT

- I sincerely thanks to the Organization of 2019 International Corrosion Engineering Conference, for inviting me as one of Plenary Speakers.
- It is my great honor to be here.

Research Career (Hidenori Hamada)

1. April 1983 – March 1986 (3 years)

   Kyushu University (student)

2. April 1986 – March 2006 (20 years)

   PHRI (Port and Harbour Research Institute)

   PARI (Port and Airport Research Institute)

   (2). October 1992 – September 1993 (1 year)

   University of Sheffield, England, U.K.

3. April 2006 – October 2019 (13.5 years)

   Kyushu University (Academic staff)

Prepared Contents

1. Why now! Do we need to use seawater for concrete production ?
2. Present situation of Seawater usage in concrete production.
3. Conceptual model of RC deterioration due to the chloride attack.
4. What is the long-term exposure test ? How it is important to understand long-term performance ?
5. Can we use seawater for concrete production safely ? What kind countermeasure for corrosion prevention of steel in seawater mexed concrete ?
6. Finally, before closing .....Concluding Remark.

Topic 1

Why now! we need to use seawater for concrete production ?

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- Our world is now facing :
  - Water scarcity !
  - Water stress !!
  - Water crisis !!!
- However, it is difficult to realize it in modern city, in developed country.

Water scarcity ?

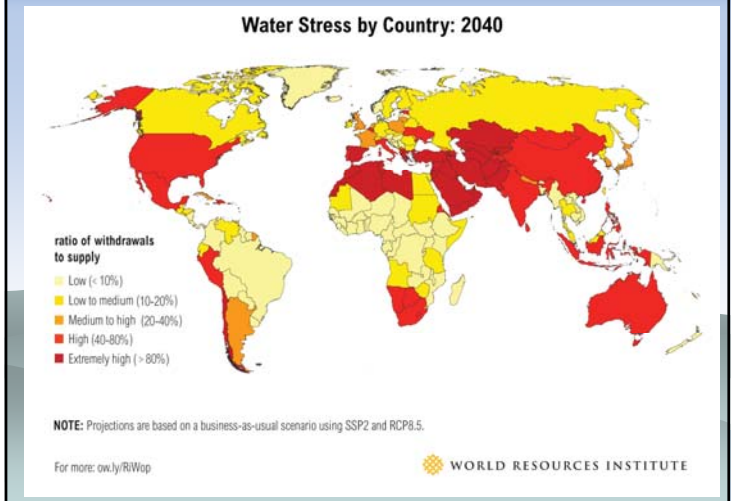
- The lack of fresh water resources to meet water demand.
- A mere **0.014%** of all water on Earth is both fresh and easily accessible. Of the remaining, **97%** is saline and a little less than **3%** is hard to access.
- The essence of global water scarcity is the geographic and temporal mismatch between freshwater demand and availability.

Water stress ?

- More than **one in every six people** in the world is water stressed, meaning that they do not have sufficient access to potable water.
- Those that are water stressed make up **1.1 billion people** in the world and are living in developing countries.

Water crisis ?

- When there is **not enough potable water for a given population**, the threat of a water crisis is realized.
- In 2025, **2/3 of world population** will be suffered from water shortage, even drinking water.



Pure Water : How important for human life !!

- **90%** of all natural disasters are water-related.
  - (UNISDR)
- **340,000 children** under five die every year from diarrhoeal diseases.
  - (UNICEF 2015)

Water : The new oil ! In 21st Century

Goldman Sachs estimates that global water consumption is doubling every 20 years, and *United Nations* expects that demand for pure water will outstrip the supply by more than 30% by 2040.

Water : The new oil !

In Australia ,
brokers in urban areas are buying up water rights from farmers.

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Water : The new oil !

Rural residents *around the US* are trying to sell their land and water to multinational water bottlers.

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Topic 2

Present situation of Seawater usage in concrete production

JCI (JAPAN CONCRETE INSTITUTE) TECHNICAL COMMITTEE ON THE USE OF SEAWATER IN CONCRETE 2012 -

- In the field of concrete, **billions tons of freshwater** is consumed annually for mixing, curing and washing.
- Seawater is presently not permitted to be used for these purposes. Active use of seawater in the field would help more effective use of freshwater resources.

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Committee report

- Chapter 1 Objectives and activities of the Committee
- Chapter 2 **Case studies** of concrete structures
- Chapter 3 Evaluation of the material properties of concrete
- Chapter 4 **Durability** of concrete mixed with seawater
- Chapter 5 Higher performance of concrete mixed with seawater and appropriate reinforcement
- Chapter 6 Investigation of manufacturing and casting methods for concrete
- Chapter 7 Overall summary and future outlook

- HOW TO ORDER
- Please ask us how to order by e-mail address as below.
- **jci-books@jci-net.or.jp**

Seawater for Concrete Production ?

Negative aspect:

* All the standards in the world inhibit using seawater as mixing water for RC.
* Almost all the authorities in the world are against.

Positive aspect:

* Some researchers reported "not so bad" to use seawater with mineral admixtures.

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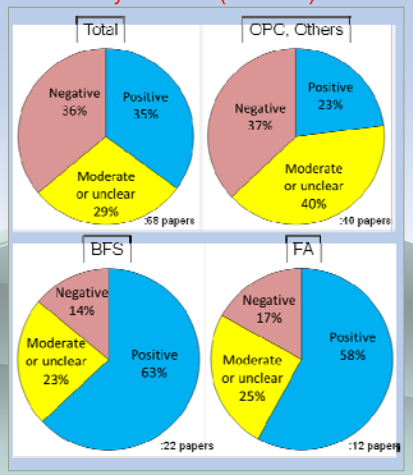
Literature review on seawater mixed concrete

By T Nishida (P. A. R. I.)



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Then !

What is problem of seawater use for concrete production ??

Physical property ?
Long term durability ?
(Chemical property ?)

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Is seawater harmful for cement hydration ??

not harmful !!

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Is seawater harmful on fresh concrete property ??

Slightly !!

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Is sea water harmful for

initial strength development ??
long term strength development ??

Not harmful !!

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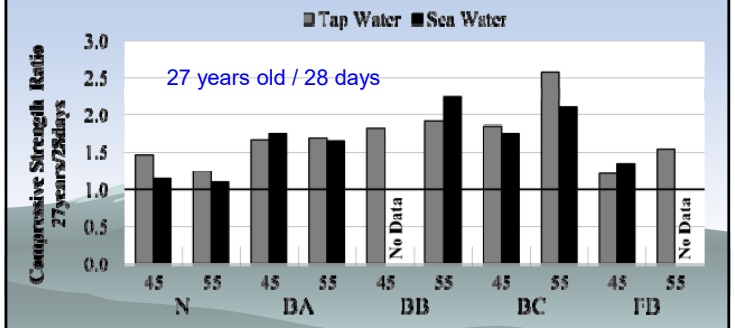
27 years' Compressive strength of seawater mixed concrete



From PARI & Kyushu University Collaboration,
By Adiwijaya, in his doctoral thesis of Kyushu Univ..

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Is seawater harmful for durability ??

Carbonation ?? May be “no” !!

Chloride attack ?? Sure “yes” !!

Alkali silica reaction ?? May be “yes” !!

Chemical attack ?? May be “no” !!

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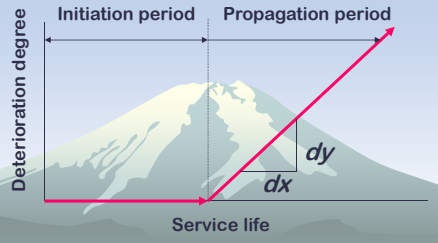
Topic 3

Conceptual model of RC deterioration due to the chloride attack.

Deterioration Progress *(by K. Tutti)*



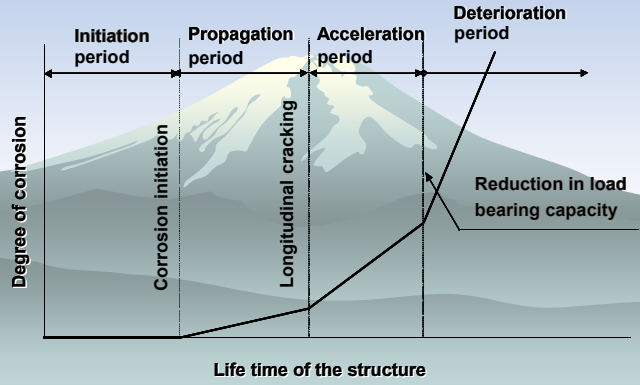
“*dy / dx*” is quite small

in case of steel corrosion even under marine condition

→ 0.4mm / year → 0.04mm / month → 1μm / day

→ it is impossible to measure a dairy change

Deterioration Progress Due to Chloride Attack by Prof. T. Miyagawa (Japan)



Initial chloride content in fresh concrete

normal concrete : 0 – 0.6 kg/m^3

“sea water” mixed concrete : 3.0 kg/m^3

”sea water” + “unwashed sea sand” : 4.8 kg/m^3

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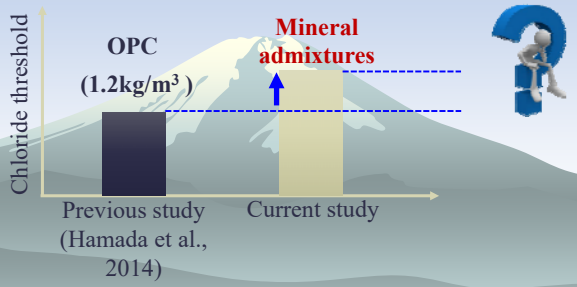
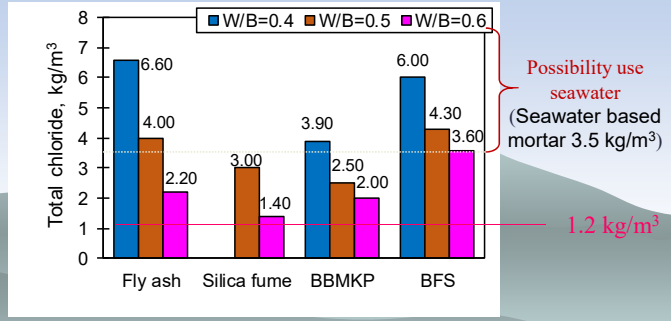
How is “the chloride threshold value” for corrosion initiation of steel in concrete ?



By Dahlia Patah, in her doctoral thesis, Kyushu University, 2019.

Chloride Threshold Value for various kinds of cement (binder)



By Dahlia Patah, in her doctoral thesis, Kyushu University, 2019.

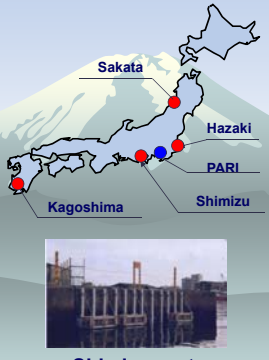
Topic 4

What is the long-term exposure test ?

How it is important to understand long-term performance ?

Exposure-site Operated by PARI (PHRI)

Sakata port

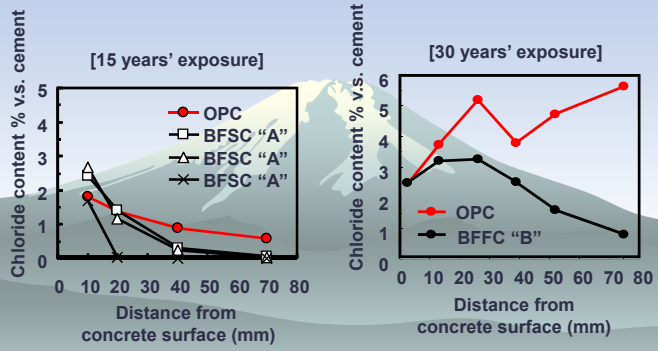


Kagoshima port

Shimizu port

PARI

Chloride Distribution in the Specimen Exposed under Marine Tidal Condition



Chloride Diffusion Coefficient Obtained from "Long-term Exposure Test"

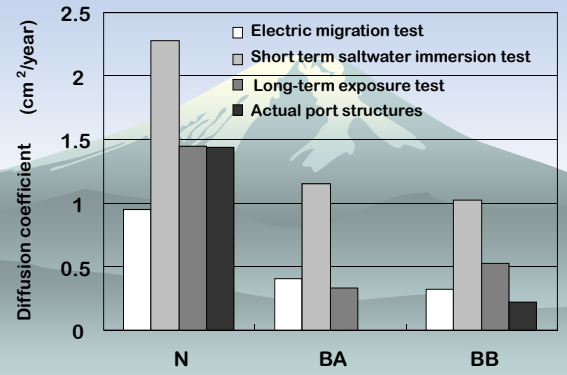
$$\frac{\partial C}{\partial t} = D_C \frac{\partial^2 C}{\partial x^2}$$

Cement type	Diffusion Coefficient (mm^2 / year)
OPC	145
BFSC type "A"	33
BFSC type "B"	22
BFSC type "C"	10

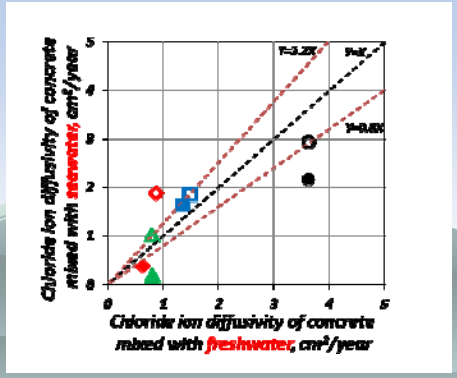
Estimated Length of "Initiation Period"

Specimen No.	W/C	Estimated Initiation Period (years)	
		Cover depth = 35mm	Cover depth = 55mm
OPC	0.45	3.9 year	Over 21 years
OPC	0.60	1.8 year	5.1 year
OPC	0.75	0.6 year	2.4 year
Blast Furnace Slag	0.60	Over 12 years	Over 21 years
Fly Ash	0.60	3.7 year	Over 21 years
Silica Fume	0.60	Over 12 years	Over 21 years
Blast Furnace Slag	0.75	2.4 year	19.6 year

Various Diffusion Coefficients Obtained by Different Method



Chloride diffusion coefficient



By N. Otsuki & T Nishida (Tokyo Institute of Technology)

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Long-tem exposure test is a message…

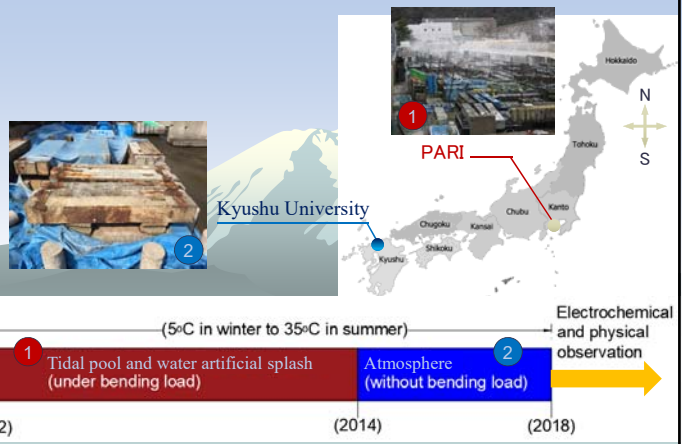
(1) From senior to junior over several generations.

(2) Conversation with natural environments through the language of specimen, or response from environments to us.

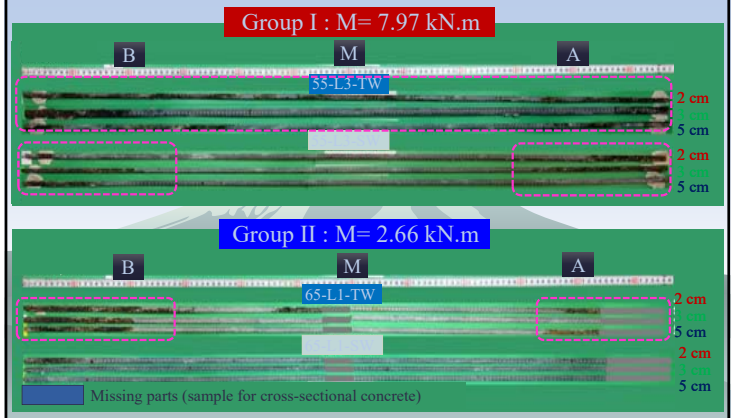
Performance of Seawater-mixed Concrete in Natural Corrosion Environments

By Dahlia Patah,
Kyushu University, in her doctoral thesis, 2019.

History of RC Beam

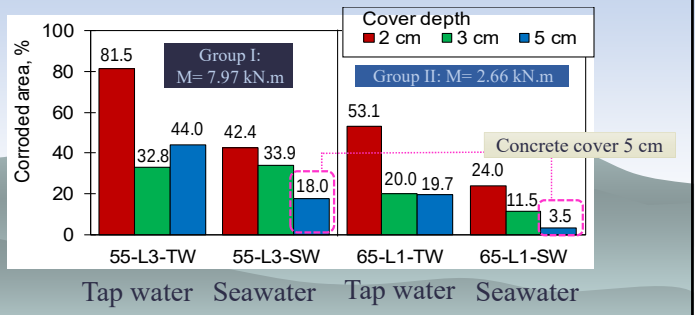


Appearance of Steel Bar



◆ Most damage zone (close to position at maximum crack width and depth)

Total Corroded Area



Topic 5

Can we use seawater for concrete production safely ?

What countermeasure is necessary for corrosion prevention of steel in seawater mixed concrete ?

Several experiences of sea water mixed real concrete structures in Japan.

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Light house in Nagasaki Pref.

Light house in Nagasaki Pref.

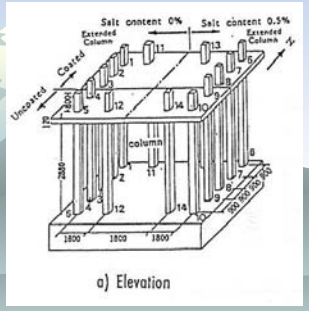
From old research

By Prof. Oshiro & Dr. Tanikawa

Effectiveness of surface coating

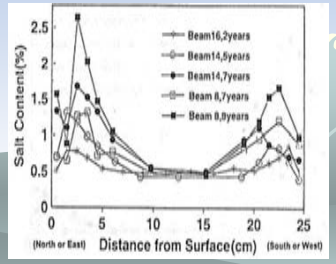
Marine Exposure test by Prof. Oshiro and

Dr. Tanikawa, in Okinawa Island

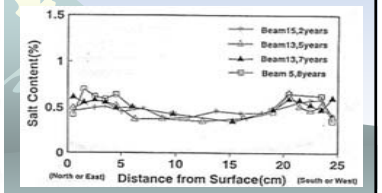


Chloride content in concrete

--- with initially added chloride ---

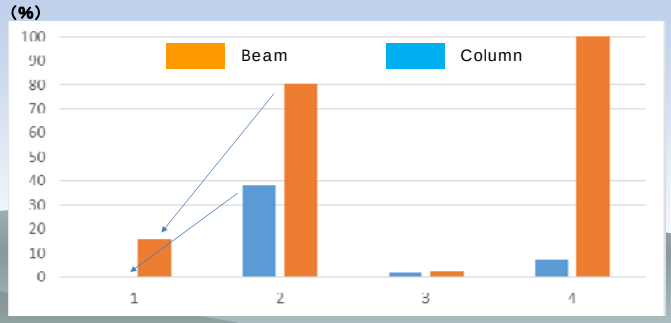


Without coating



With coating

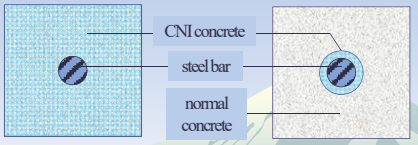
Corroded area（4 years' Exposure）



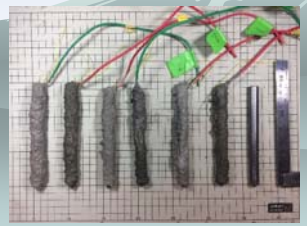
An application of corrosion prevention, Calcium Nitrite-based corrosion Inhibitor (CNI)

By Sabrina Harahap,
in her Master thesis, Kyushu University, 2019.

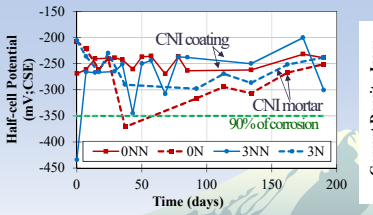
SPECIMEN DESIGN



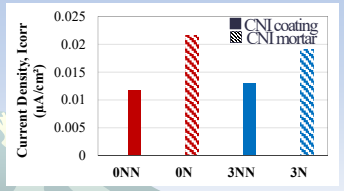
How's CNI working in seawater-mixed concrete?
Can CNI coating prevent corrosion?



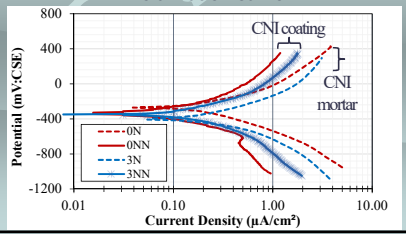
- Half-Cell Potential



- Maximum current density



- Polarization curve

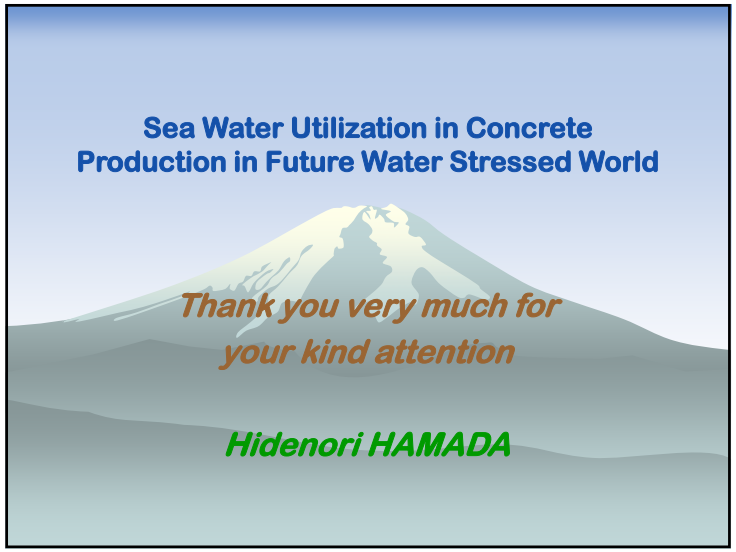


My bitter memory in Viet Nam in 2001

ACKNOWLEDGEMENT

- I express my sincere thanks to **all participants** in the research group, JCI (Japan Concrete Institute), Kyushu University.

- In near future, seawater mixing will be inevitable technique in concrete engineering almost all over the world under collaboration of **concrete engineer** and **corrosion engineer**.


Sea Water Utilization in Concrete
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Thank you very much for
your kind attention
Hidenori HAMADA