JICA issue-specific training projects

Concrete Maintenance Engineering

- A case study of concrete structures in Okinawa -

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Course contents

- Symptoms and mechanisms of deterioration of concrete structures
- Geographical features and environmental effects of Okinawa Prefecture
- Salt damage deterioration & alkali silica reaction (ASR) case
- Transition of durability design in Okinawa Prefecture
- Efforts aimed at 100-year durability
- Summary

<Definition of words>

- Deterioration
- Refers to a material or structure that degrades and progresses over time.
- Initial defects
- Refers to cracks, candied bean slabs, cold joints, etc. that occur during construction.
- Damage
- Refers to cracks and/or peelings caused by external forces.

- Deterioration
- Initial defects
- Damage
- Other symptoms

} Deformation

Symptoms and mechanism of deterioration of concrete structures

<Deterioration and anomalies in the concrete itself>

- Alkali-silica reaction (ASR): Deterioration caused by reactive aggregates
- Frost damage: Deterioration caused by freezing and thawing
- Chemical erosion: Deterioration caused by acidic substances and sulfate ions
- <Anomalies in the rebar>
- Salt damage: Corrosion of reinforcing bars (steel) by chloride ions
- Neutralization: Corrosion of reinforcing bars (steel) due to carbon dioxide
- <Initial Defects>
- Candied bean slabs (honeycombs), cold joints, shrinkage cracks, thermal cracks, etc.
- <Other>
- Fatigue: due to heavy vehicle traffic and repetitive loading
- Abrasion: due to wear and tear

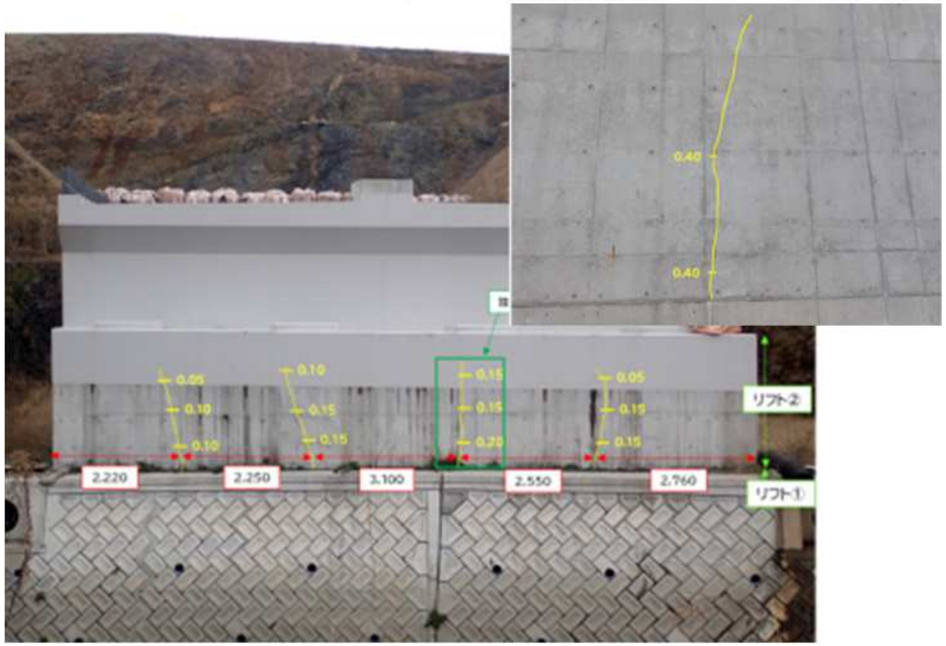
Fatigue cracks on the underside of the floorboards

Example of cracks caused by initial defects

Junk (Bean plate)

Cold joint

Cracks by drying and shrinkage



Geographical features and environmental effects of Okinawa Prefecture

(Geographical features)

Islands surrounded by the sea on all sides!

Resolving remote island suffering

Okinawa → environment of islands

Completed remote island bridge: 21 bridges

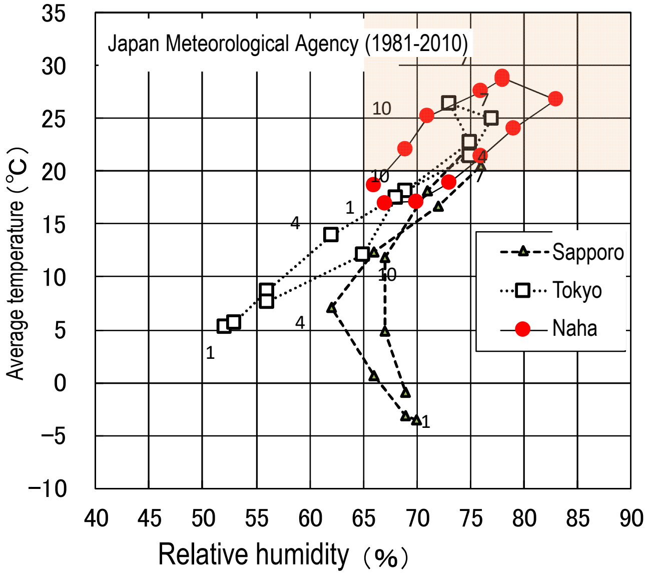
①本土復帰前に完成した橋：１橋
②本土復帰後に完成した橋：20橋
- うち国土交通省所管：17橋（国直轄：２橋、県施工：13橋、市町村施工：２橋）
- うち農林水産省所管：２橋（県施工：２橋）
- うち経済産業省所管：１橋（市町村施工：１橋）

※ Having many remote island bridges!

番号	橋名	市町村名
1	桃原橋	うるま市
2	奥武橋	南城市
3	羽地奥武橋	名護市
4	伊計大橋	うるま市
5	瀬底大橋	本部町
6	藪地大橋	うるま市
7	慶留間橋	座間味村
8	池間大橋	宮古島市
9	屋我地大橋	名護市
10	来間大橋	宮古島市
11	宮城橋	大宜味村
12	浜比嘉大橋	うるま市
13	奥武橋	久米島町
14	世開橋	うるま市
15	平安座海中大橋	うるま市
16	塩屋大橋	大宜味村
17	阿嘉大橋	座間味村
18	野甫大橋	伊平屋村
19	古宇利大橋	今帰仁村～名護市
20	ワルミ大橋	名護市～今帰仁村
21	伊良部大橋	宮古島市

Many remote island bridges are being built →
Large-scale and see-crossing bridges

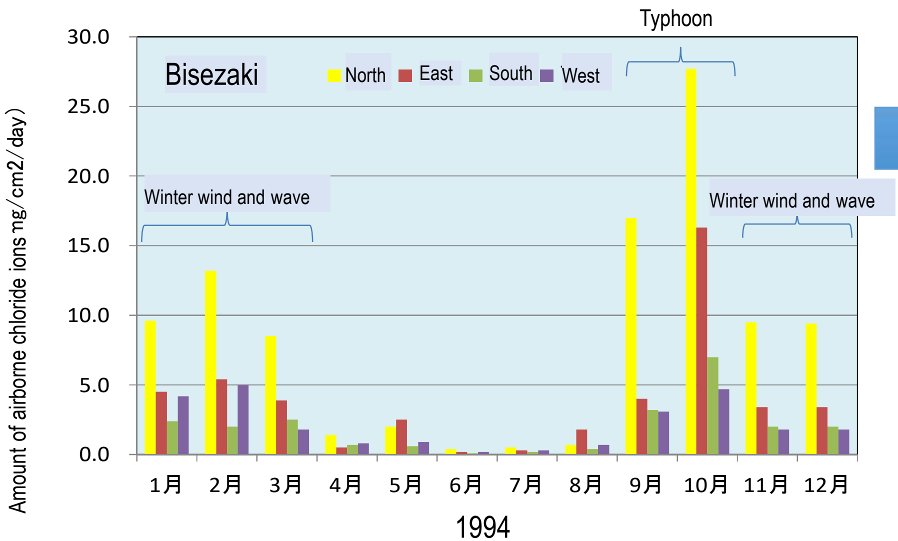
(Environmental action)



Climograph

* Subtropical oceanic climate: hot and humid

＋



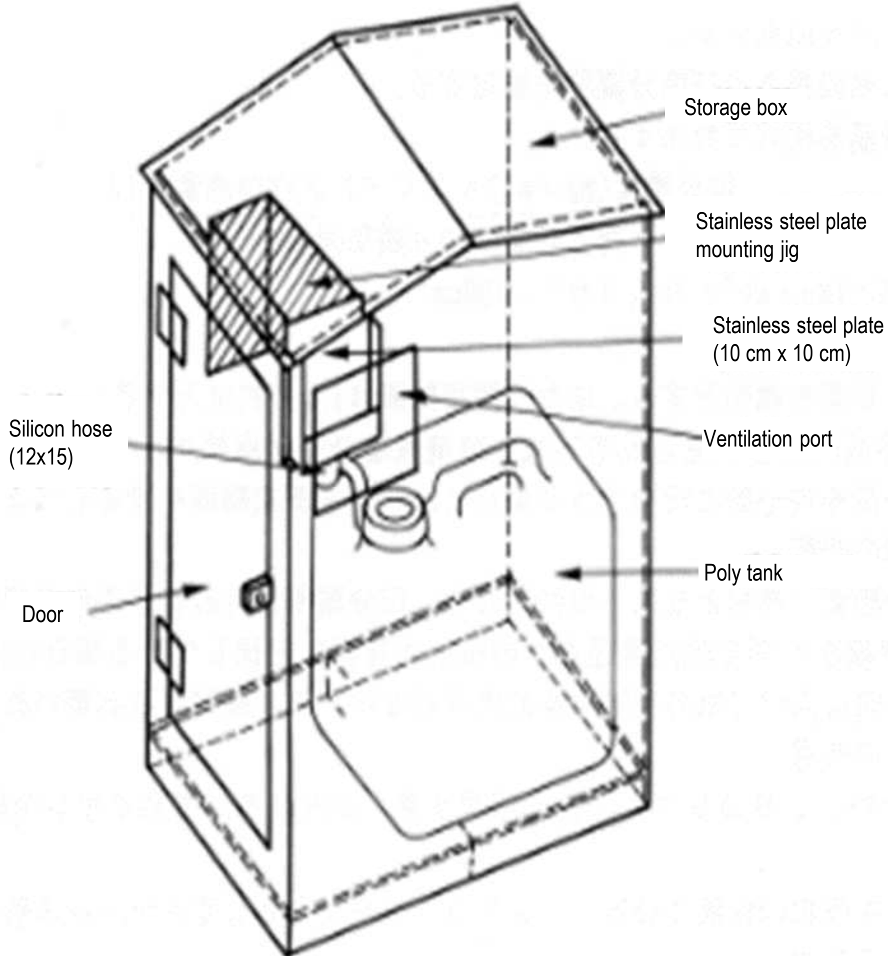
Amount of flying salt

Harsh natural environments for structures

Fast degradation rate

* Typhoon, winter wind and wave → A large amount of airborne salt coming in (supply)

PWRI (Public Works Research Institute) type airborne salt collector



Soil research type airborne salt collector (principle)
The salt that has entered through the ventilation port adheres to the 10 cm x 10 cm stainless steel plate in the back. Rinse the deposited salt with water into a plastic tank inside. Collect the plastic tank and analyze the recovered salt by potentiometric titration.

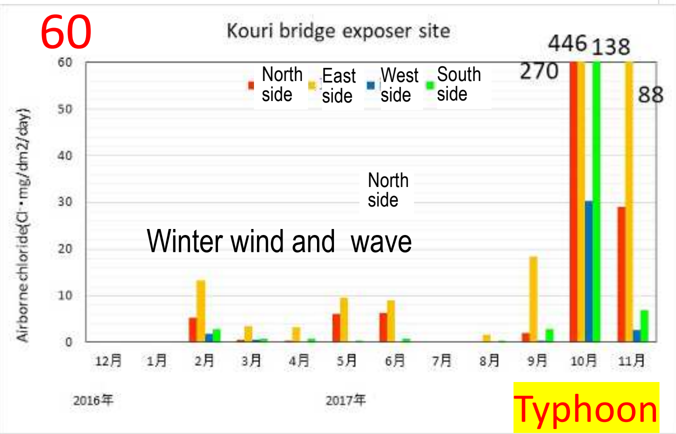

PWRI Type Flying Salt Collector (1 direction)


PWRI Type Airborne Salt Collector (4 directions)

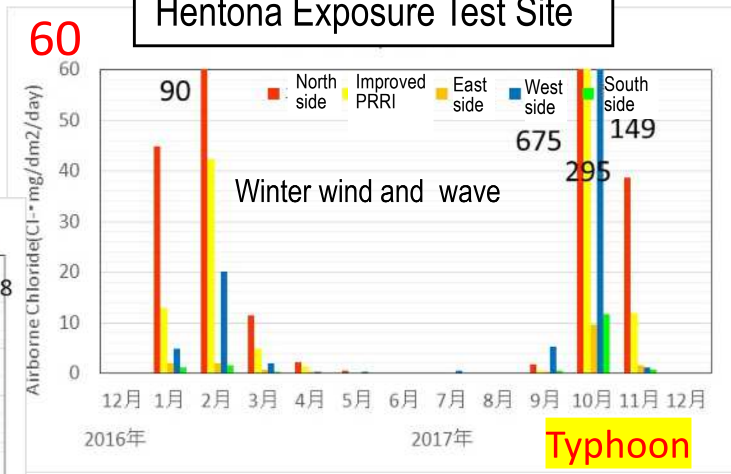
Salt damage environmental survey (exposure test site) (2017) Continued even now

Airborne salt (Cl⁻:mdd)

Kouri Bridge Exposure Test Site

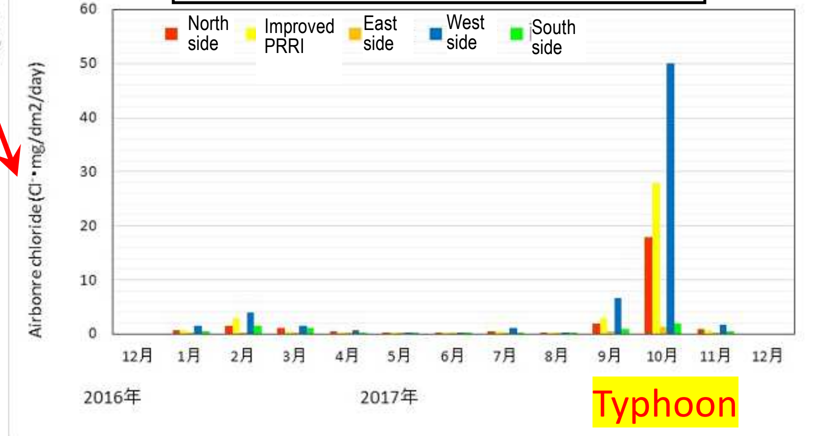


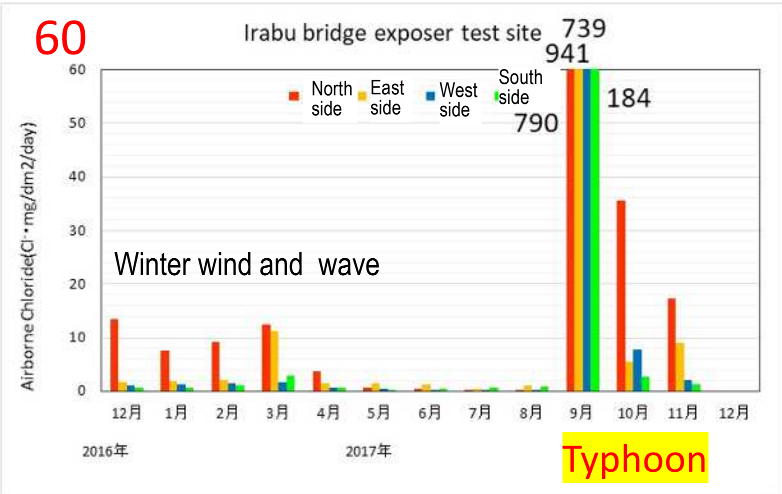
Hentona Exposure Test Site



PWRI Type Tank (4 directions)

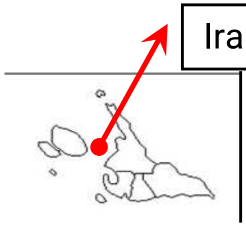
Benoki Exposure Test Site





Okinawa main island

Irabu Bridge Exposure Test Site



Miyako Island

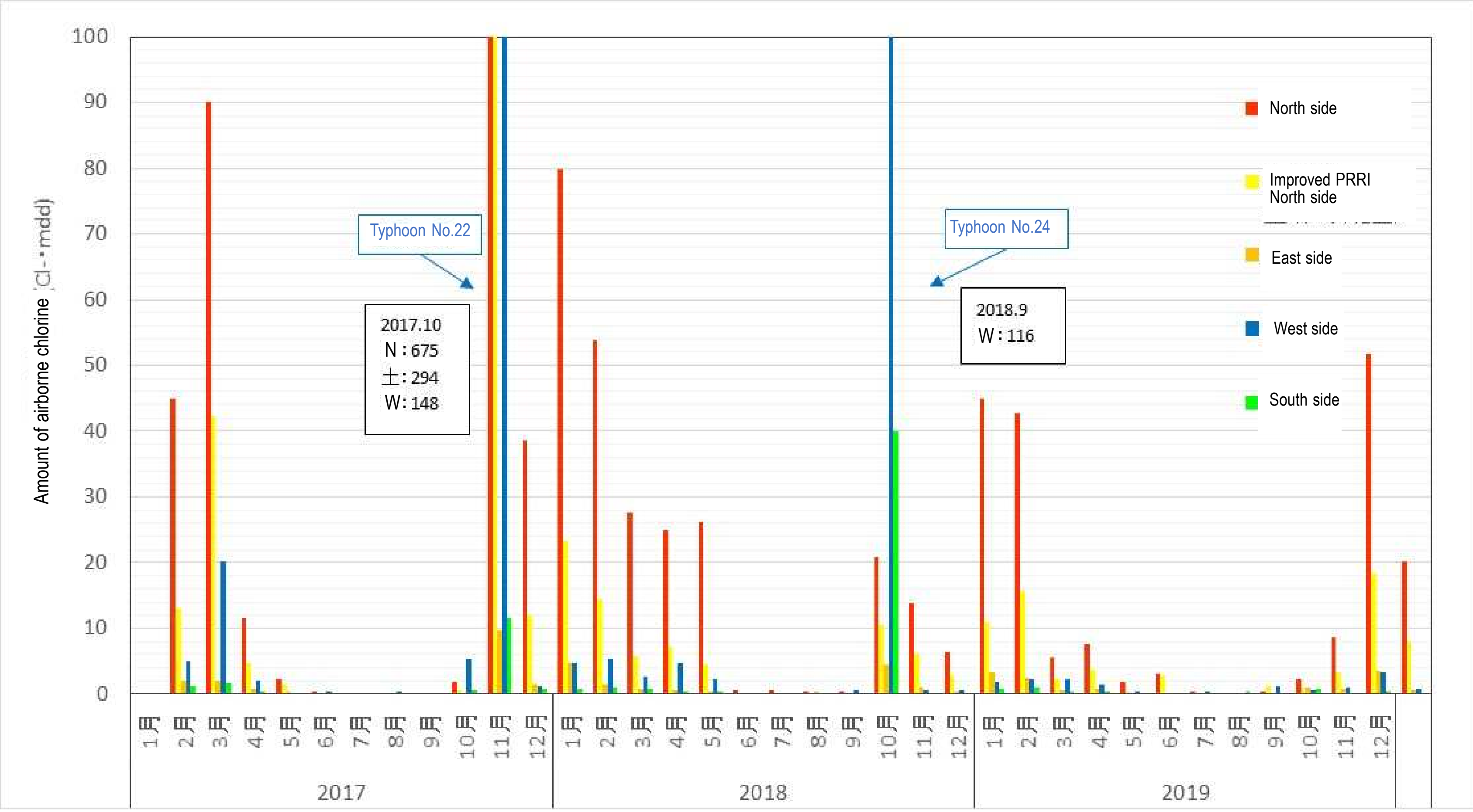
Winter winds and waves and typhoons provide a lot of salt from the sea.

Construction Materials Laboratory, University of the Ryukyus, Okinawa Construction Technology Center, and R&A Joint Research

Salt damage environmental survey (2017-2019)

- Large amount of airborne salt supply environment due to winter wind waves and typhoons

Steel material corrosion starts fast.

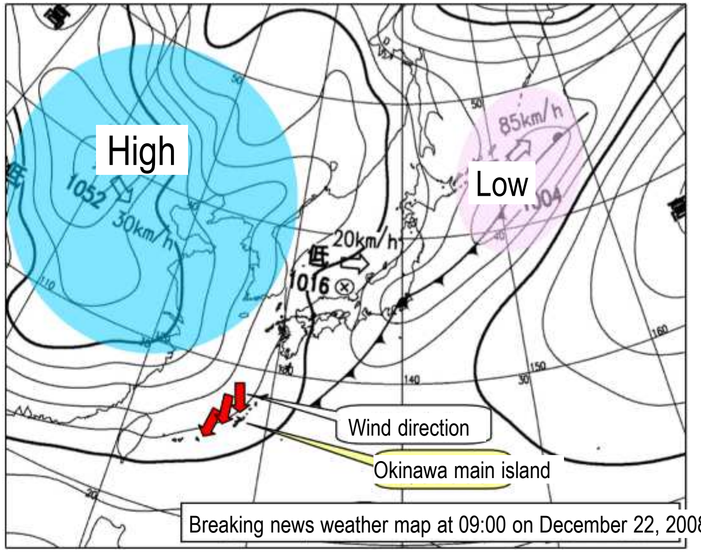


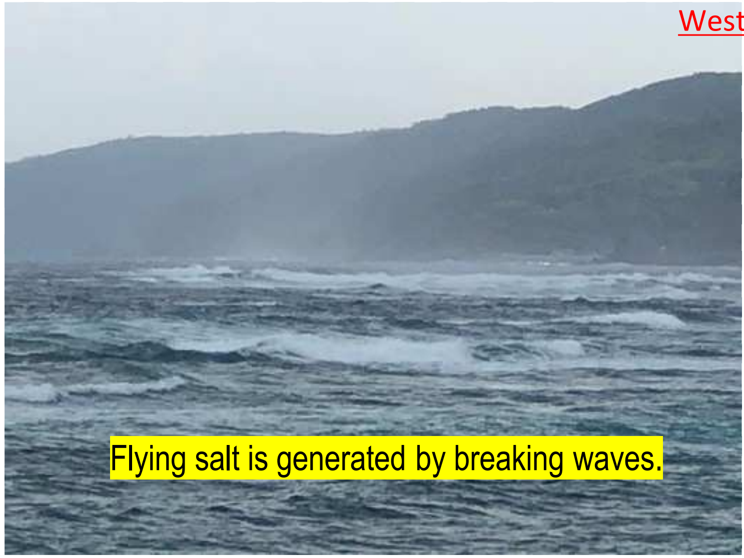
Salt damage environment survey a using PWRI type flying salt collector (Hentona exposure test site)

Construction Materials Laboratory, University of the Ryukyus, Okinawa Construction Technology Center, and R&A Joint Research

Tidbits of information on meteorological fields (about airborne salt generation) (Appendix)

Winter: Typical winter-type pressure distribution with high west and low east (wind speed is proportional to the difference in pressure)



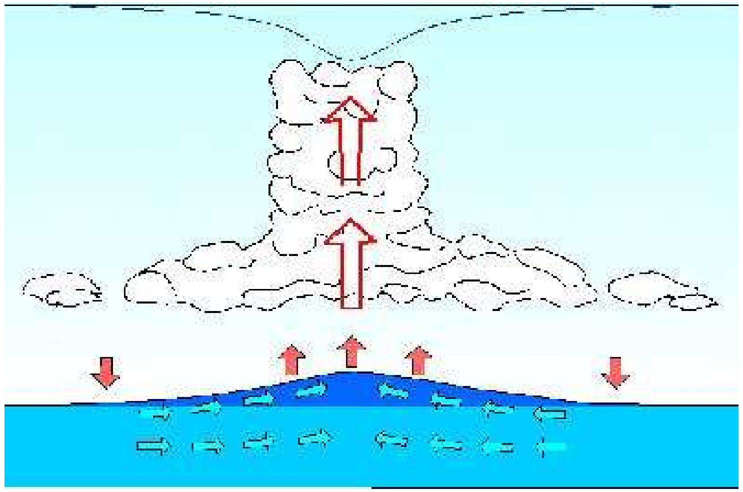


West coast in winter (Okinawa prefecture)

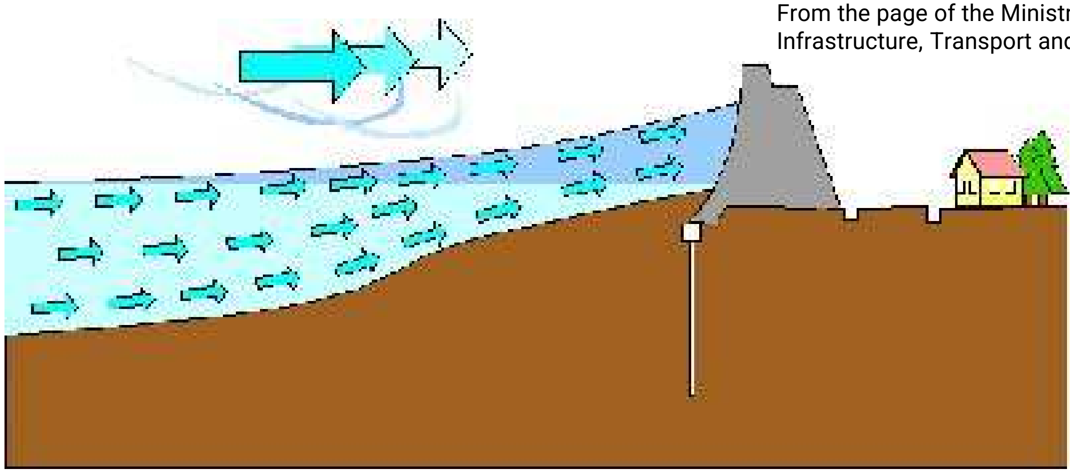
A large amount of flying salt is generated.

http://www.city.ginowan.okinawa.jp/DAT/LIB/WEB/1/fuyunokisetufuu.pdf

Typhoon / Storm Surge: Sea level rise due to atmospheric pressure decrease + wind blowing effect



From the page of the Ministry of Land, Infrastructure, Transport and Tourism

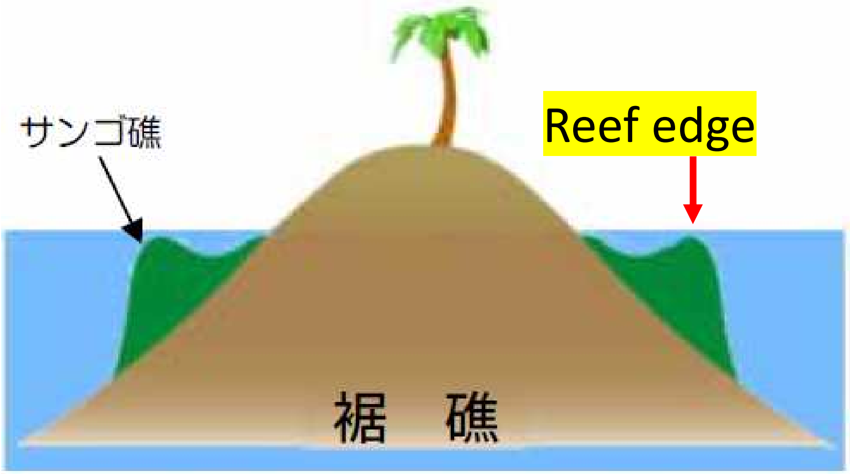


- When the atmospheric pressure drops by 1 hPa, the sea level rises by about 1 cm.

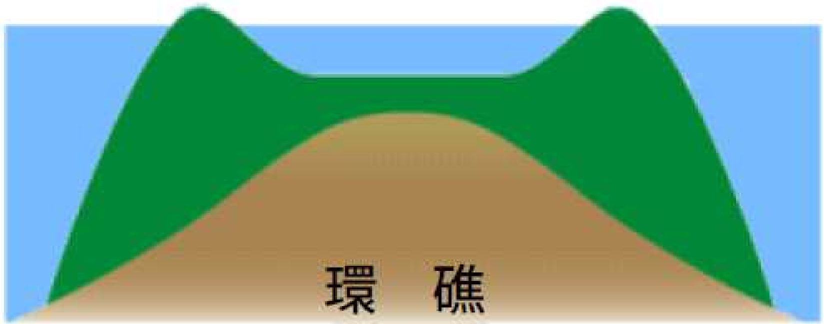
* Wind tends to flow from high pressure to low pressure.

Relationship between coral reefs and airborne salt

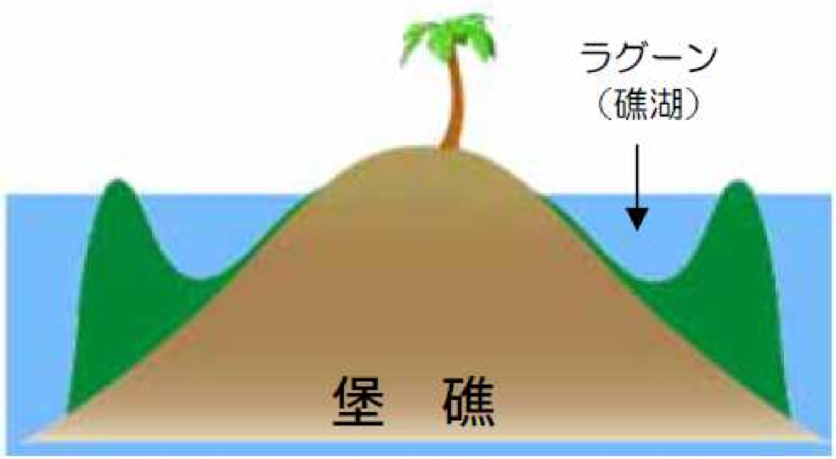
Three types of landforms created by coral reefs: fringing reefs, barrier reefs and atolls
A schematic cross-sectional diagram of the most common fringing reefs in Okinawa and a representative growing coral



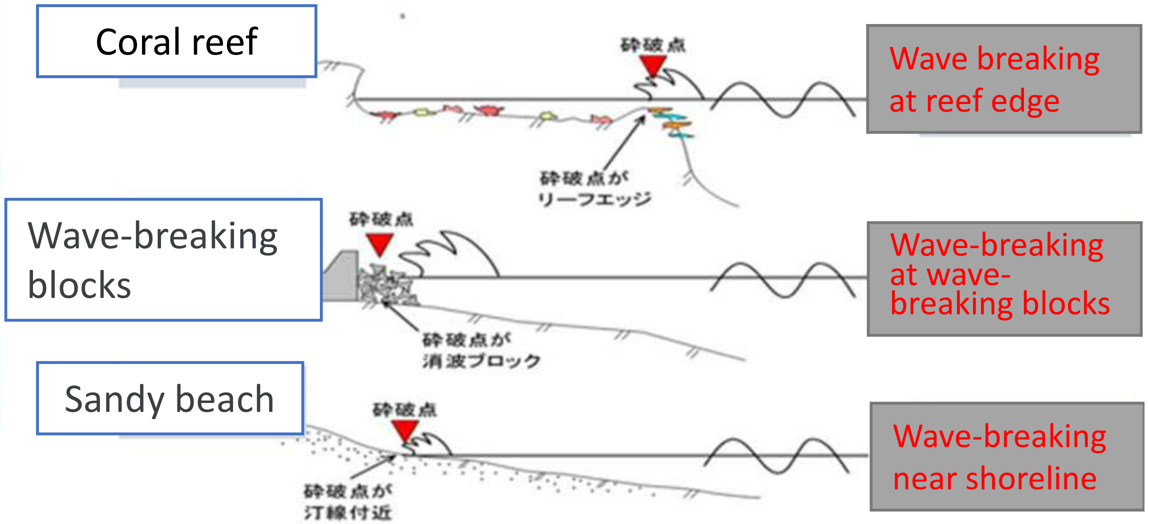
島の周囲をサンゴ礁が囲んでいます。
サンゴは沖へ沖へと成長していきます。



島が沈んだあと円形のサンゴ礁だけが海面に残り、中央に陸地がありません。



裾礁と似ていますがサンゴ礁の内側に１０m～１００mの深い海（礁湖）ができています。



Beach type and location of wave breaking

Example of two-stage wave breaking: reef edge ＋ coastline

Deterioration Cases (Salt Damage, ASR)

Summary of main factors of aging deterioration in Okinawa Prefecture

- **Salt damage**

- Intrinsic salt: Salt contained in unwashed sea sand (constructed before 1986)

Sea sand desalination status: Sprinkling method

【5 days = 1 process】

2,500 m^3 of sand is piled up and about 3,000 tons of industrial water is sprinkled continuously for 4 days.2

Drain in 24 hours and confirm that the amount of chloride (as NaCl) is 0.04% or less.

Foreign salt content: Sea-derived salt content such as flying salt content and droplets

- **Alkaline Silica Reaction (ASR)**

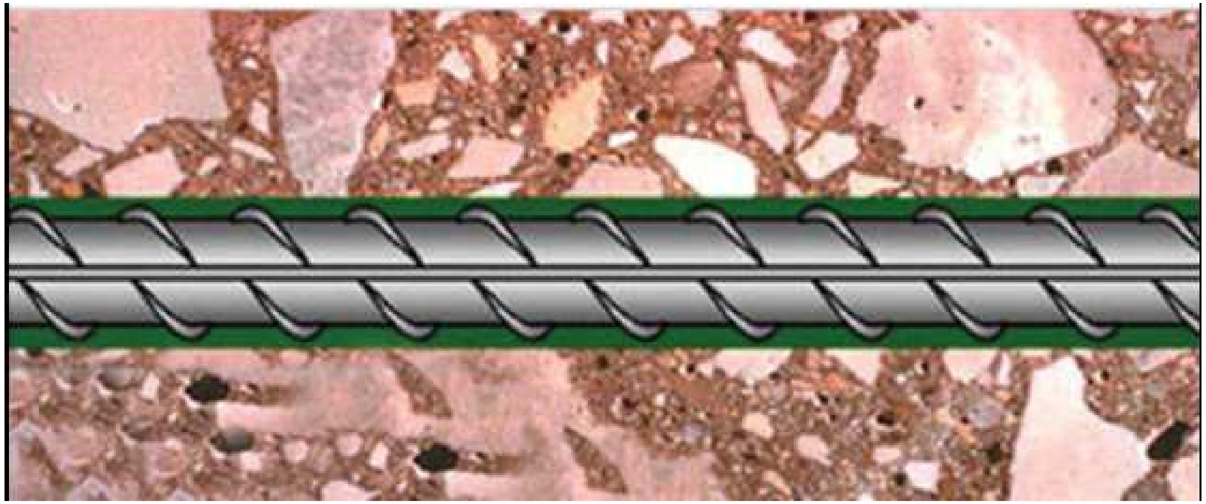
Rapid expansion: Aggregate outside the prefecture (precast product produced outside the prefecture)
Porphyrite intruding into Motobu limestone

Delayed expansion: Imported aggregate (river gravel and river sand from Hualien, Taiwan)
Sea sand （from off Arakawa）

* ASR deterioration caused by sea sand is slight and limited..

Why do reinforcing bars in concrete corrode?

- Generally, concrete has a highly alkaline environment with pH of 12-13.
- In such an environment, a passive film (oxide film) is formed on the surface of the steel in the concrete, which inhibits steel corrosion.



Passive film

Why does steel in concrete corrode?

Chloride ion

Neutralization

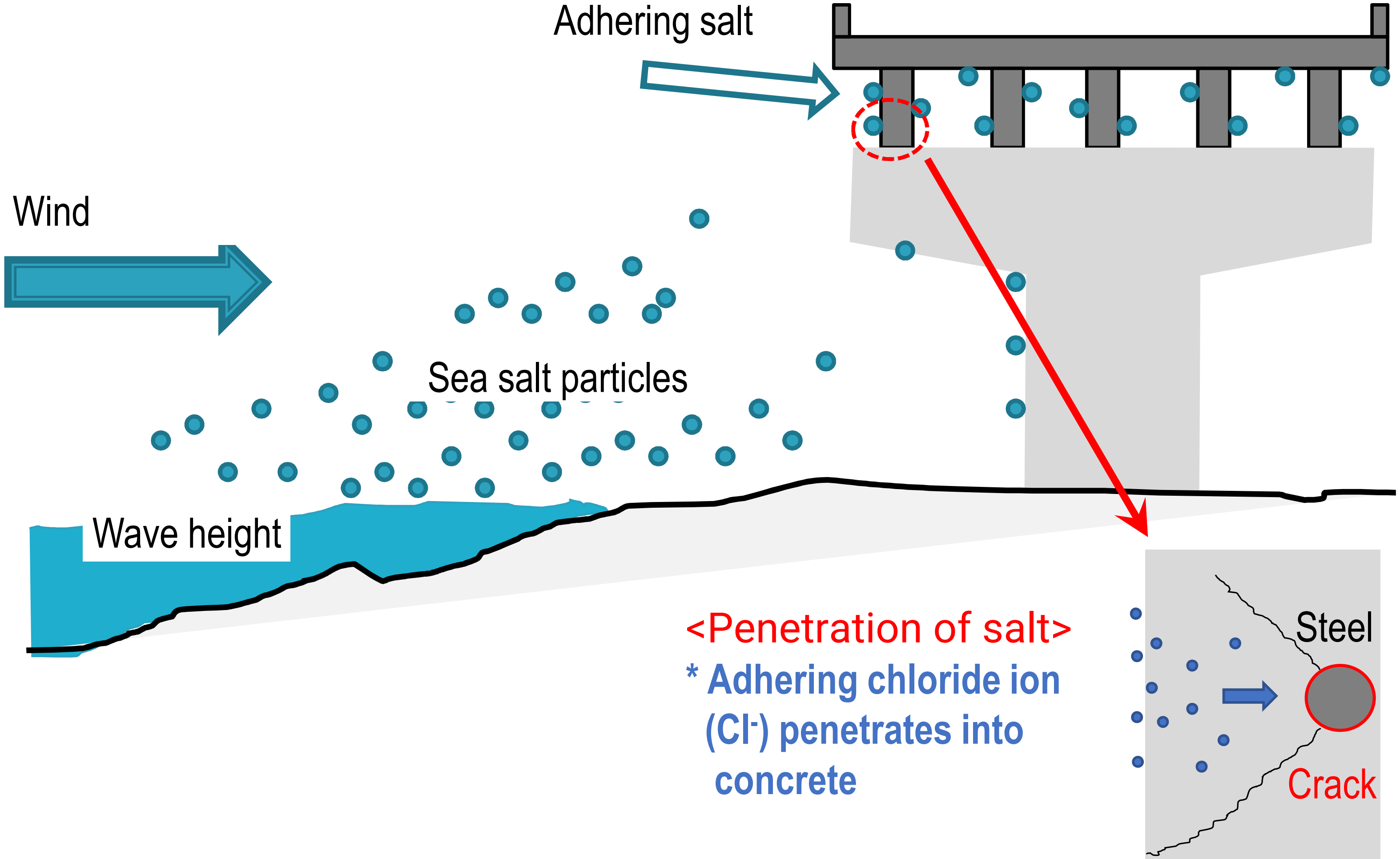
Steel corrosion starts due to the destruction and disappearance of the passive coating.

* Water and oxygen required for the corrosion reaction are present in concrete.

Schematic diagram of salt damage caused by foreign salt

Where are the chloride ions supplied?

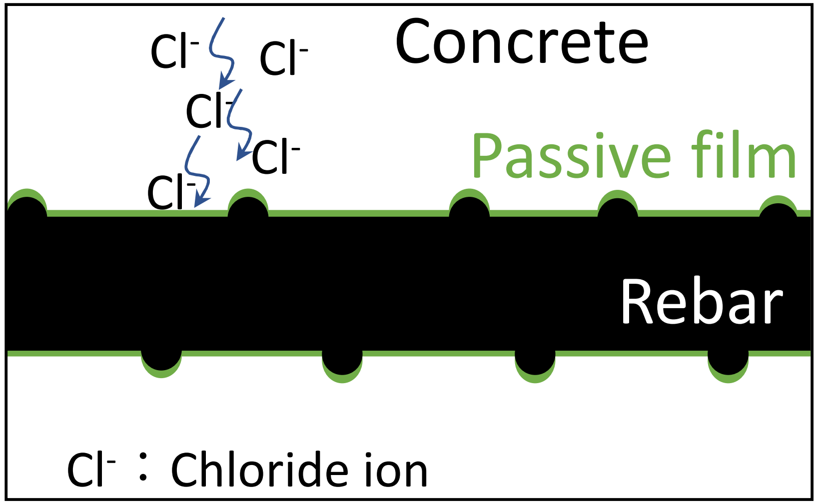
In the case of Okinawa Prefecture, it is supplied from the sea because it is surrounded by the sea on all sides.

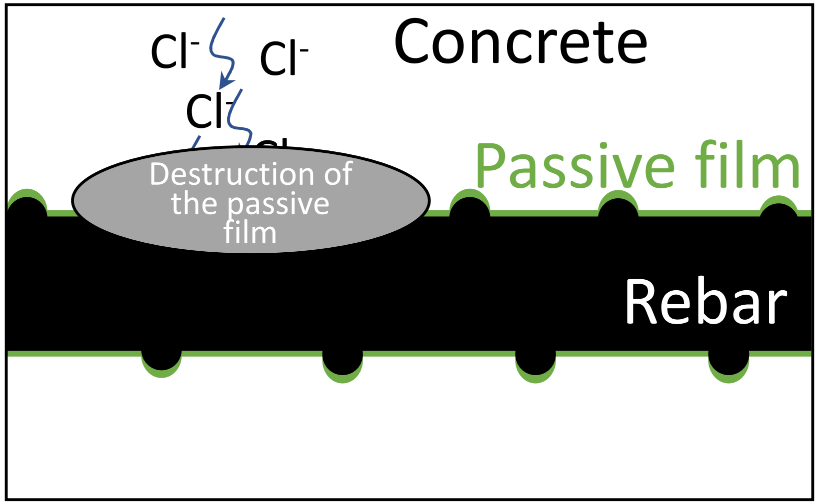


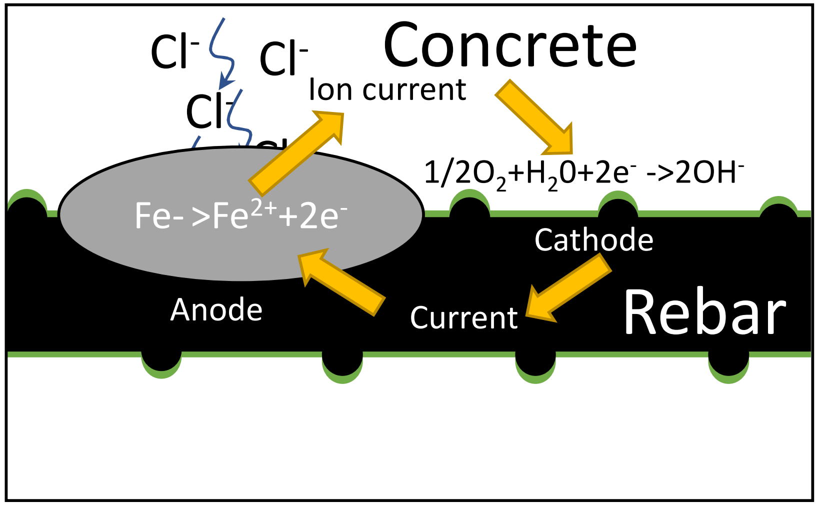
Passivation film fracture: Corrosive expansion of steel

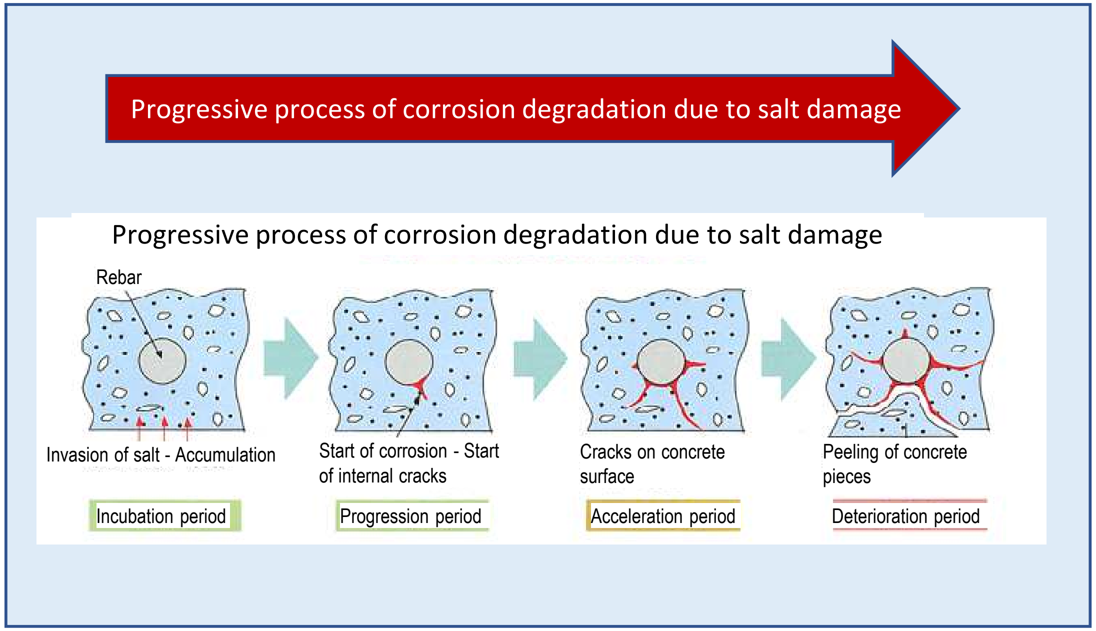
Mechanism of salt damage deterioration

Cl^- : Chloride ion

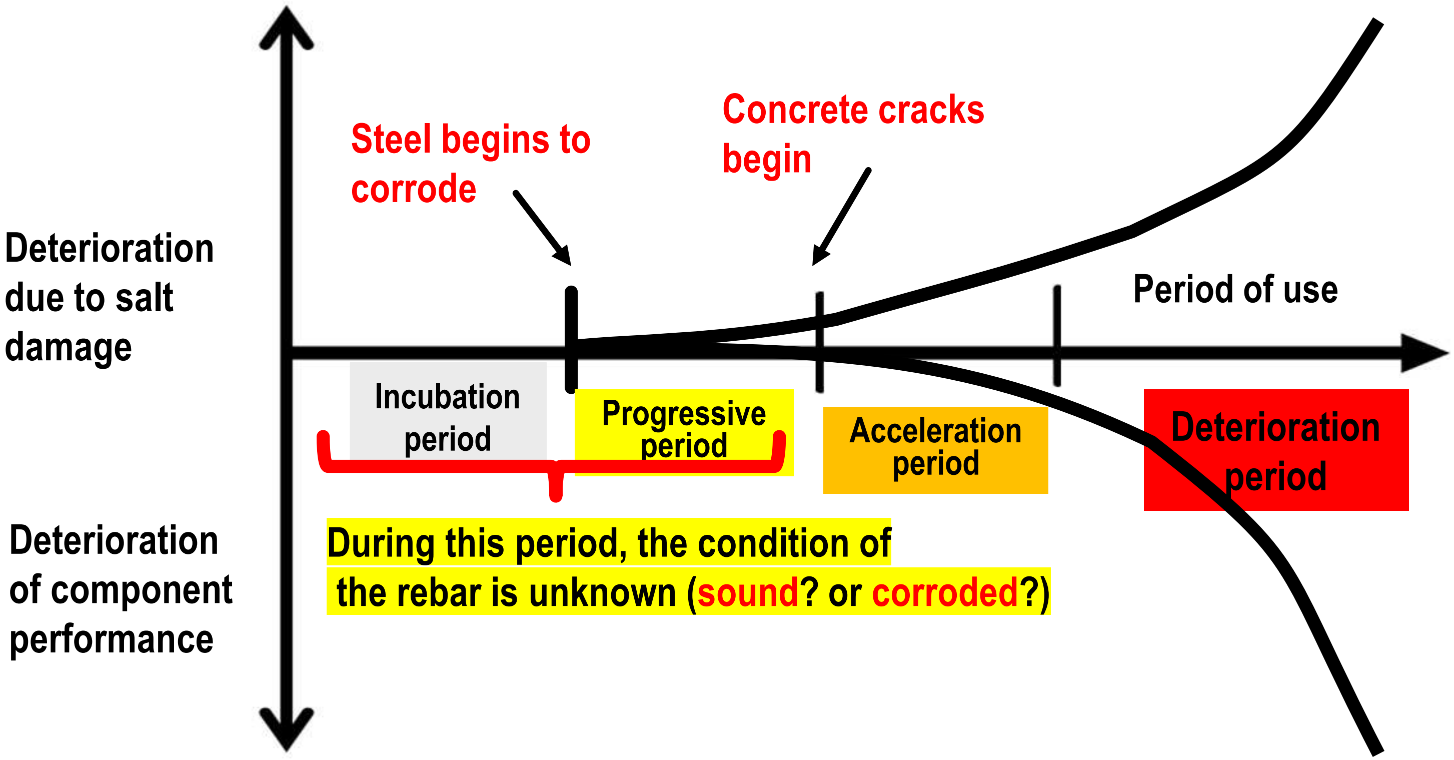


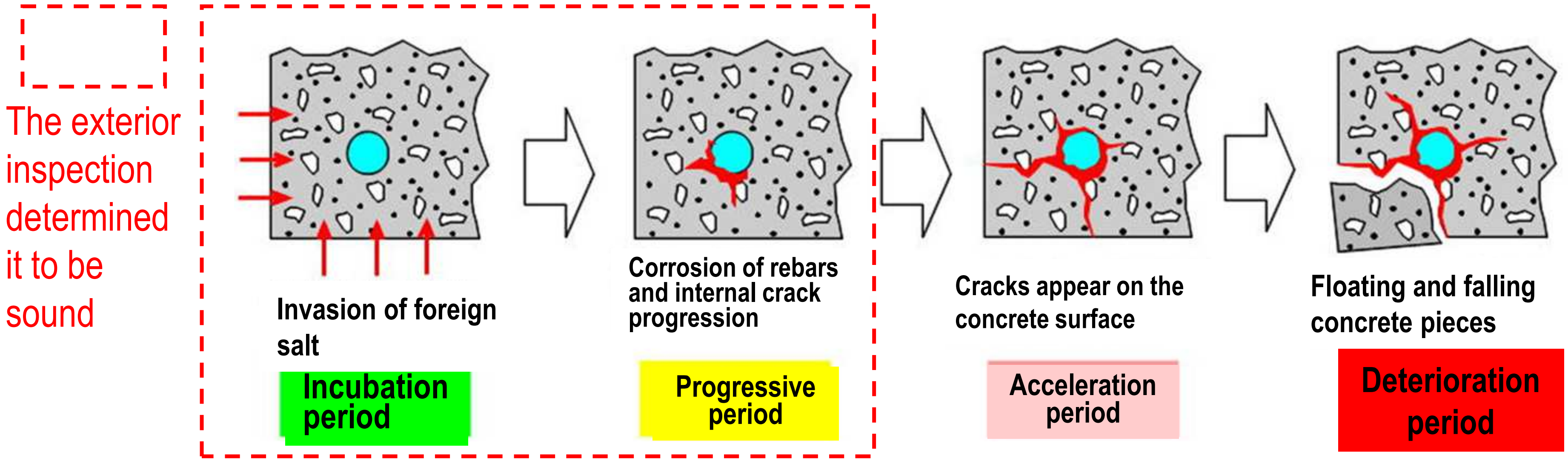






Progression of salt damage degradation





Examples of degradation process of salt damage

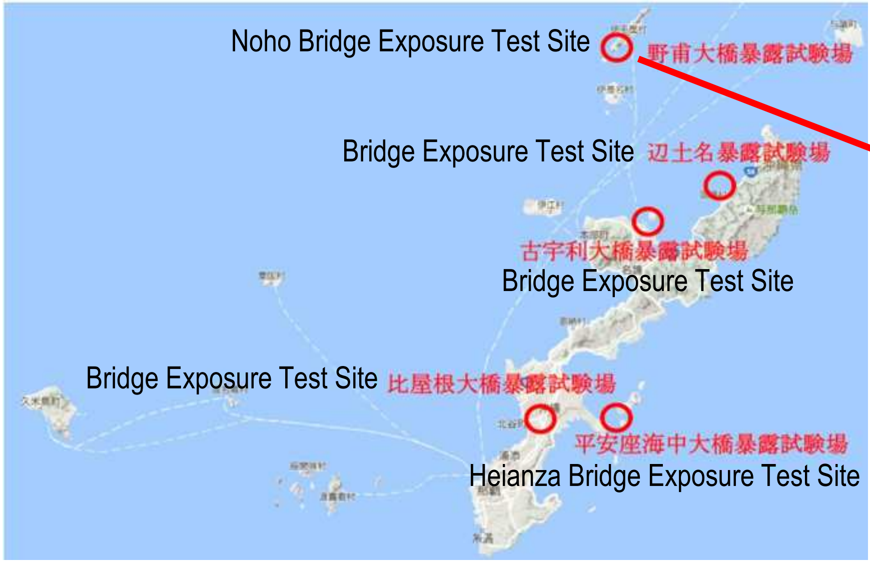
【Incubation period】 and 【Progression period】
・ No deformation has occurred yet.

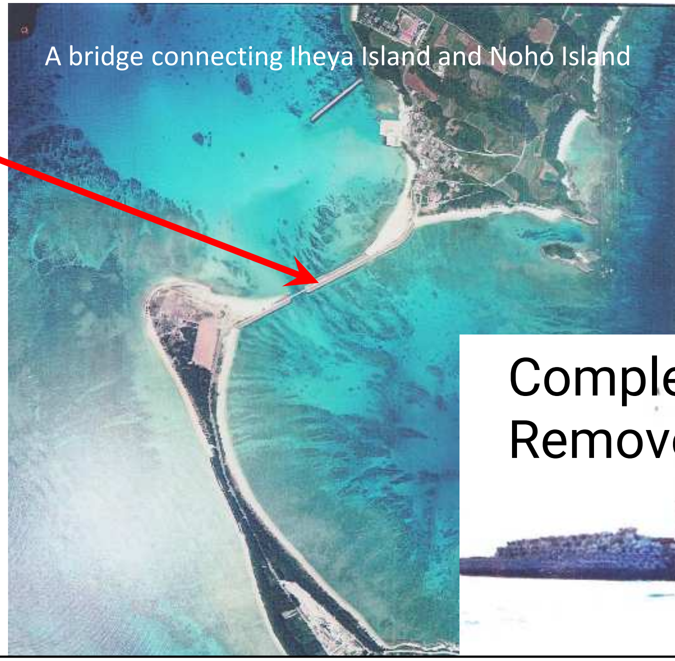
【Early acceleration period】
・Minor cracks and lifting occur.

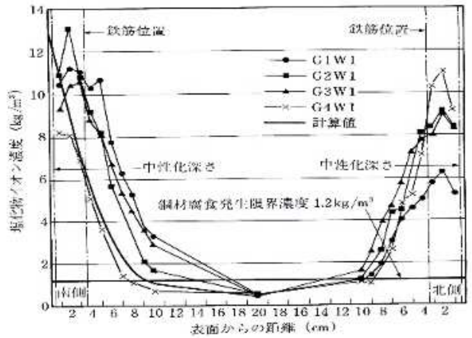
【Late acceleration period】
・Many cracks, floats, and peeling occur.

【Deterioration period】
・ Large scale spalling, decrease in cross section of reinforcing rebar

Salt damage deterioration case (former Noho Bridge)







Completed in 1978
Removed in1999

The first remote island bridge since Okinawa returned to Japan:
After 21 years of construction, salt damage led to deterioration and replacement.

Durability design of Shin (New) Noho Bridge

Provided by Mr. Hiroshi Kazama, R & A

Shin Noho Bridge

(Opened in March 2004)

PC5 spaced continuous box girder bridge
Bridge length 320m (54.25 + 3 @ 70 + 54.25)

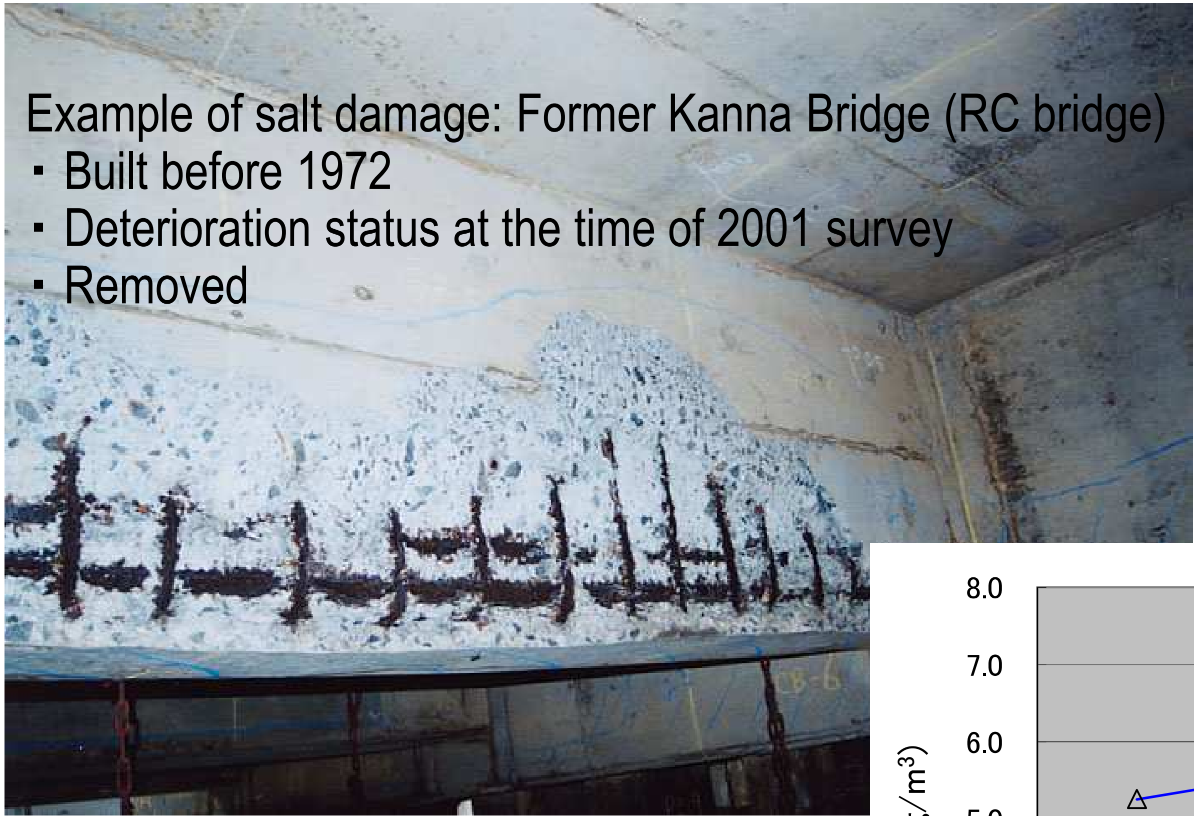
Measures against salt damage:

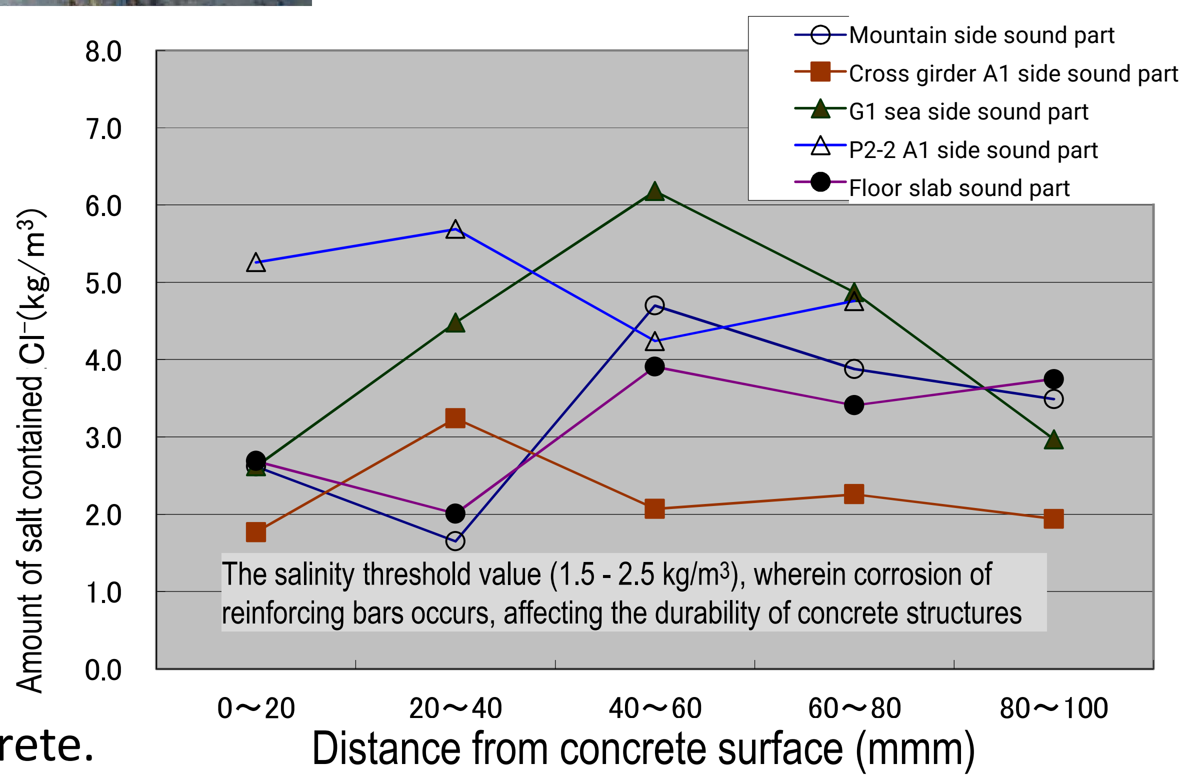
1. Securing cover 70 mm
2. Adoption of epoxy resin coated reinforcing bars
3. Adoption of epoxy resin coated PC steel material
4. Adoption of polyethylene sheath

Examples of salt damage deterioration of concrete structures

Cases of salt damage deterioration due to intrinsic salt

Provided by Mr. Hiroshi Kazama, R & A





High concentration salt exists inside concrete.

Examples of salt damage deterioration of concrete structures

Cases of salt damage deterioration due to intrinsic salt   Provided by Mr. Hiroshi Kazama, R & A

Salt damage example: PC bridge

Constructed with Ocean Expo immediately after Okinawan reversion (1975).

Examples of salt damage deterioration (others)





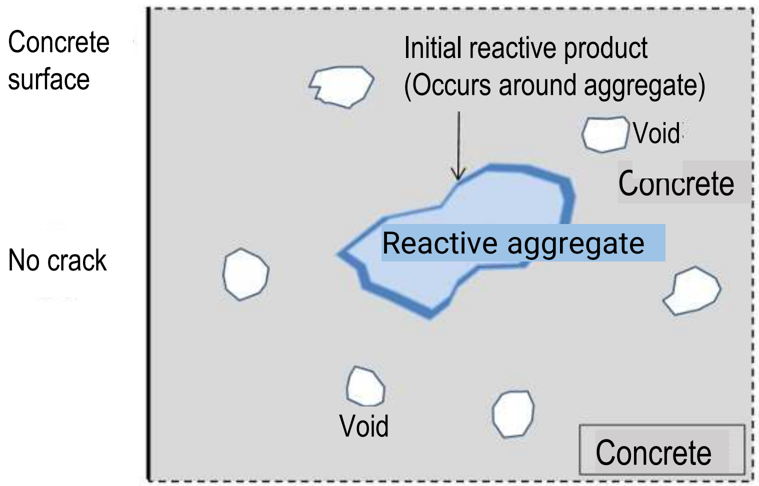


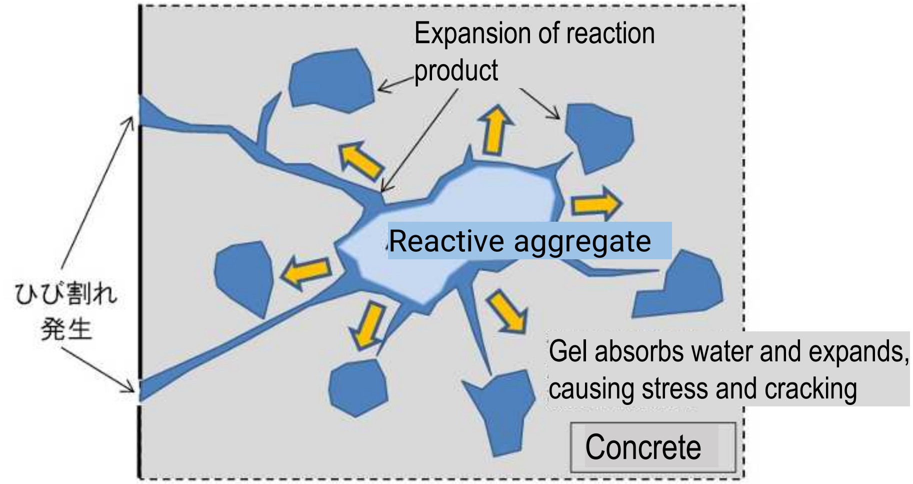

Examples of deterioration seen in inside cast-in-places in Okinawa

- In many cases, the sidewalls are visibly sound, but the lower surface of the top plate has significantly deteriorated.

Problems of ASR deterioration in Okinawa Prefecture

Schematic diagram of ASR deterioration





Example of ASR degradation (Taiwanese aggregate: delayed expansion)

Cracks harmful to concrete

＋

In some cases, rebar breakage

Classification of ASR by reaction time

- Rapid expansion
- Delayed expansion

Problems with ASR in Okinawa

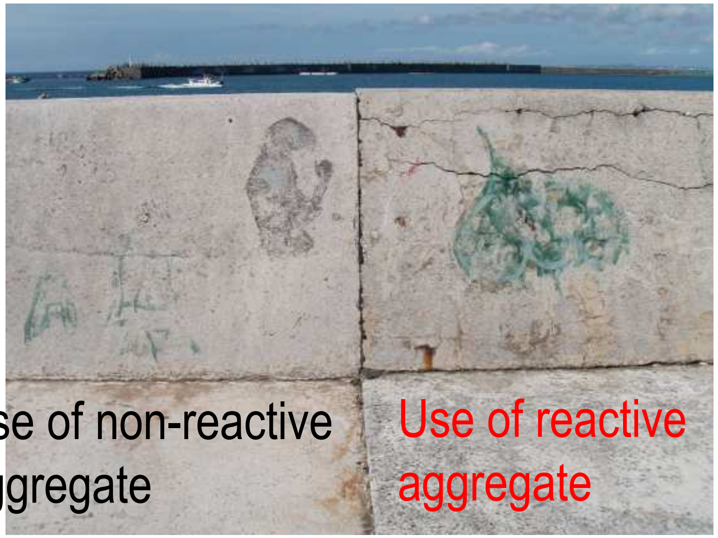
Sea sand used in fine aggregate contains minerals that show delayed expansion.

The risk of delayed expansion ASR cannot be detected by the current JIS ASR tests (chemical and mortar bar methods).

Crack pattern due to ASR deterioration

When the internal binding force is small

When the internal binding force is large



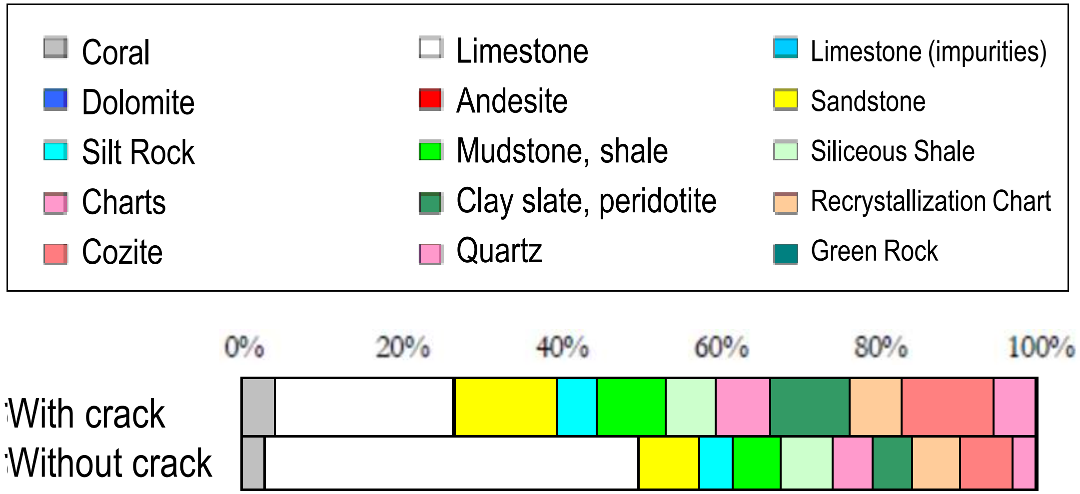
Impact of non-reactive and reactive aggregates

Impact of water splash

Example of delayed expansion ASR degradation

Viaduct A

Although the degradation is <u>slight and limited</u> and it will necessarily be harmful in the future, in an environment with severe salt damage such as Okinawa Prefecture, there is a concern about the deterioration <u>combined with salt damage</u>.



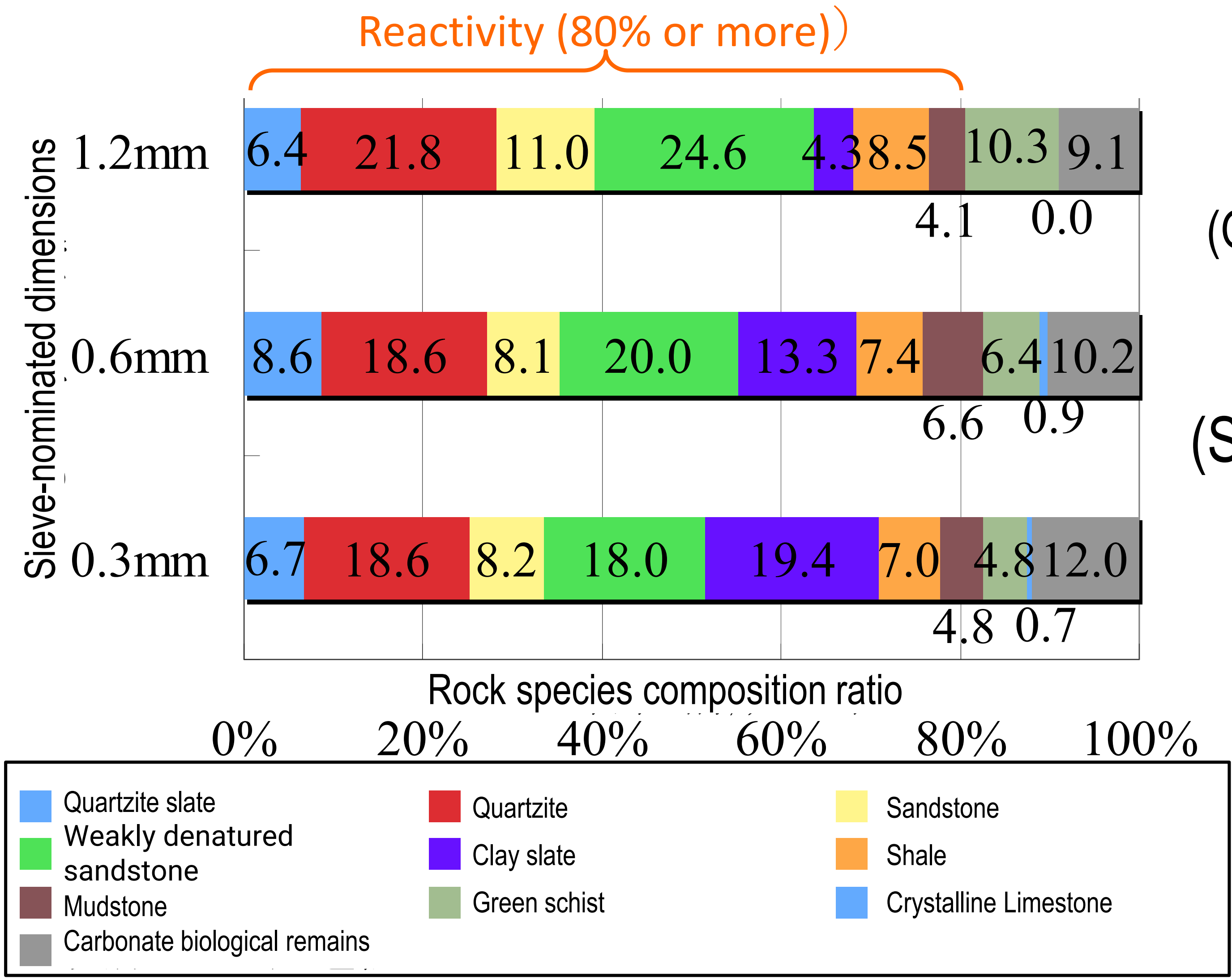
Katayama, T., et al: Late-expansive ASR due to imported sand and local aggregates in Okinawa Island, southwestern Japan. Proceedings of the 13th International Conference on Alkali-Aggregate Reaction in Concrete, Trondheim, Norway, pp.862-873, 2008

About delayed expansion ASR of sea sand in Okinawa

- Sea sand used for fine aggregate

Limestone crushed sand from Motobu + Sea sand from off Arakawa → Mixed sand

Risk of delayed expansion ASR



Rock type composition ratio of sea sand from off Shinkawa)

Sedimentary rock
(Quartzite slate, quartzite, etc.)

Metamorphic rock
(Sandstone, mudstone, etc.)

↓

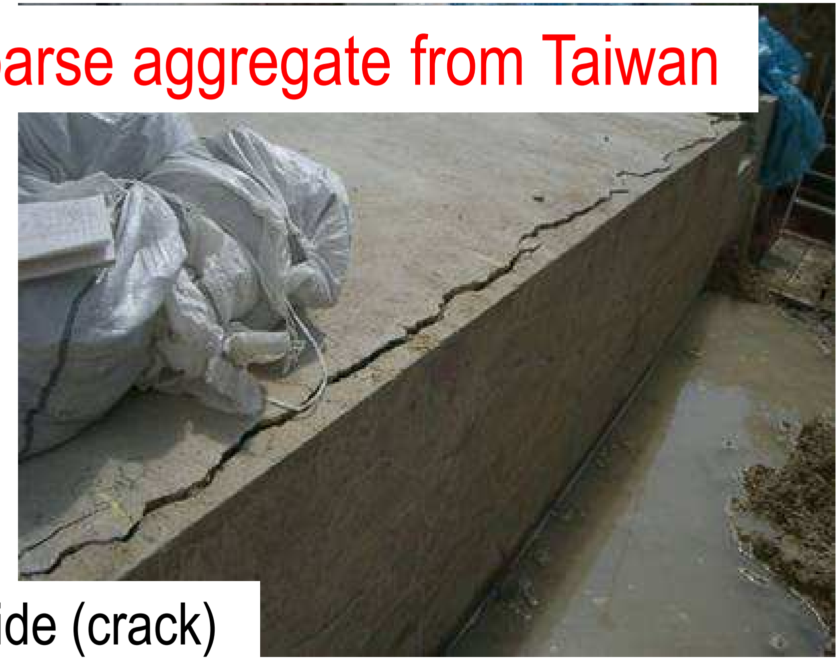
Microcrystalline quartz and cryptocrystalline quartz

↓

Possibility of delayed expansion ASR

Example of ASR deterioration (Bridge A)

ASR damage caused by coarse aggregate from Taiwan

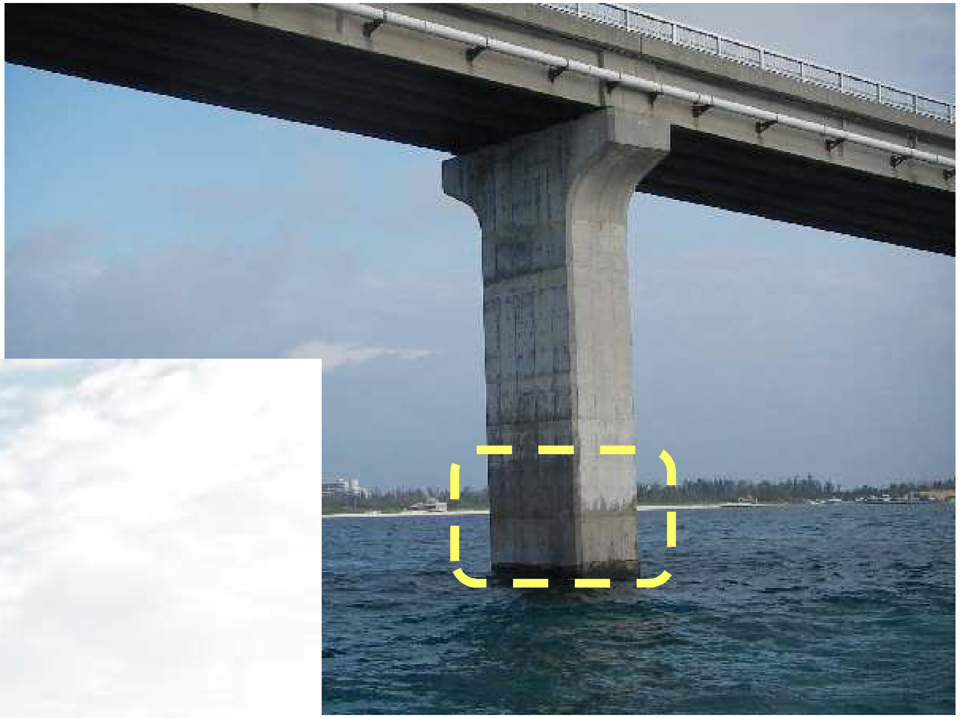
Footing top / side (crack)

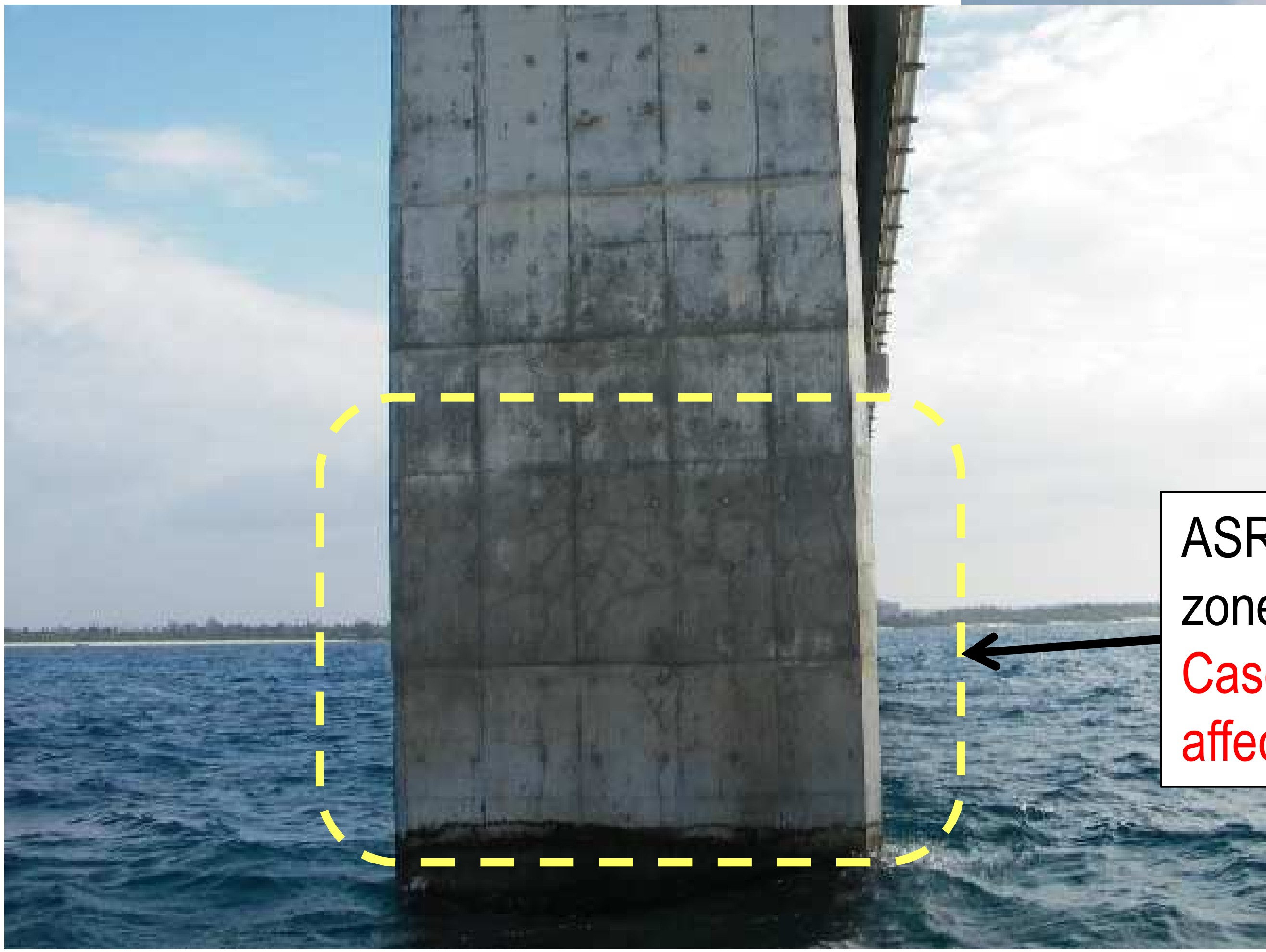

Footing rebar breakage situation

Example of ASR deterioration (Bridge B)

ASR marine bridge piers with river sand (fine aggregate) from Taiwan

* Case where foreign alkali promoted the progression of ASR





ASR is occurring in the splash zone where the waves splash.

Cases where seawater affected ASR deterioration

Example of ASR deterioration (Bridge C)

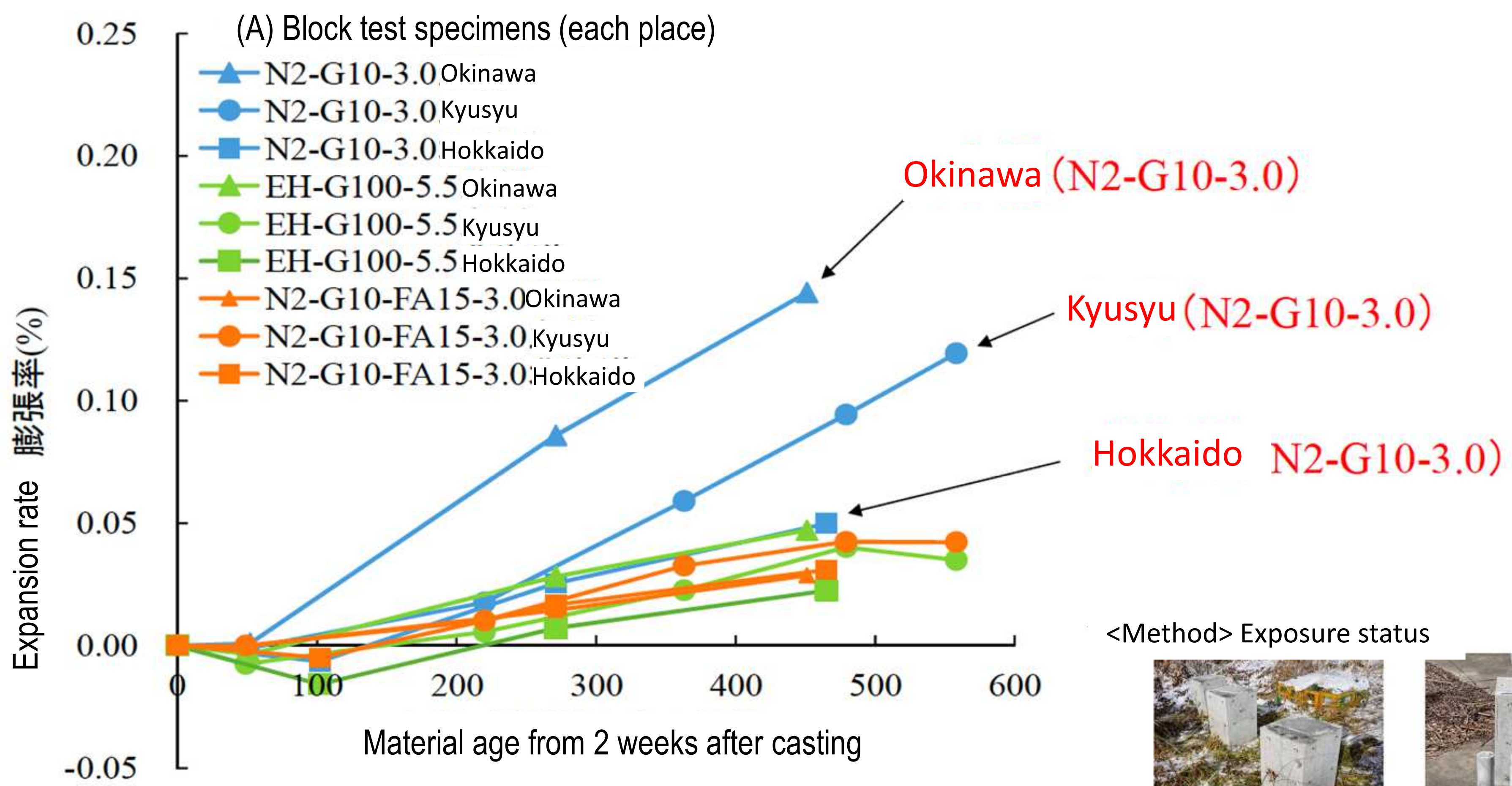
Brdige C

Construction environment: inland area
Completion year: lower 1983, upper 1984
Damage status: ASR occurred on the abutment and piers

ASR due to porphyrite (coarse aggregate) from Okinawa Prefecture

ASR in Okinawa Prefecture is progressing fast!

<Results> Comparison of exposed areas (Hokkaido / Kyushu / Okinawa)



Okinawa Prefecture, which has a hot and humid environment throughout the year, showed a faster reaction rate and larger expansion of ASR than Kyushu and Hokkaido.

<Method> Exposure status

Average temperature (past 10 years)
Hokkaido: 6.4 °C
Kyushu: 16.7°C
Okinawa: 23.4°C

July 11, 2019 JCI年次大会(札幌)

Shoichi Ogawa, Kazuo Yamada, Yasutaka Sagawa, Shinya Tawara, Exposure Tests of Alkali-Aggregate Reaction Specimens, Annual Proceedings of Concrete Engineering, 41, 1, 887-892, 2019.07.

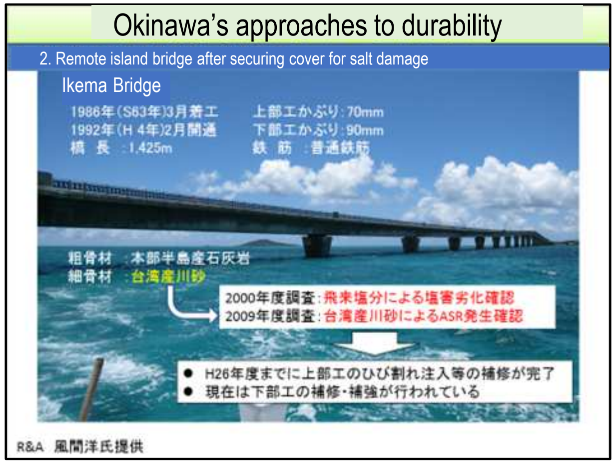
ASR deteriorated structures and factors in Okinawa (example)

1975 - early 1960

Structure name (part)	**Factors of ASR**
Tomari Bridge (footing)	River gravel and river sand from Hualien, Taiwan (delayed expansion)
Yamashita Kakihana Viaduct (upper / lower work)	
Okinawa Sogo Undo Koen (beams / pillars)	
Nagura Bridge (upper / lower work)	
Yamahara Bridge (substructure)	
Seto Bridge (A1 Pier)	
Meiji Bridge (upper / lower work)	River sand from Hualien, Taiwan (delayed expansion)
Ikema Bridge (upper / lower work)	
Core irrigation facility Tarama B Reservoir (slope wall)	
Kurima Bridge (substructure)	
Arakaki Bridge (substructure)	
Aragaki Bridge (retaining wall)	
Noborimata Viaduct (substructure)	
Yadaniya Viaduct (substructure)	
Futenma River Bridge (substructure)	
Yanagibashi (substructure)	Crushed stone porphyrite from headquarters (rapid expansion)
Kitanakagusuku Viaduct (pier)	Sea sand from off Shinkawa (delayed expansion)
Ueti Bridge (upper structure)	
Matsumoto Bridge (upper structure)	
Arakaki Bridge (retaining wall)	
Noborimata Viaduct (substructure)	
Kubaga Bridge (substructure)	

Transition of durable design of concrete structures

(1986～1992)



Superstructure cover: 70mm
Substructure cover: 90mm
Rebar: ordinary rebar

(1993～1998)

Superstructure and substructure covers: 70mm
Rebar: epoxy resin coated rebar
Sheath: galvanized sheath
Others: painting of base of aluminum railing support columns

(1996～2005)

<First domestic 100-year durability>
Superstructure cover: 70mm
Substructure cover: 90mm
Rebar: epoxy resin coated rebar
Sheath: polyethylene sheath, polyethylene sheath coupler
PC steel wire: PC steel with epoxy resin coating
Concrete: high-strength concrete
Other: anti-corrosive treatment fixture

(2007～2015 - Current)

<100 year durability>
Uses fly ash concrete as highly durable concrete
(Measures against Salt damage, ASR and thermal cracks)
Substructure: 20% fly ash concrete
Superstructure: 100% crushed sand + 3% outer split fly ash concrete
(Air volume: not specified)
Measures against salt damage other than concrete: Similar to Kouri Bridge

Why use fly ash for durability?

- Ensuring cover is not enough. ： Ikema Bridge

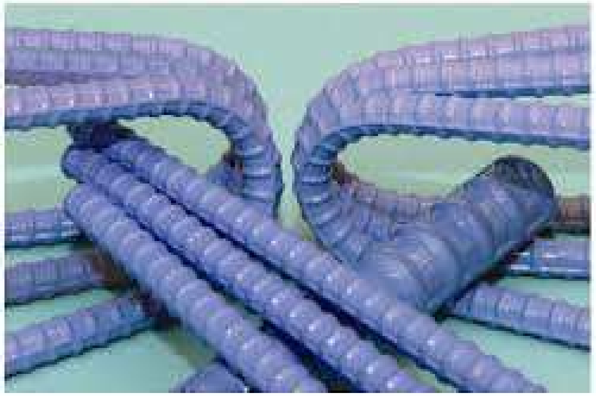
- Epoxy coated rebar also corrodes. ：

Provided by Professor Ichiro Iwaki, Nihon University

Hiroshi Ueda, Go Iidoi, Yasuhiro Koda, Tatsuhiko Saeki, Ichiro Iwaki, Motoyuki Suzuki: Detailed survey of PC road bridges 15 years after replacement in severe salt damage environment, proposals for future maintenance, Japan Society of Civil Engineers Proceedings E2 (Material / Concrete Structure), Vol.71, No.2, pp161-180, 2015.)

- Concerns about delayed expansion ASR of sea sand

Main materials used to prevent salt damage




Epoxy resin coated rebar

Stainless steel rebar

All-strand epoxy resin coated PC steel strand

Epoxy resin coated PC steel strand

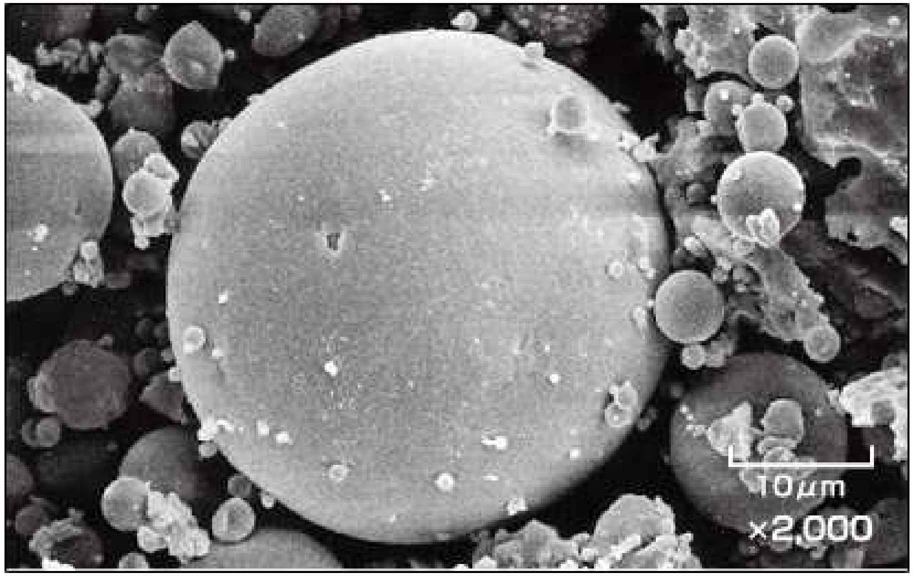
Galvanized steel sheath

Polyethylene sheath

What is fly ash?

Japan Fly Ash Association

Fly ash

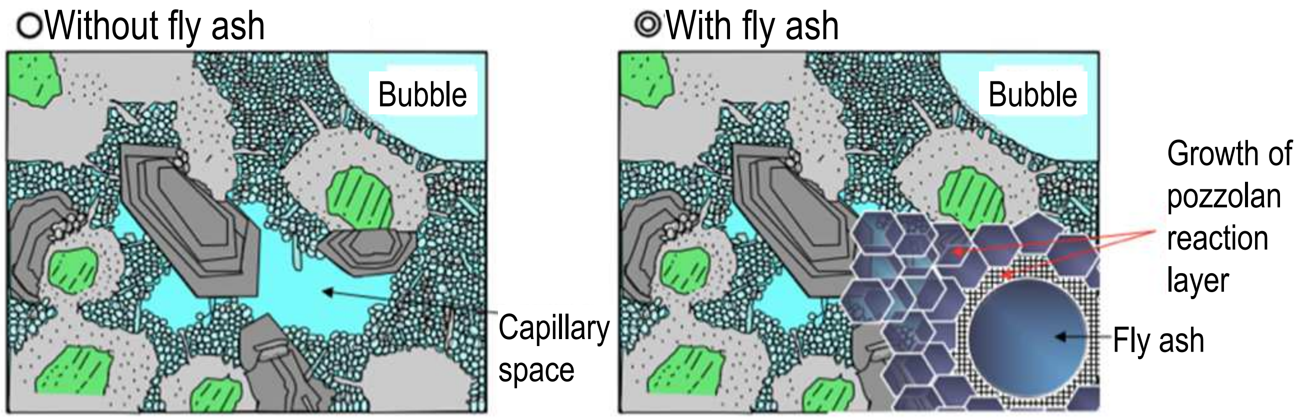


Electron micrograph

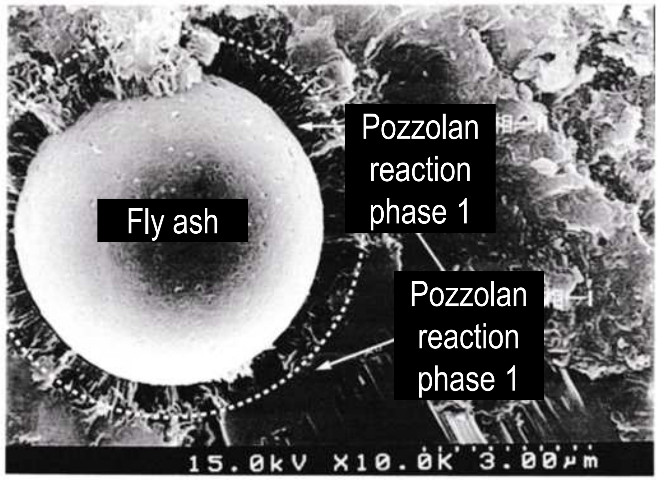
- Fly ash: About 90% of coal ash is very fine and is carried with combustion gas. This is called fly ash.
- Clinker ash (bottom ash): Since the temperature inside the boiler exceeds 1,000 ℃, about 10% of the ash melts and sticks to each other, so it falls to the bottom of the boiler. This is called clinker ash or bottom ash.

Pozzolan reaction

- A reaction in which Ca (OH) $_2$ produced by hydration of cement reacts slowly with SiO_2 and Al_2O_3 in fly ash to form a stable hydrate (pozzolan reaction phase)



(Provided by Professor Torii, Kanazawa University)



Pozzolan reaction phase grows to fill capillary voids involved in the movement of substances that affect the durability of concrete, such as carbon dioxide and chloride ions => Cement structure densification => Long-term strength enhancement => Improved durability

Pozzolan reaction phase formed radially around the fly ash (Central Research Institute of Electric Power)

ASR suppression effect by fly ash mixing

- ✓ The effect of reducing the total amount of alkali in concrete by replacing it with cement
- ✓ The effect to make the concrete solid due to the pozzolan reaction of fly ash
- ✓ The effect to make alkali in the pore solution adsorbed into the pozzolan reaction layer during the pozzolan reaction of fly ash

Okinawa Prefecture's original fly ash concrete guidelines

Aiming for 100-year durability

Fly ash concrete (FAC) is used for Irabu Bridge

(First for a bridge managed by the Civil Engineering Department of Okinawa Prefecture)

(Main objective) Three durability improvements

- **Salinity Inhibition**
- **Alkali-silica reaction (ASR) suppression**
- **Reduction of thermal stress due to heat of hydration**

The use of FAC has been promoted in important structures ordered by Okinawa Prefecture, but since we do not have guidelines or manuals regarding FAC formulation and construction, it has been individually examined and adopted at each site.

Provided by Masaya Higa, Okinawa Prefectural Construction Technology Center

Formulation of Guidelines for the Mixing and Construction of Fly Ash Concrete in Okinawa Prefecture (Draft)

(December 2017)

Improving durability and longevity of concrete structures

Environmental load reduction effect by effective use of industrial waste

Fly ash concrete blending pattern

■ Classify fly ash concrete into three blend types

C-replace : partial replacement of cement
S-replace :partial replacement of fine aggregate

Conceptual diagram of three blend types

Blend type	Main purpose	Target structure
(Ex.) General concrete blending (FA-free) Water (W) / Cement (C) / Fine aggregate(S) / Coarse aggregate(G) / Admixture / Air		
① C-replace + S-replace blend type Water (W) / Cement (C) / (FA1) / Fine aggregate(S) / (FA2) / Coarse aggregate(G) ・FA1 (C-replace): 20% mass (C) replacement ・FA2 (S-replace): partial mass (S) replacement ※ F1＋F2≦100kg/m³	・Suppression of temperature rise due to heat of hydration ・Suppression of ASR ・Suppression of salt damage	Thermal stress-prone structures * Mass concrete
② C-replace type Water (W) / Cement (C) / (FA1) / Fine aggregate(S) / Coarse aggregate(G) ・FA1 (C-replace): 10 - 20% mass (C) replacement * 15-20% for ASR suppression	・Suppression of ASR ・Suppression of salt damage	Thermal stress-prone structures * Mass concrete
③ S-replace blend type Water (W) / Cement (C) / Fine aggregate(S) / (FA2) / Coarse aggregate(G) ・FA2 (S-replace): 3 - 5% mass (S) replacement * At this time, (S) is only crushed sand.	・Measures against ASR ・Improvement of liquidity	・Relatively small structure with less thermal stress ・Structures for early demolding and lifting of precast PC girders and PC segment girders

* C + FA1: Binder, S + FA2: Fine aggregate

Features of C-replace and S-replace blends

Features of C-replace

- Heat generation is suppressed and effective for mass concrete
- The pozzolanic reaction of FA increases strength and microstructure densification and improves salt shielding properties and durability.
- Slower onset of initial intensity, but greater long-term intensity
- If the amount of substitution is increased, the strength and durability are reduced compared to cement alone, and there is a limit to the amount used.

Features of G-replace

- Because the amount of cement is constant, minimum concrete strength is secured.
- The pozzolanic reaction of FA increases strength and microstructure densification and improves salt shielding properties and durability.
- Slump loss tends to increase as FA increases, but the ball bearing effect of FA may improve liquidity.
- With the increase in FA, the amount of admixture increases, which makes it more expensive.
- Can be used in larger quantities than C-replace.

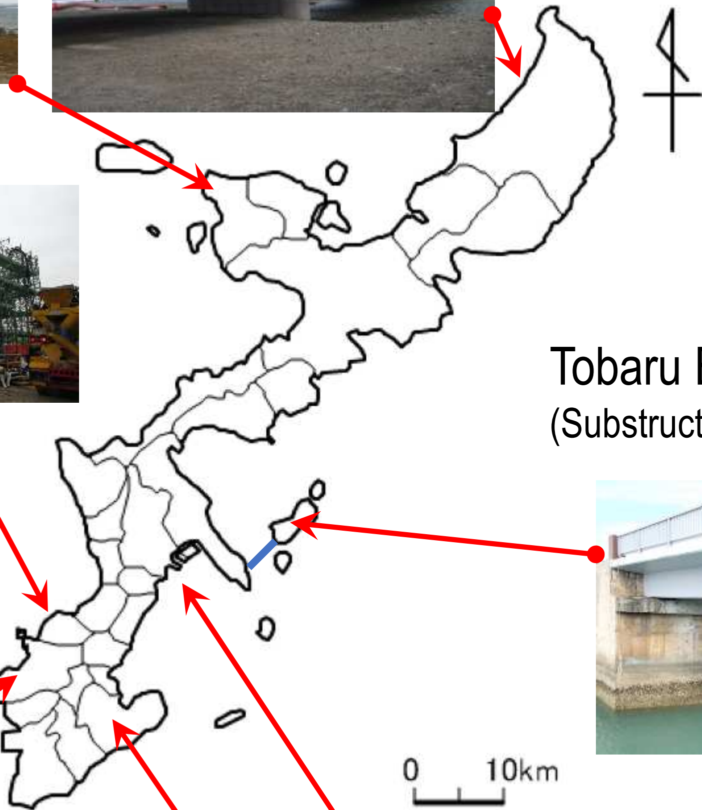
Actual achievements of fly ash concrete used

New Motobu Bridge
(Substructure: C- & S-replaces)

Sate Bridge
(Superstructure: S-replace)

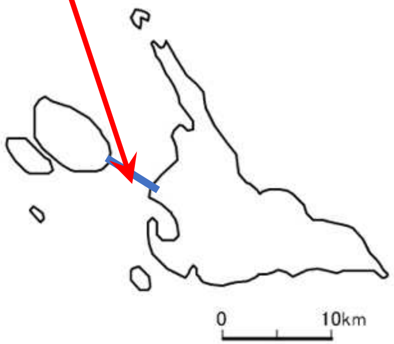
Superstructure/S-replace (no sea sand used)

- Kochinda Viaduct
- Tomigusuku Viaduct
- Okinawa Urban Monorail Track Girders (expanded section)



Minatogawa Viaduct
(C- & S-replaces)

Irabu Bridge
(Superstructure: S-replace, substructure: : C- & S-replaces)



Tobaru Bridge
(Substructure: C- & S-replaces)

Awase Bridge (tentative name)
(Superstructure: S-replace, substructure: C- & S-replaces)

Naha Bridge
(Substructure: C- & S-replaces)

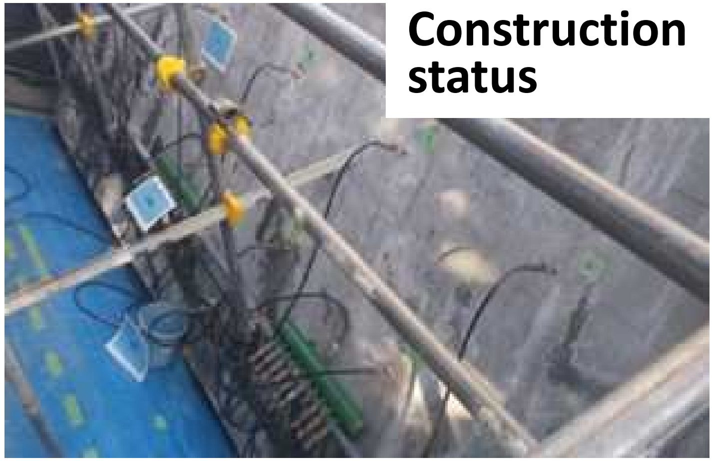
Southern East Road
(Superstructure: S-replace, substructure: C- & S-replaces)

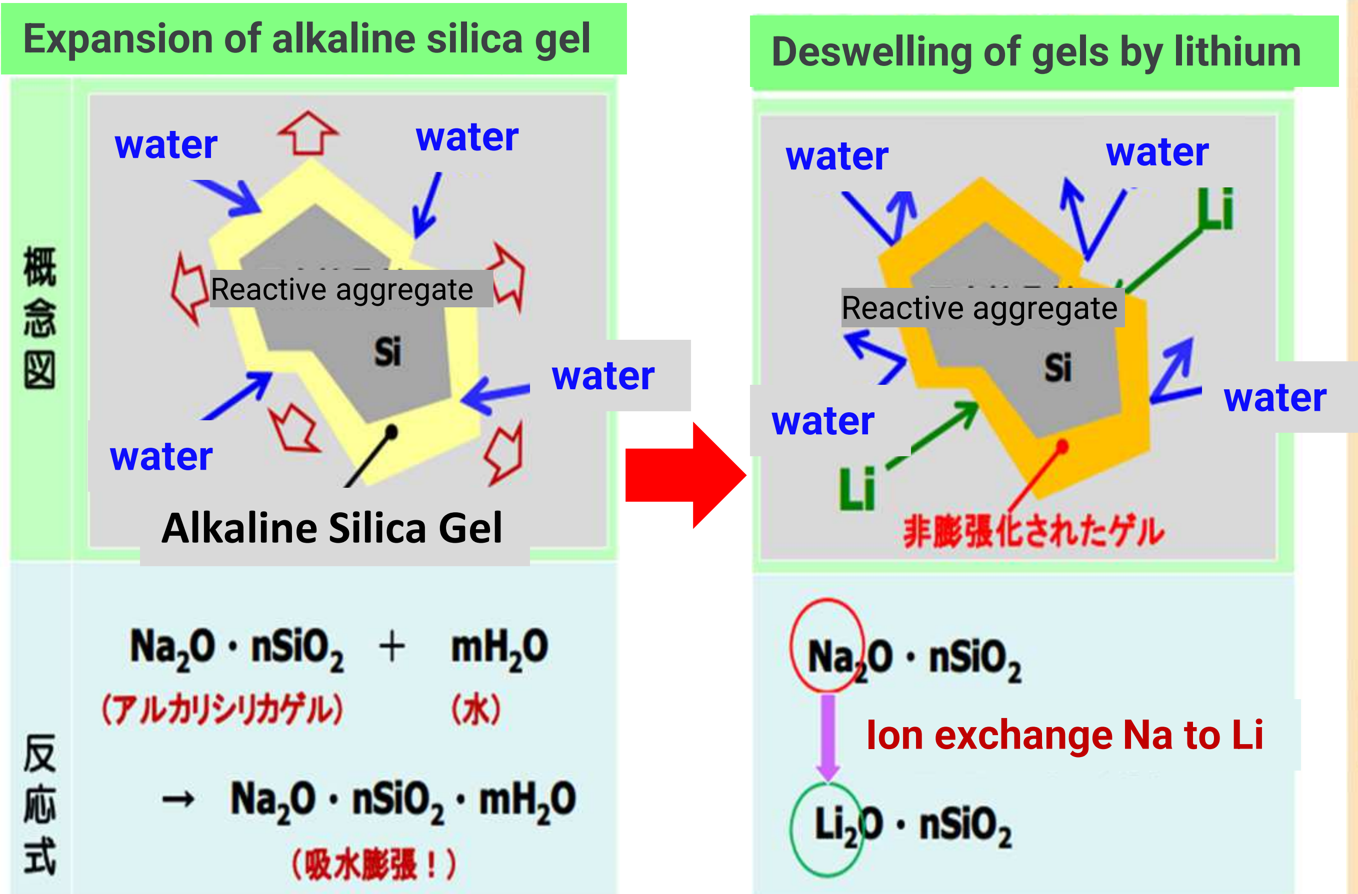
A repair method effective against ASR and salt damage (appendix)

Effect of lithium nitrite solution

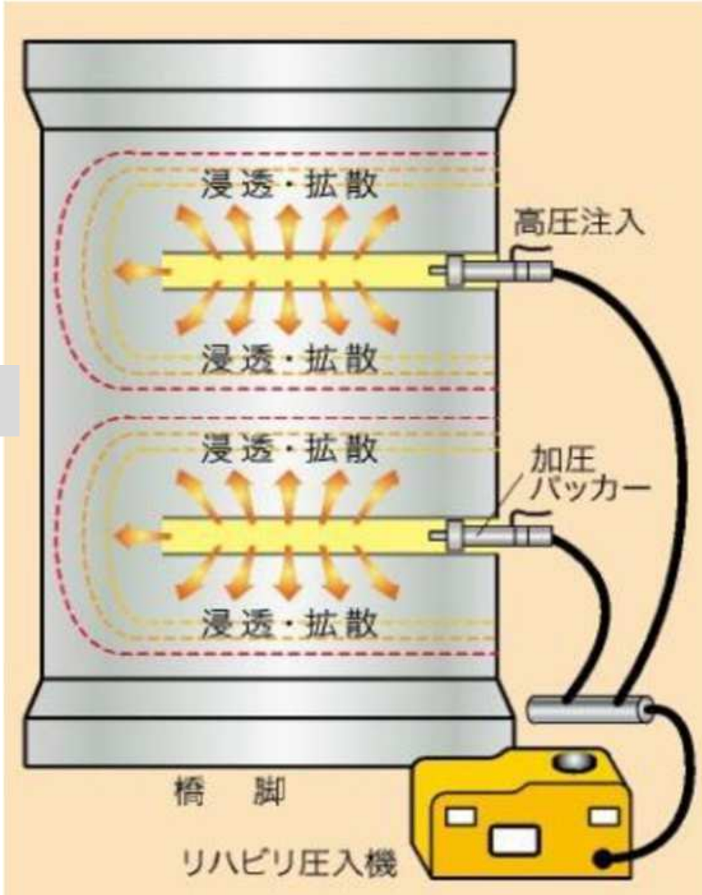
① Inhibition of rebar corrosion by nitrite ions
[〖NO〗 _2^−]

② Suppression effect of ASR expansion by lithium ions
[〖Li〗 ^+]



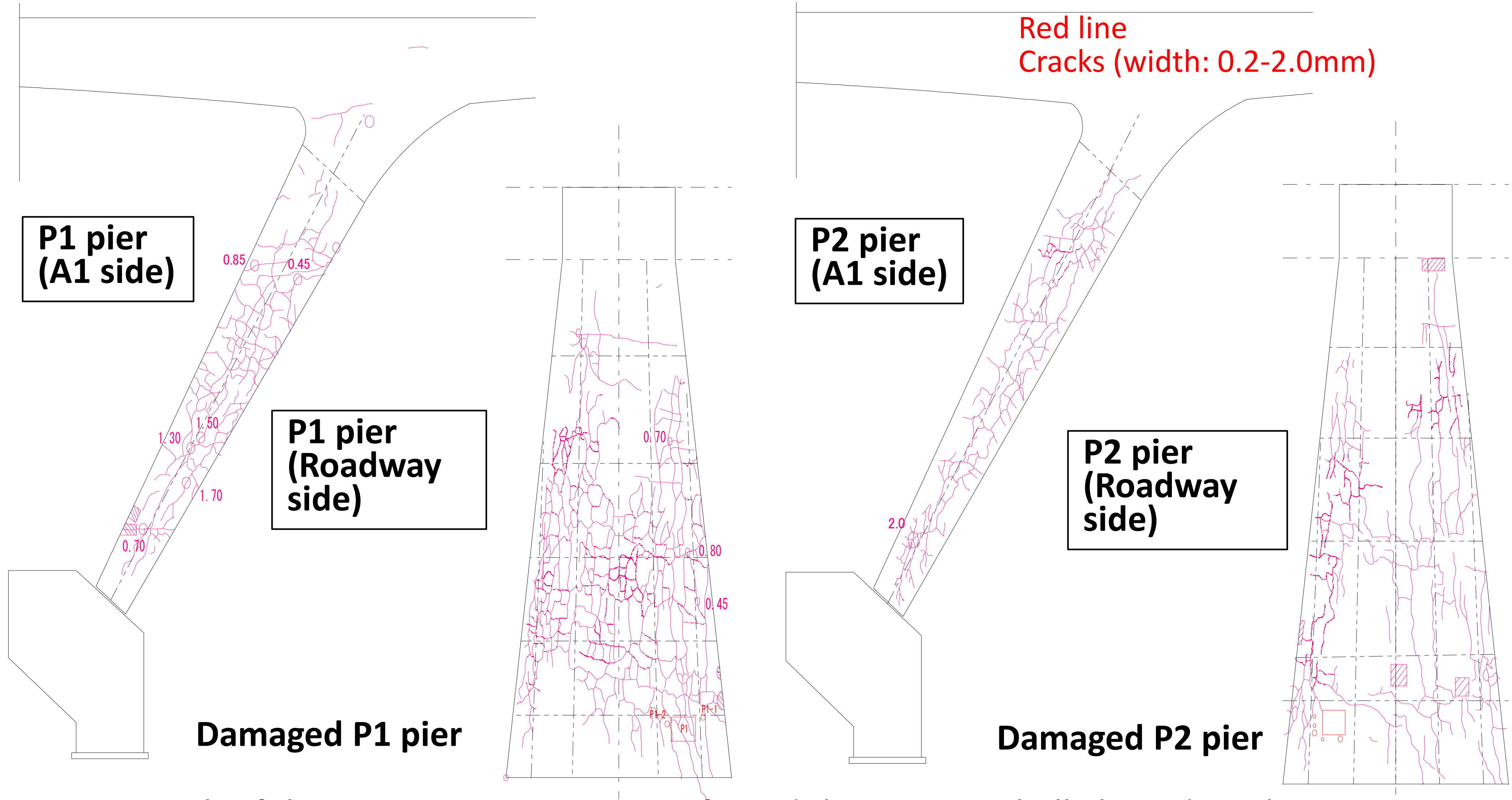


Non-expansion of gel by lithium ions



Conceptual diagram of internal pressure injection method

A repair method effective against ASR and salt damage (appendix)

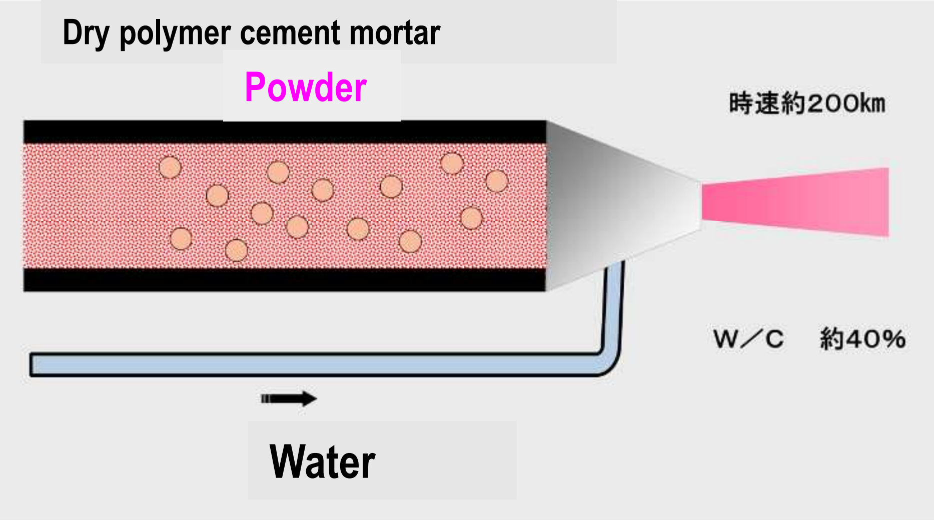


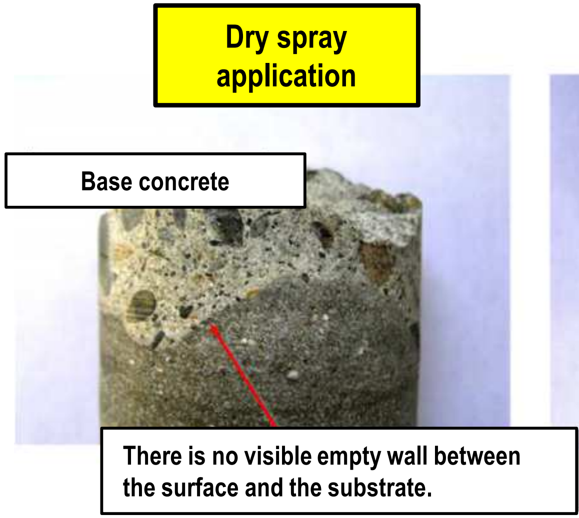
- As a result of the investigation, it was confirmed that tortoiseshell-shaped cracks measuring 0.2mm to 2.0mm in width, believed to be caused by ASR, had occurred throughout both the P1 and P2 piers.
- It was also confirmed that where the cracks were connected, there was some concrete peeling.

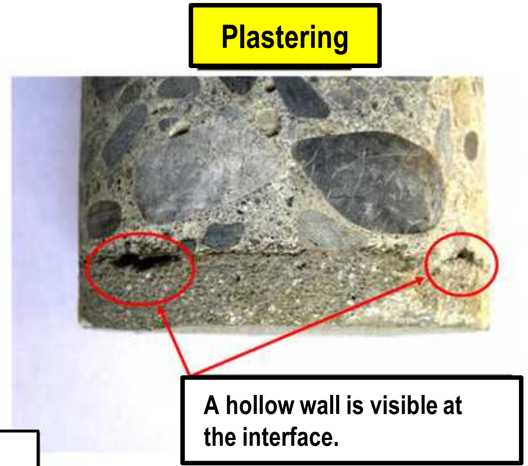
⇒ Lithium nitrite is being injected into this structure to confirm its effectiveness.

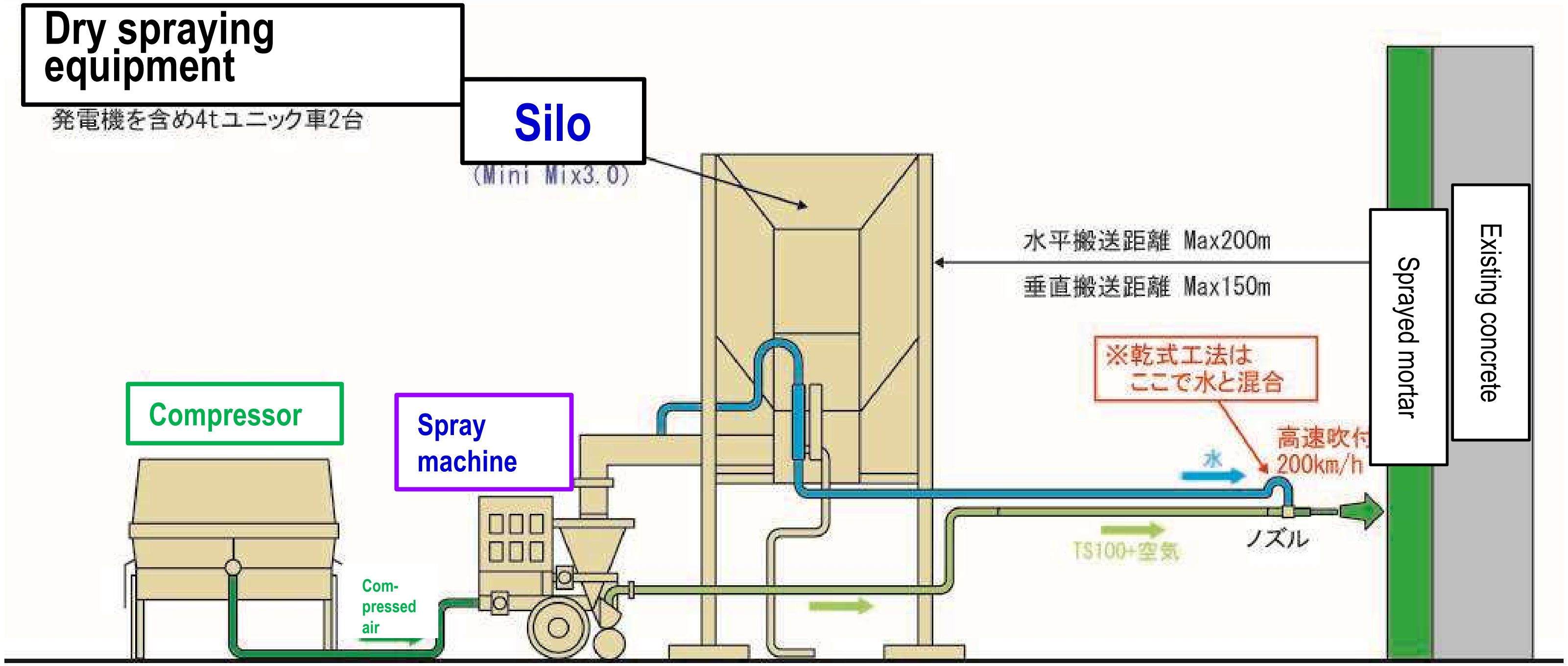
Sto dry spraying method system overview

Dry spraying method: Condition of the nozzle tip







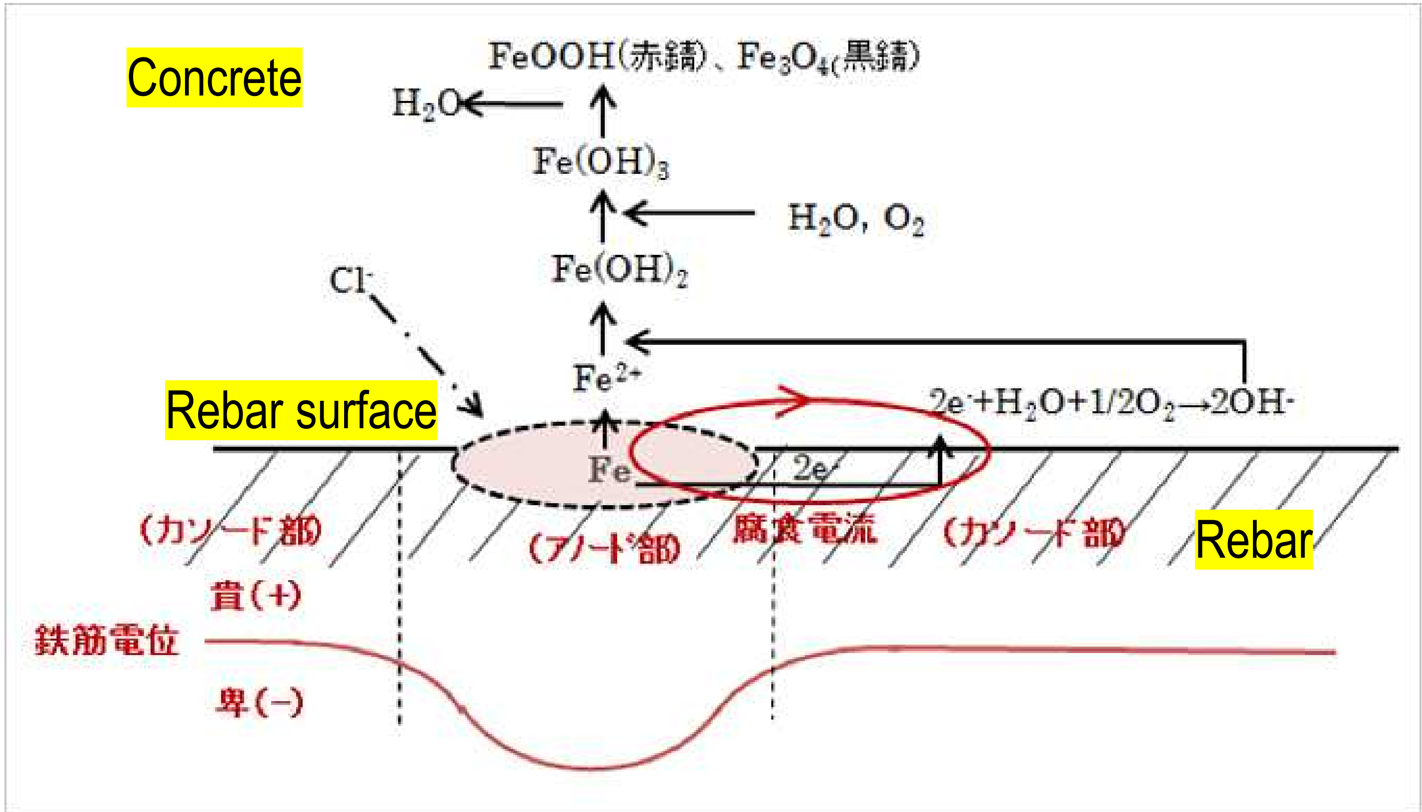


Example of cross-section repair using the spraying method (appendix)

Example of cross-section repair using the spraying method (appendix)

Lithium nitrite-added dry spraying method

Electrochemical corrosion prevention method (appendix)



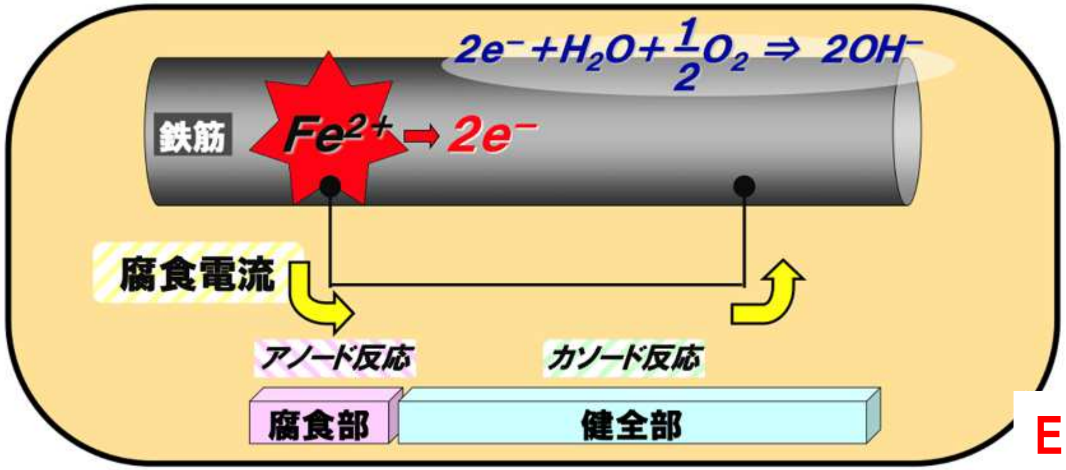
Corrosion reaction (electrochemical reaction)

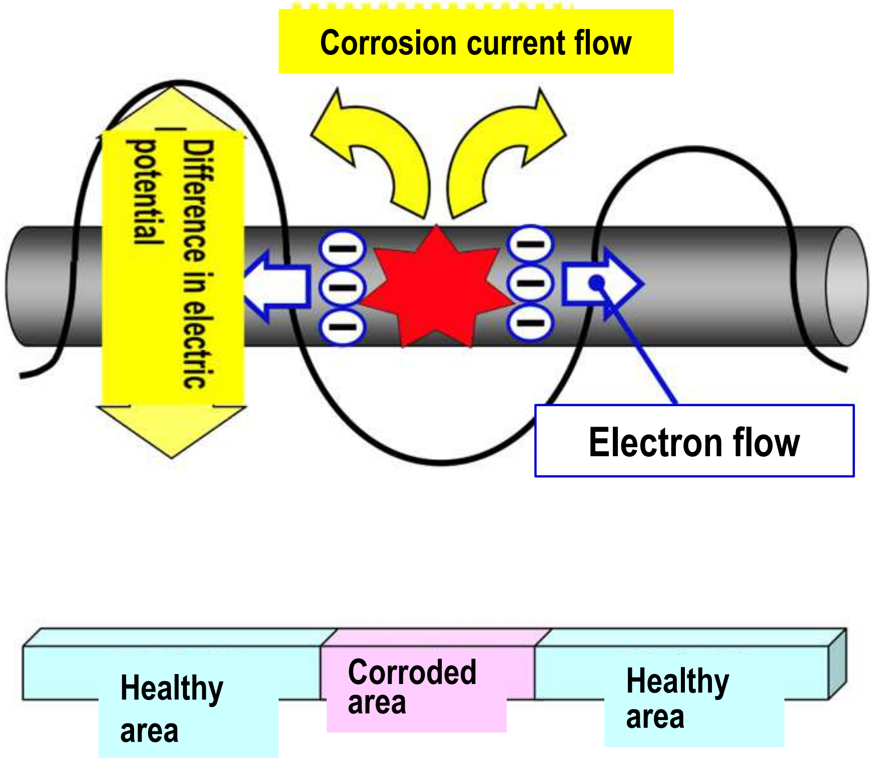
If no potential difference, corrosion can be suppressed!

Electrochemically control the potential!

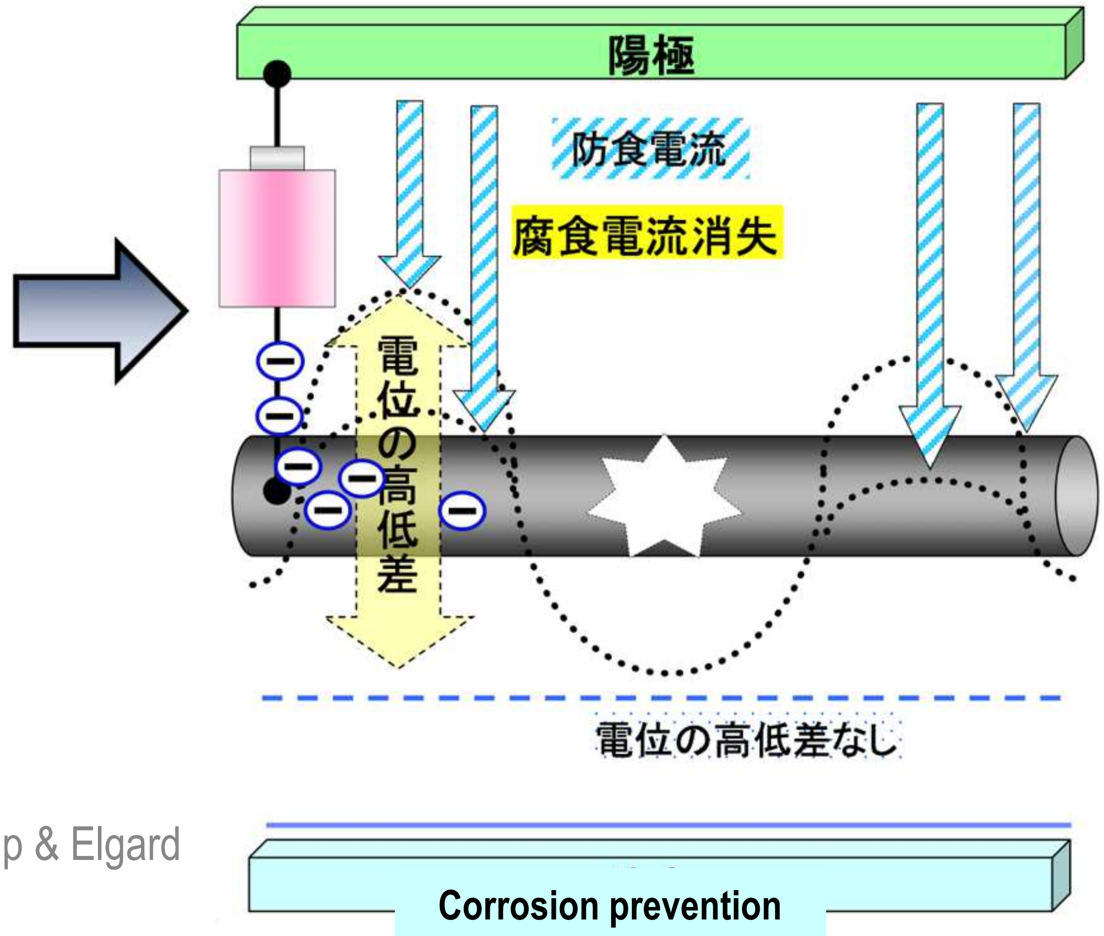
Electrochemical corrosion prevention method

Corrosion reaction





Electrochemical protection

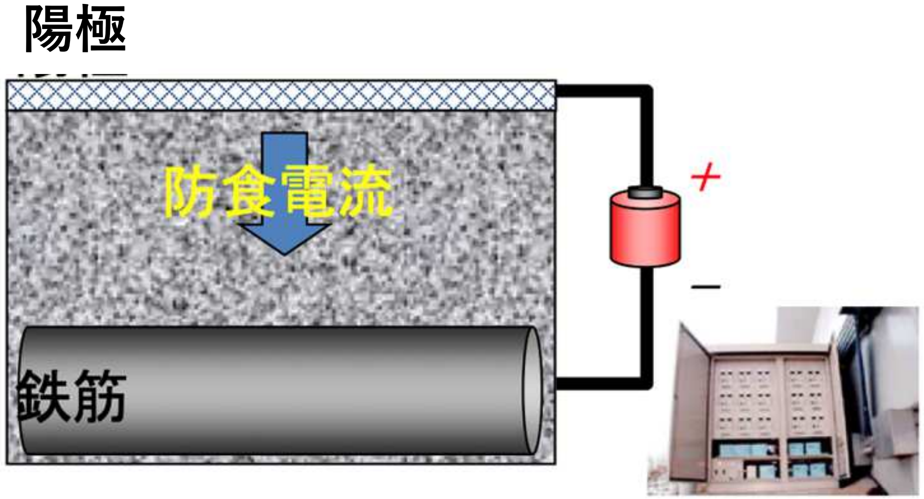


From the 2018 CP Construction Method Research Group & Elgard Association materials

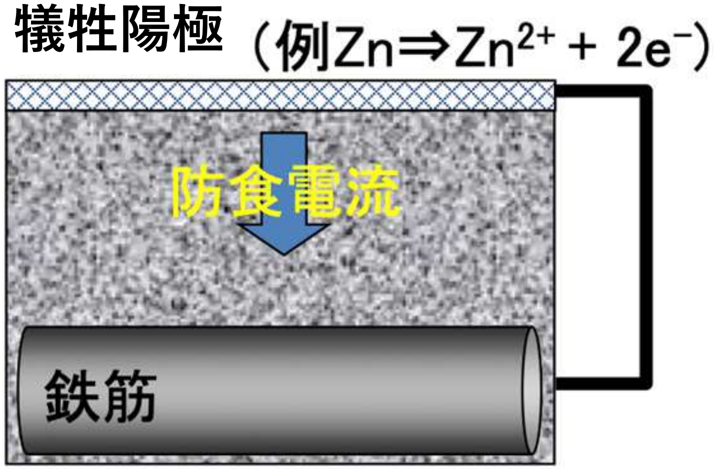
Electrical corrosion prevention method

Two main types of anticorrosion current supply methods:

External power supply method



Sacrificial anode method



Use a DC power supply

Adjustable anticorrosion current

Uses tendency of rebar and metal to ionize (no DC power supply required)

Impossible to adjust the protection current

From the 2018 CP Construction Method Research Group & Elgard Association materials

Example of external power supply system

https://www.j-cma.jp/j-cma-pics/10005399.pdf?utm_source=chatgpt.com

Public bridge

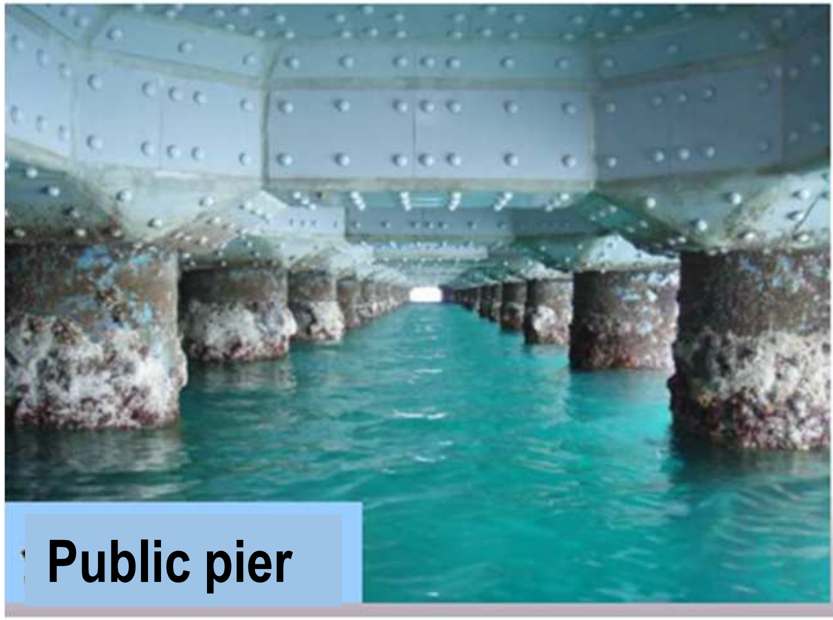
Private pier

Public shaft

Public regulation pond

Example of galvanic anode method

https://www.j-cma.jp/j-cma-pics/10005399.pdf?utm_source=chatgpt.com



Summary

- About the environment of Okinawa

In addition to the high temperature and humidity throughout the year, a large amount of salt is carried by winter waves and typhoons, which is a harsh environment for structures.

- About salt damage

Some are caused by intrinsic salt and foreign salt, and some are caused by both. Structures built after 1986, when total chloride levels were regulated, were damaged by foreign salt.

- About ASR

Has rapid expansion and delayed expansion. In Okinawa Prefecture, it is necessary to take measures against delayed inflatable ASR.

- For durability design of concrete structures

Fly ash concrete is being actively adopted to improve the durability of concrete structures in Okinawa Prefecture.