MLIT

New technology information provision system（NETIS）

Registration number　 QSK-080005-A

An Alternative Salt Damage prevention method to replace the electrochemical corrosion prevention method for concrete

Concrete structure reinforcing steel corrosion prevention method (GF protect method)

(SLAG LEAD method)

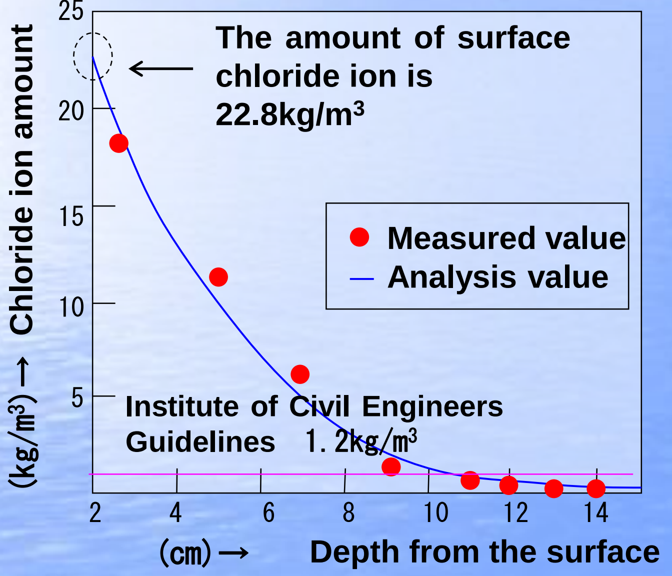
- Summary of R & D

For the purpose to prolong the life of concrete structures due to neutralization or salt damage. To prevent the corrosion in the reinforcing steel using nitrite and to maintain the structures by cross-section restoration using an embedded mold etc which are environmentally friendly methods to repair / reinforcement.

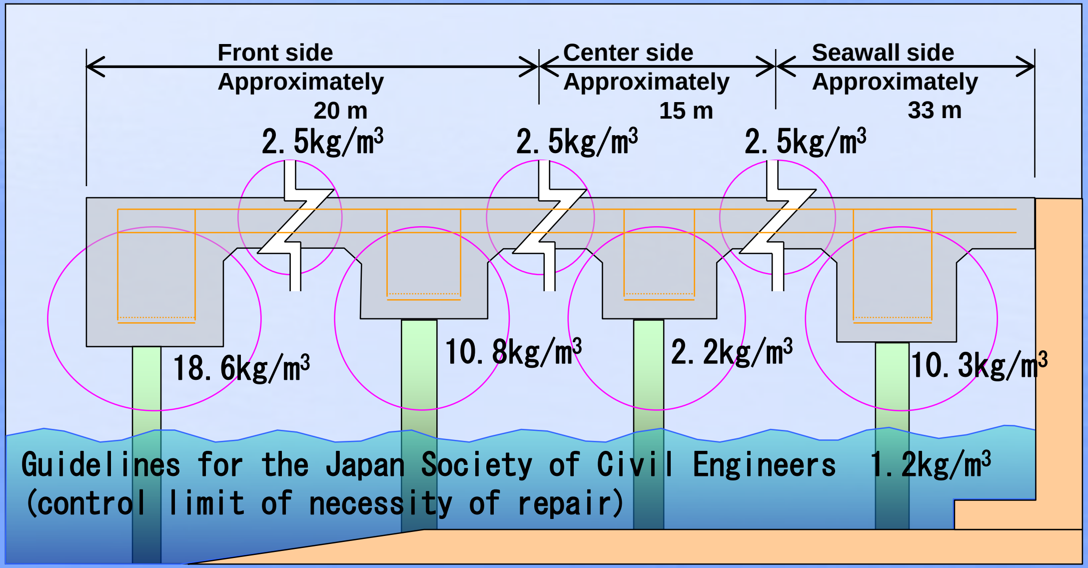
① Background

- *If there is chlorine ion in the reinforced concrete, the passive film of the reinforcing steel will be destroyed and a large damage such as deterioration of the concrete will occur*

■Relation between the depth from the surface and the amount of chloride ion



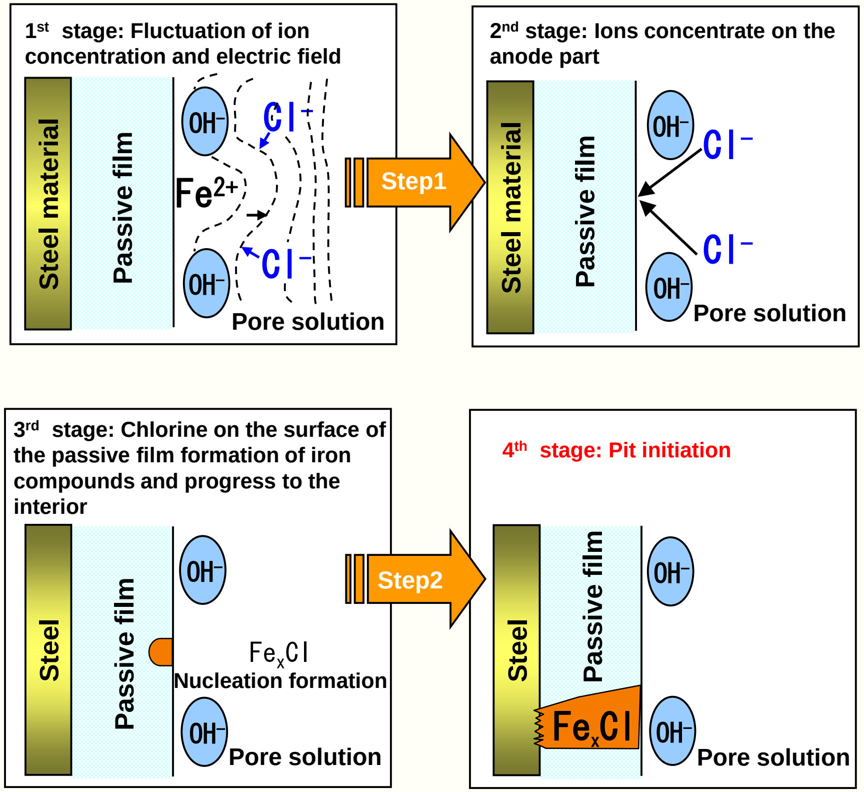
■Illustration of surface chloride ion content on quay (pier / pier)



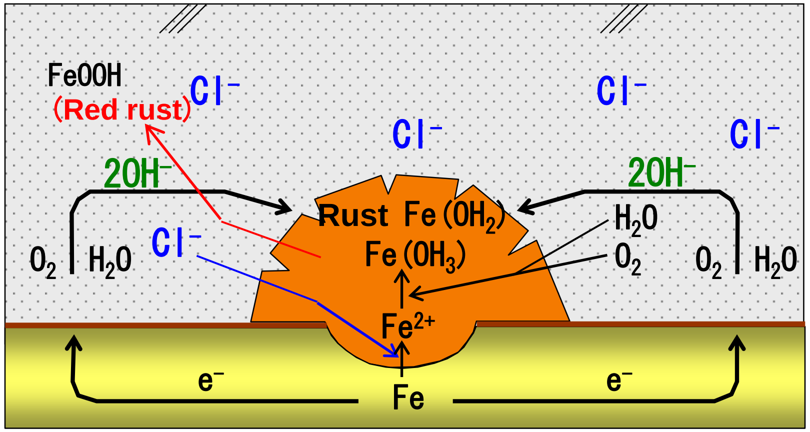
- ***Reinforcing material incorporation (nitrite) Mortar (grout) establishes rebuilding technique of reinforcing steel passive film, protects rebar from chlorine ions remaining inside the existing concrete structure, and corrosion newly ingress from the outside We developed a method to eliminate or reduce factors.***

② Corrosion potential of Reinforcing Bar

If the reinforcing bar inside a good condition concrete, the corrosion is less likely to occur because of the high alkalinity that concrete shows, because it forms "passive film" on the surface of it.



However, due to neutralization and salt damage (concrete pH decreases or a certain amount of Cl - ion exists), destruction of this passive film breaks the electrochemical equilibrium and corrosion of reinforcing bar begins .



(1) $Fe \rightarrow Fe^{2+} + 2e^-$ (Anodic reaction; Corrosion part)

(2) $H_2O + 1/2\ O_2 + 2e- \rightarrow 2OH^-$

(Cathode reaction; corrosion prevention part)

$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2 \rightarrow Fe(OH)_3 \rightarrow FeOOH$

(Ferrous hydroxide) ↑ (Ferric hydroxide) ↑ (Red rust)

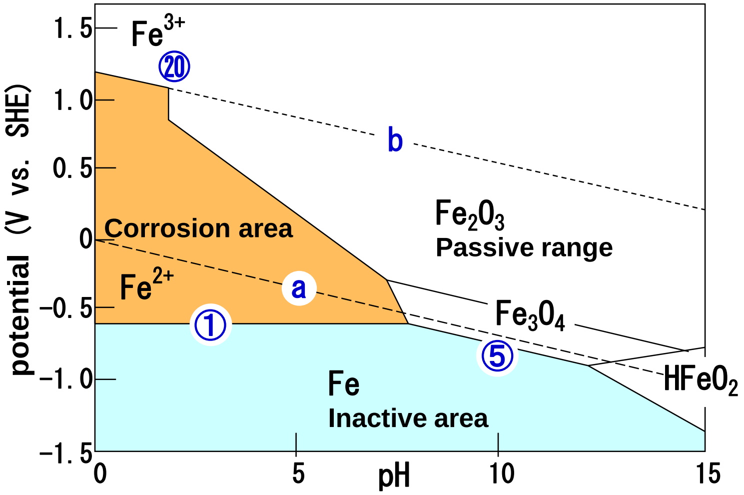
OH^- H_2O

(Copper - copper sulfate electrode)		(Pb Electrode)	
−126～−150	🟩	+675～+651	More than 90% Corrosion Won't Occur.
−151～−175	🟩	+650～+626	
−176～−200	🟩	+625～+601	
−201～−225	🟨	+600～+576	Corrosion uncertainty
−226～−250	🟨	+575～+551	
−251～−275	🟨	+550～+526	
−276～−300	🟧	+525～+501	
−301～−325	🟧	+500～+476	
−326～−350	🟧	+475～+451	
−351～−375	⬛	+450～+426	More than 90% Corrosion will Occur
−376～−400	🟦	+425～+401	
−401～−425	🟦	+400～+376	
(mV)		(mV)	

(Corrosion evaluation standard of ASTM C 876)

Relation between the Iron potential-pH and Mechanism of the electrical corrosion prevention

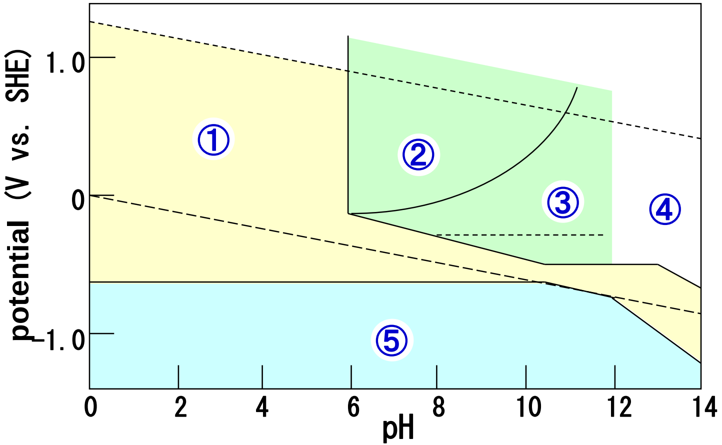
(a) Calculated value by chemical thermodynamics



a Hydrogen generation, b Oxygen reduction

①$Fe=Fe^{2+}+2e^-$ ⑤$3Fe+4H_2O=Fe_3O_4+8H^++8e^-$ ⑳$2Fe^{3+}+3H_2O=Fe_2O_3+3H^+$

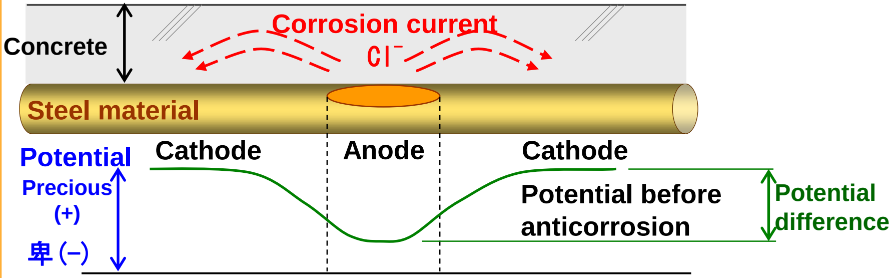
(b) Local corrosion occurrence in an environment containing 10-2 M NaCl



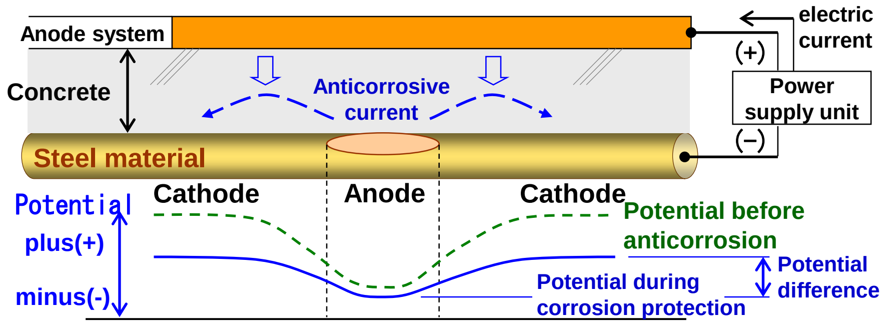
① Overall corrosion area ② Pitting area ③ incomplete Passive range
④ Complete passive range ⑤Inactive area

Electrochemical application to concrete structures 1998.2
Waseda University Faculty of Science and Technology Professor Kunihiro

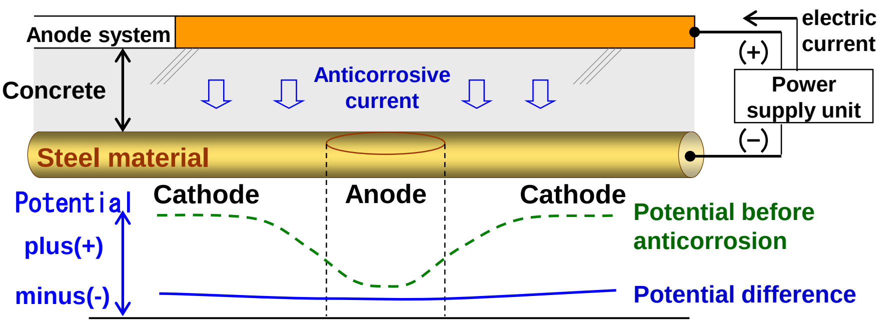
(a) Corrosion of steel materials (before corrosion prevention)



(b) When the corrosion prevention electric current is insufficient



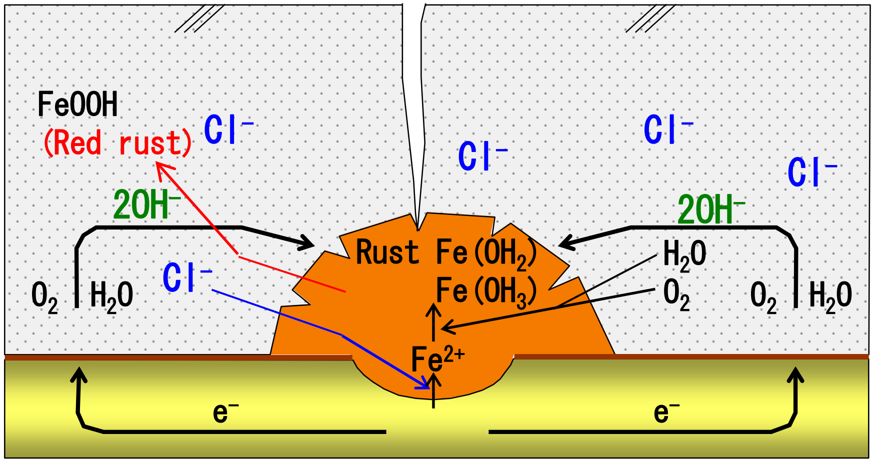
(C) When the corrosion prevention electric current is sufficient



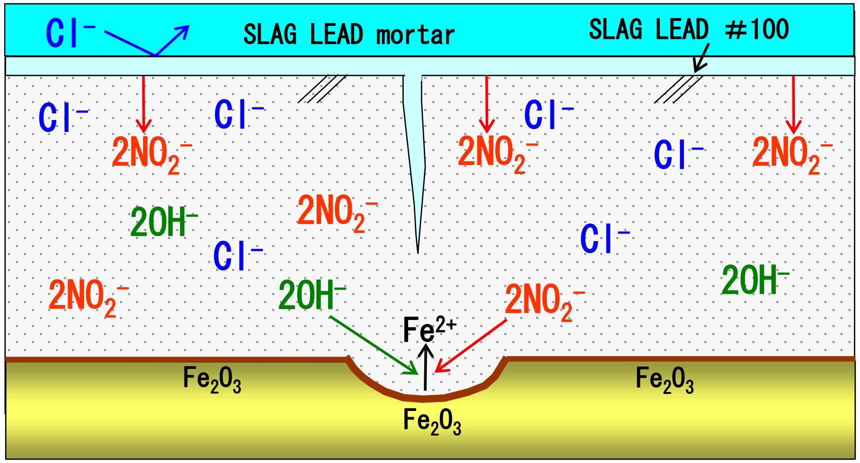
Electrochemical corrosion prevention method
Design and construction guidelines (draft)
Civil Engineering Society

③ *Antirust effect of SLAG LEAD # 100 · # 110*

Corrosion concept



Rust proof concept of SLAG LEAD



Antirust effect of SLAG LEAD # 100 · # 110

The passive film is a dense iron oxide (Fe_2O_3), the chloride ion (Cl^-)dissolves the passive film, iron of the metal and elutes as bivalent Fe^{2+}. Nitrite ion (NO_2^-))reacts with divalent$Fe^{2+}$to regenerate the passive film ($2Fe^{2+}+2OH^-+2NO_2^-\rightarrow Fe_2O_3+H_2O+2NO$).

Anode section $Fe \rightarrow Fe^{2+} + 2e^-$

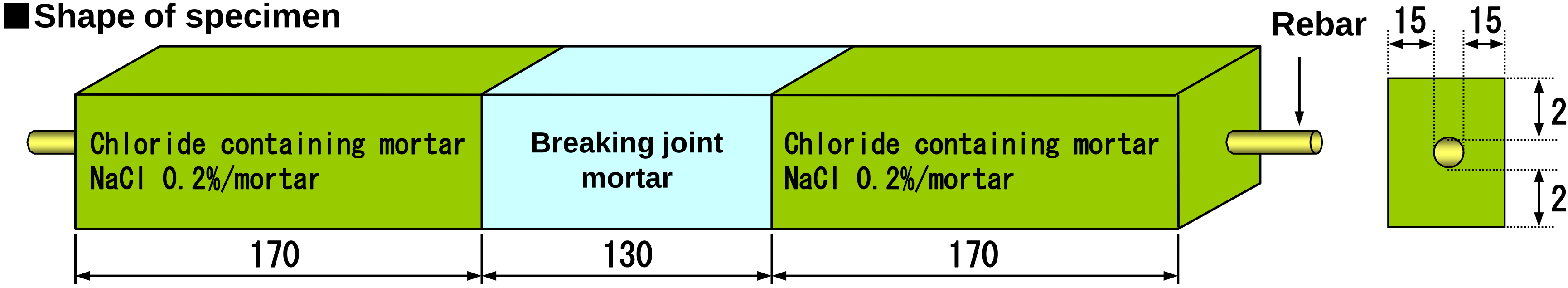
Cathode section $H_2O + 1/2\ O_2 + 2e^- \rightarrow 2OH^-$

$$2Fe^{2+}+2OH^- \rightarrow Fe(OH)_2 \underset{\substack{\uparrow \\ OH^-}}{\rightarrow} Fe(OH)_3 \underset{\substack{\downarrow \\ H_2O}}{\rightarrow} FeOOH$$

$$\underset{\substack{\uparrow \\ \text{(Iron ion)}}}{2Fe^{2+}}+2OH^-+\underset{\substack{\uparrow \\ \text{(Nitrite ion)}}}{2NO_2^-} \rightarrow \underset{\substack{\uparrow \\ \text{(Iron oxide)}}}{Fe_2O_3} + H_2O + \underset{\substack{\uparrow \\ \text{(Nitric oxide)}}}{2NO}$$

④Differences in corroded reinforcing bars due to different types of breaking joint mortar

■Shape of specimen



■contents of the test

By comparing the type of Breaking joint mortar, we compare corrosion and suppression situation of rebar.

Breaking joint mortar

- A. Chloride containing mortar (NaCl 0.2% / mortar)
- B. Ordinary cement mortar
- C. Polymer cement mortar
- D. Anticorrosive agent mixed mortar

■Test results

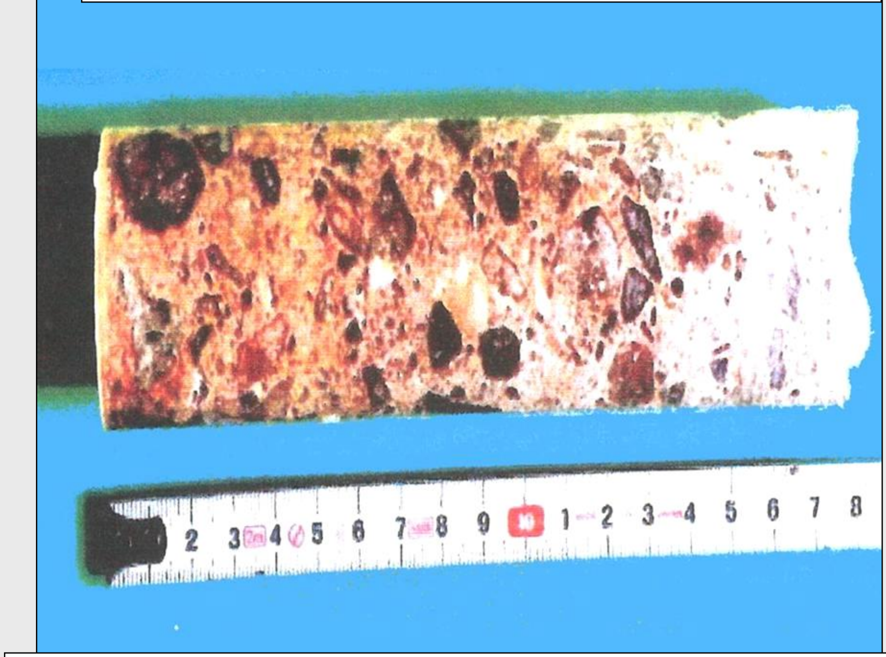
Breaking joint mortar	Corrosion situation of rebar 🟨 :Normal part 🟧 : Corrosion part 170 / 130 / 170	Corrosion area ratio %		
		left	center	right
Mortar containing Chloride NaCl 0.2% / mortar	 Rebar	**100**	**81**	**79**
Ordinary cement Mortar	 Rebar	**99**	**23**	**100**
Polymer cement Mortar	 Rebar	**72**	**13**	**97**
Anticorrosive agent mixed mortar SLAG LEAD # 100 # 450	 Rebar	**0**	**0**	**41**

(70 ° C. - Relative humidity 90% or more - 48 hr / 15 ° C. - Relative humidity 60% - 48 hr) × corrosion state of rebar after 15 cycles

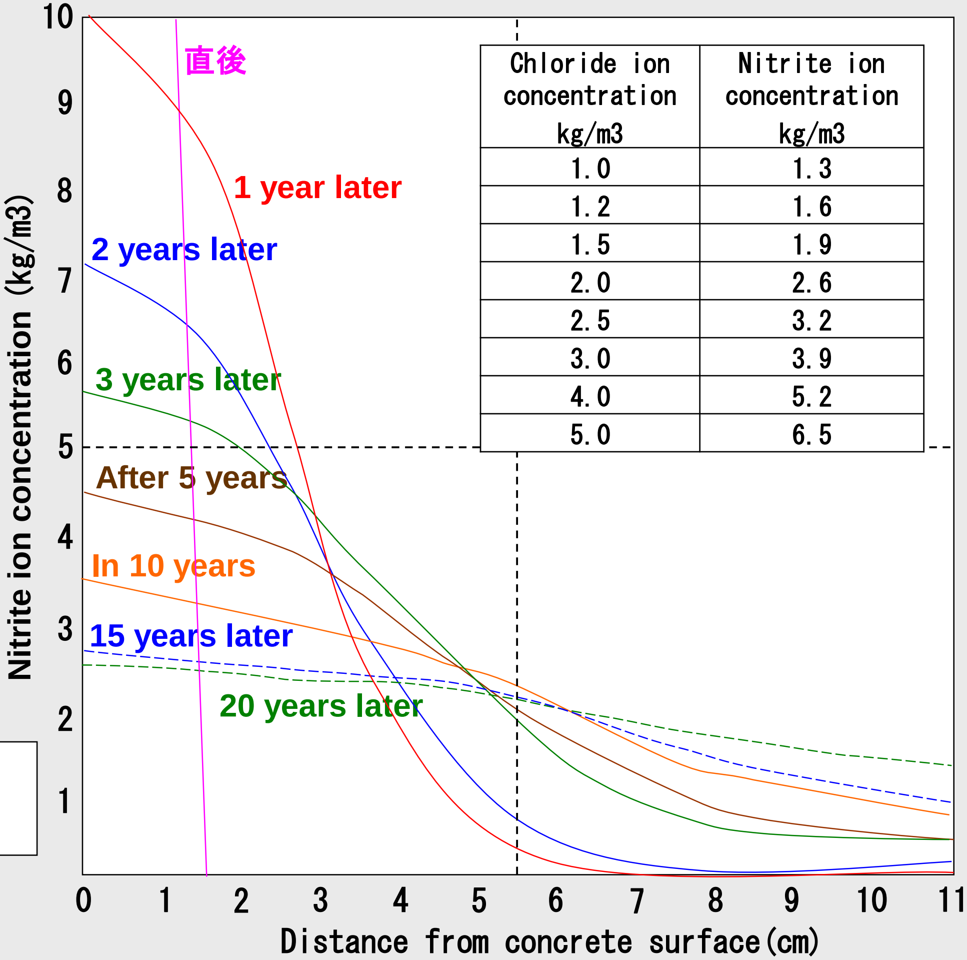
⑤Diffusion of lithium nitrite

1 . Test point ・ Lower structure of expressway
2 . Expiration years ・ 10 years
3 . Coating volume ・ 40% lithium nitrite aqueous solution 200g/m^2
・ mortar brush coating(containing 4.7% of lithium nitrite) 0.5mm thickness

Expressway pier　Expiration 10 years



Application of coloring liquid:
The brown color part is diffusion zone of nitrite ion



Chloride ion concentration kg/m3	Nitrite ion concentration kg/m3
1.0	1.3
1.2	1.6
1.5	1.9
2.0	2.6
2.5	3.2
3.0	3.9
4.0	5.2
5.0	6.5

Materials of Nissan Chemical Industries, Ltd.

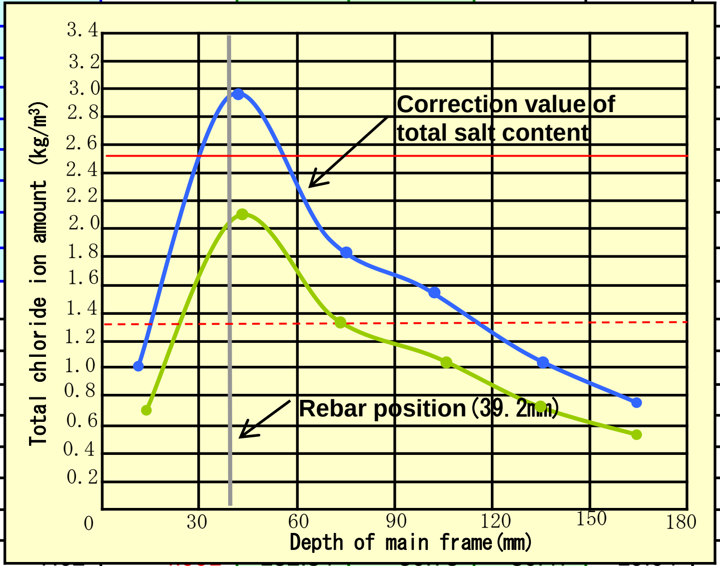
⑥Conversion table of SLAG LEAD #100 (lithium nitrite)

🟦 Troweling range
(Within 5 mm of coating thickness)
(Mortar ironing· FRP sticking)

🟩 Grout injection
(Coating thickness above 20 mm)
(GF protect)

※Conversion table of Mortar paint thickness was diverted by Cantab (standard item)

Indicated value	Chlorine ion				Desalination Mortar(coating thickness: mm)												
Cantab Display	Cl^- (%)	Cl^- (kg/m^3)	$NaCl^-$ (%)	$NaCl^-$ (kg/m^3)	LiNO 25% Aqueous solution (kg/m^2)	Concrete covering 5cm Versus cement ratio					LiNO 25% Aqueous solution (kg/m^2)	Concrete covering 10cm Versus cement ratio				
						1%	3%	5%	8%	10%		1%	3%	5%	8%	10%
Standard	0.010	0.23	0.015	0.34	0.114	3.49	1.16	0.70	0.44	0.35	0.229					0.70
2.6	0.059	1.36	0.088	2.03	0.675	20.62	6.87	4.12	2.58	2.06	1.351					4.12
2.7	0.064	1.47	0.096	2.20	0.733	22.36	7.45	4.47	2.80	2.24	1.465					4.47
2.8	0.069	1.59	0.103	2.37	0.790	24.11	8.04	4.82	3.01	2.41	1.580					4.82
2.9	0.073	1.68	0.109	2.51	0.836	25.51	8.50	5.10	3.19	2.55	1.671					5.10
3.0	0.078	1.79	0.116	2.68	0.893	27.25	9.08	5.45	3.41	2.73	1.786					5.45
3.1	0.083	1.91	0.124	2.85	0.950	29.00	9.67	5.80	3.63	2.90	1.900					5.80
3.2	0.088	2.02	0.131	3.02	1.007	30.75	10.25	6.15	3.84	3.07	2.015					6.15
3.3	0.093	2.14	0.139	3.19	1.065	32.50	10.83	6.50	4.06	3.25	2.129					6.50
3.4	0.097	2.23	0.145	3.33	1.110	33.89	11.30	6.78	4.24	3.39	2.221	67.79	22.60	13.56	8.47	6.78
3.5	0.102	2.35	0.152	3.50	1.168	35.64	11.88	7.13	4.45							7.13
3.6	0.107	2.46	0.160	3.67	1.225	37.39	12.46	7.48	4.67							7.48
3.7	0.112	2.58	0.167	3.85	1.282	39.13	13.04	7.83	4.89							7.83
3.8	0.117	2.69	0.175	4.02	1.339	40.88	13.63	8.18	5.11							8.18
3.9	0.122	2.81	0.182	4.19	1.396	42.63	14.21	8.53	5.33							8.53
4.0	0.126	2.90	0.188	4.33	1.442	44.03	14.68	8.81	5.50							8.81
4.1	0.131	3.01	0.196	4.50	1.500	45.77	15.26	9.15	5.72							9.15
4.2	0.136	3.13	0.203	4.67	1.557	47.52	15.84	9.50	5.94							9.50
4.3	0.141	3.24	0.211	4.84	1.614	49.27	16.42	9.85	6.16							9.85
4.4	0.146	3.36	0.218	5.01	1.671	51.01	17.00	10.20	6.38							10.20
4.5	0.150	3.45	0.224	5.15	1.717	52.41	17.47	10.48	6.55							10.48
4.6	0.160	3.68	0.239	5.49	1.831	55.91	18.64	11.18	6.99							11.18
4.7	0.170	3.91	0.254	5.84	1.946	59.40	19.80	11.88	7.42							11.88
4.8	0.179	4.12	0.267	6.15	2.049	62.54	20.85	12.51	7.82							12.51
4.9	0.189	4.35	0.282	6.49	2.163	66.04	22.01	13.21	8.25							13.21
5.0	0.199	4.58	0.297	6.83	2.278	69.53	23.18	13.91	8.69							13.91
5.1	0.208	4.78	0.311	7.14	2.381	72.68	24.23	14.54	9.08							14.54
5.2	0.218	5.01	0.325	7.49	2.495	76.17	25.39	15.23	9.52							15.23
5.3	0.228	5.24	0.340	7.83	2.610	79.67	26.56	15.93	9.96	7.97	5.220	159.33	53.11	31.87	19.92	15.93

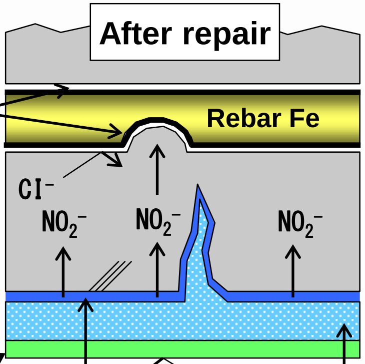


⑦ Development implementation method

(A) Surface coating method

Mortar application

(Figure of pattern)



After repair

Passive film protecting rebar from rust

Fe_2O_3

Rebar Fe

Cl^-

NO_2^-

NO_2^-

NO_2^-

Cl^-

Top coat

Prevention rust inhibitor SLAG LEAD ＃100

Rebar corrosion prevention mortar

SLAG LEAD ＃450 ＃100 mixed

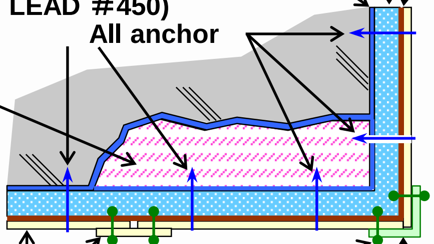
$Fe_2O_3 + H_2O + 2NO$
(Precise oxide of iron)

(B) Special FRP plate sticking method

FRP Sticking repair

(Figure of pattern)

- Adhesive
- Rebar corrosion prevention mortar
  (SLAG LEAD＃450) Paint thickness 5mm
- Prevention rust inhibitor of lithium nitrite 25%
  (SLAG LEAD #100)
- Structure repair material
  (SLAG LEAD ＃450)



All anchor

Special FRP board

Rivet

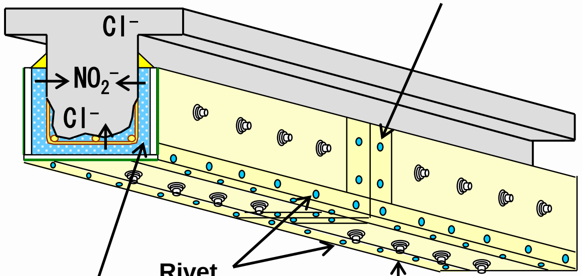
Corner angle

(C) G F protect

Grout injection by injector

(Figure of pattern)

Joint reinforcement material
(FRP Flat plate) width 100mm



Cl^-

NO_2^-

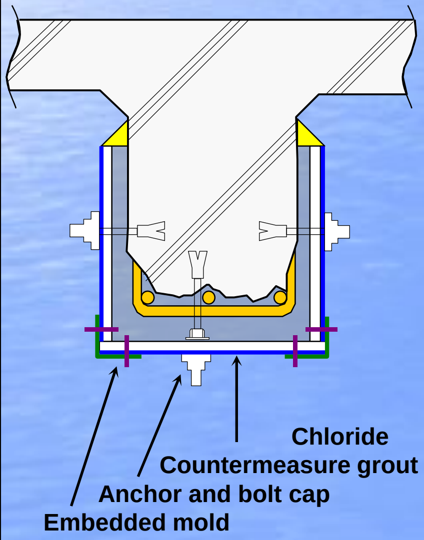
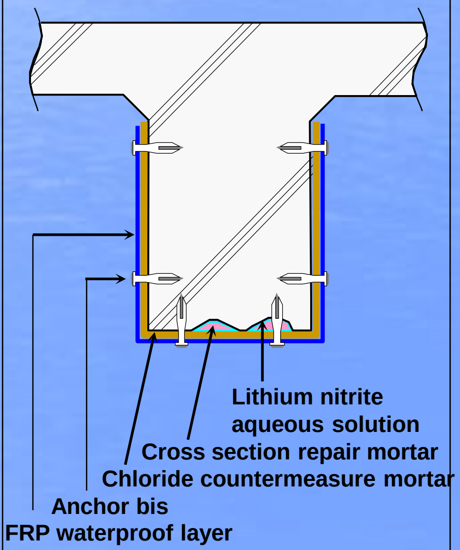
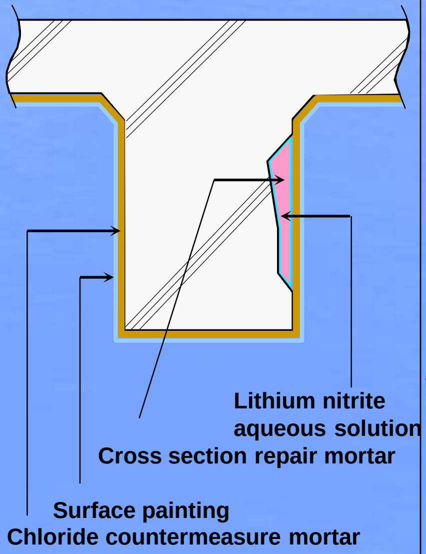
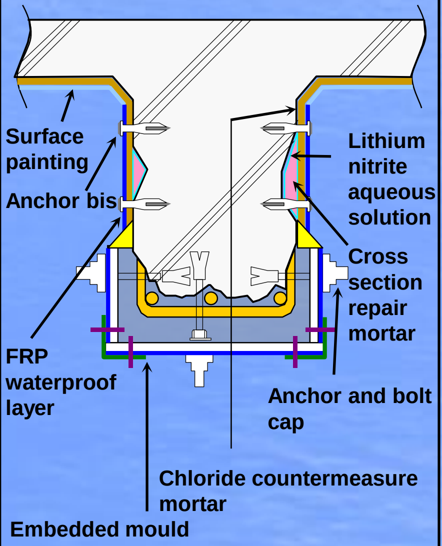
Cl^-

Rivet

Improved grout inject

Corner Reinforcement
(FRP Made L type)

⑧ Concrete structure rebar corrosion prevention method (combination according to damage situation)

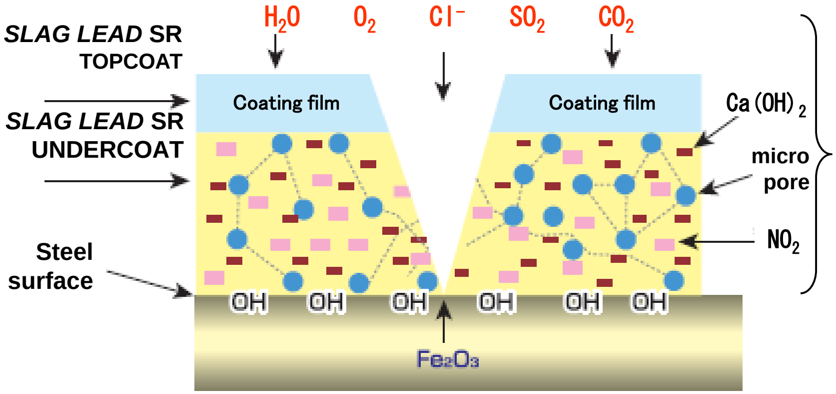
	GF Protect method (thickness 35 mm)	Surface FRP plate joining method	Surface treatment (surface coating) method	GF Protect method complex
Construction method Overview	For the purpose to prolong the life of degraded concrete structure, cross-section restoration using and embedded mold etc which environmentally friendly methods to repair/reinforcement, call concrete structure reinforcing steel corrosion prevention method.	By the simplicity of GF protect, attachment the FRP board directly and it brings close effects to GF Protect. Easy GF Protect	On the concrete surface of the entire target part, painting by lithium nitrite aqueous solution was mixed with mortar and infiltrate the rebar. Construction method which bring out rust prevention over a long term	As an example, in the left figure construction method, · GF protect method 20% · Surface FRP plate attachment method 20% · Surface coating method 60% Combined in area ratio
Schematic				

⑨SLAG LEAD S R method

■ Characteristics of SLAG LEAD SR method

Including cement, inorganic powder and nitrite in the coating film, alkali corrosion prevention and self-repairing corrosion inhibiting action simultaneously proceed, improvement of corrosion prevention dramatically.

Complex type (self-repair) corrosion prevention method



Complex type
(Self-repair)
Corrosion
prevention
method

Even if the coating film is scratched, it does not rust

$$\underset{\uparrow\ \text{(Iron ion)}}{2Fe^{2+}} + 2OH^- + \underset{\uparrow\ \text{(Nitrite ion)}}{2NO_2^-} \rightarrow \underset{\uparrow\ \text{(Iron oxide)}}{Fe_2O_3} + H_2O + \underset{\uparrow\ \text{(Nitric oxide)}}{2NO}$$

■CASS test (200 times x 8 hours = 1600 hours)

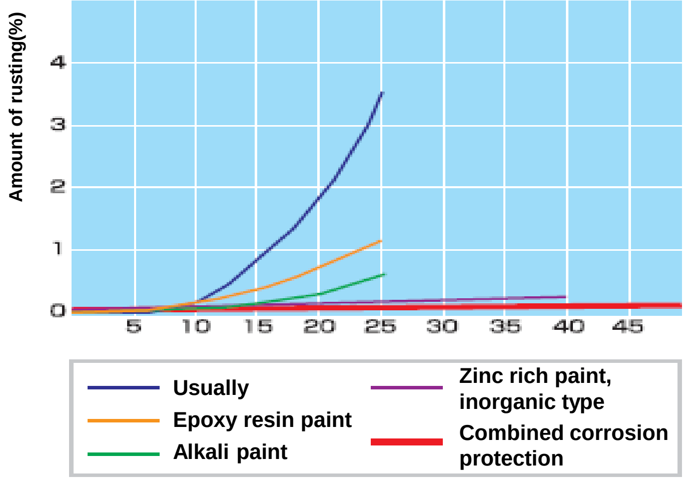
※CASS solution spray 4 hr, drying (60 ℃ , humidity 50%) 2 Hr
Moisture resistance test (50 ℃, humidity 95%) 2Hr

Composite
corrosion protection

Alkali paint

Epoxy resin paint

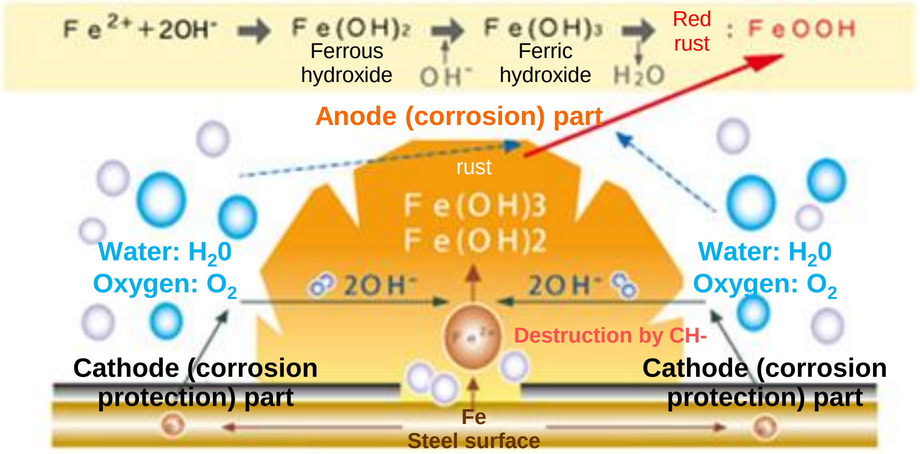
● Comparison of corrosion protection performance (salt spray test)



※ This test result is based on internal test data and does not guarantee quality.

Corrosion concept

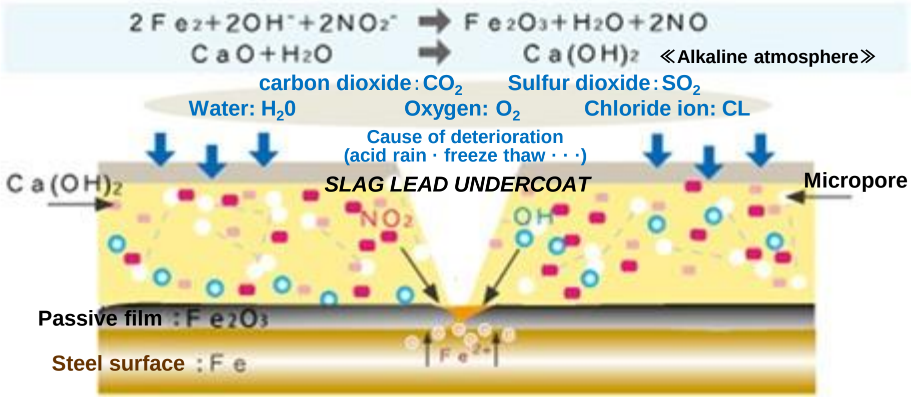
Fe 2 + of the anode reaction product and OH - of the cathode reaction product combine to become Fe (OH) 2, oxidized and change to rust such as Fe (OH) 3 · FeOOH.
Overall, it is a reaction in which iron is combined with water and oxygen to form hydrated oxides.



Technical overview

◆ *SLAG LEAD UNDERCOAT*

Iron ions combine with nitrite ions and rebuild the passive film by becoming an oxide of iron.



◆ *SLAG LEAD TOP COAT*

It is a blended design that combines hydrophobicity and hydrophilicity.
By having such performance, it contributes to adhesion and corrosion protection in the undercoat material.

Hydrophobicity: Moisture present on the surface of the undercoating film is pushed away and it is easy to come into direct contact with the object to be coated.
Hydrophilicity : Absorbs moisture which can not be excluded by hydrophobicity, making it more wet easily.

■ Fukuoka Kitakyushu Expressway Corporation Kitakyushu Road Balustrade repair work

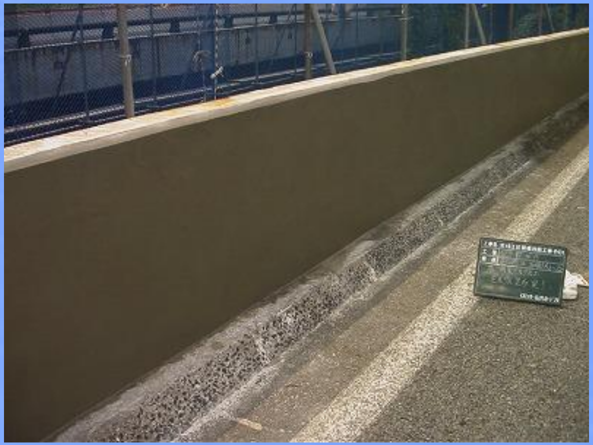
Rebar rust preventive agent SLAG LEAD # 100 Application

Chipping situation

SLUG LEAD # 100 # 450 The filling situation

cross section Repair completed

SLUG LEAD # 100 # 450 Salinity countermeasure mortar is done



Surface protective coating B specification complete

■ Implementation report ■

Before construction
(Overall picture)

Immediately after completion

Seven years after completion

Before construction
(representative place)

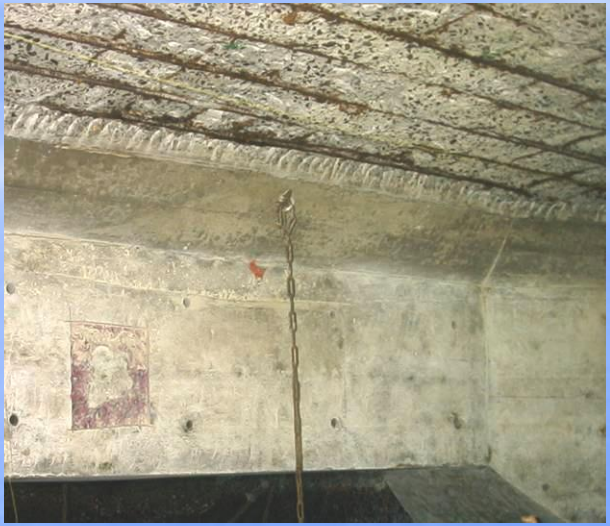
Immediately after completion

Seven years after completion

Karatsu Port pier

Before construction

Before construction



Under construction

Under construction

Under construction

completion

■ Construction example ■

Before construction

completion

Before construction

completion

Before construction

completion

Construction example

Under construction

completion

Before construction

completion

Under construction

completion

Construction result

Yahata Steel mill - Stacker Crane

Before construction

After construction

Construction in China / Dalian

Application status of undercoat material

Application status of topcoat material

Transport situation

■ Construction result


NYB Outdoor Exhaust Facility
Before construction

Cement silos
Before construction


Chemical factory
Before construction


NYB Outdoor Exhaust Facility
3 years after construction


Cement silos
After construction


Chemical factory
After construction

■ Construction result

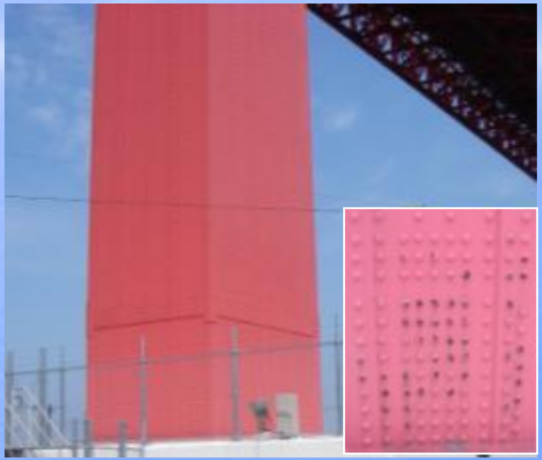
Monorail - movable bearing

Before construction

After undercoat application

Wakatooohashi
- The flank of the pier

Before construction



After construction

Kitakyushu Airport
Tent Square

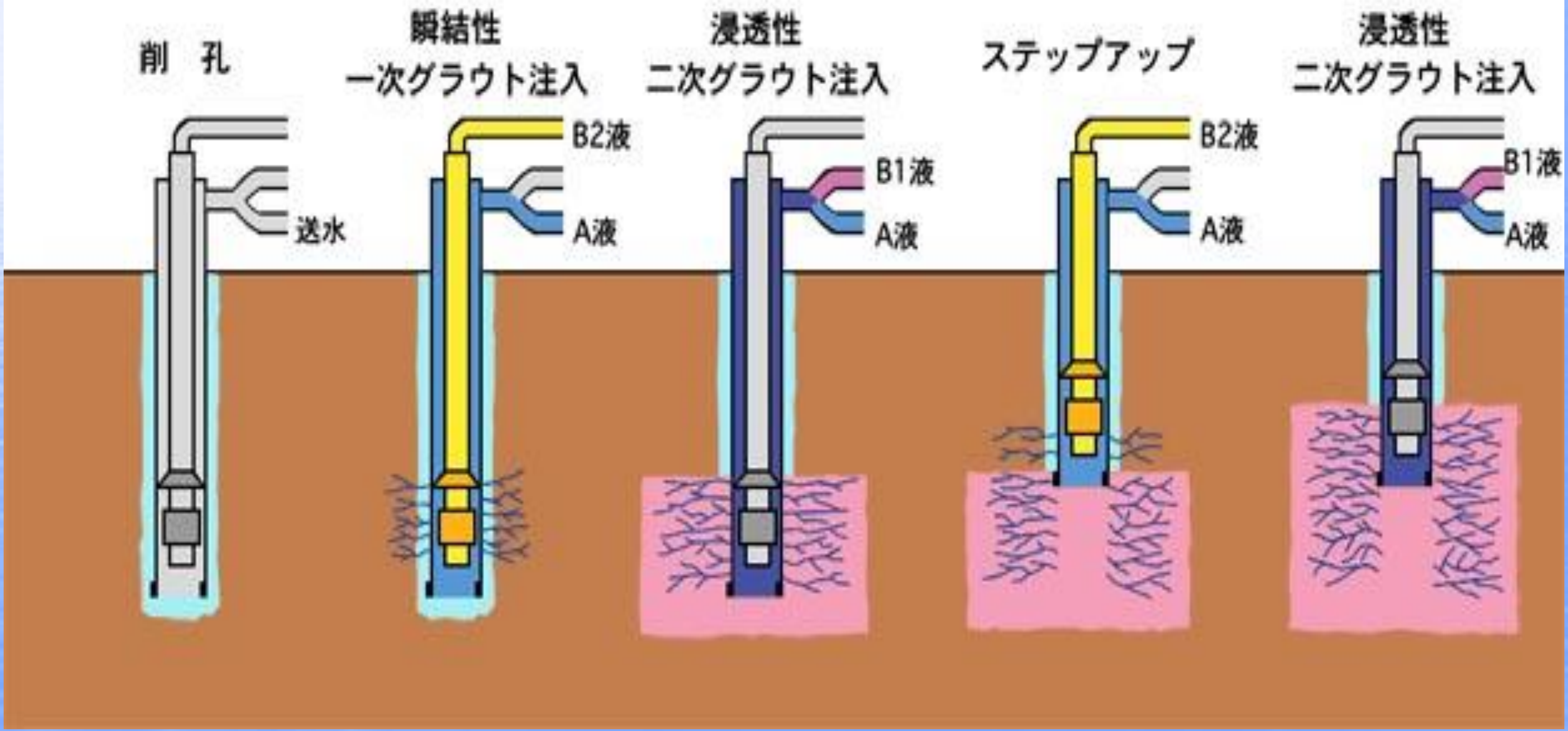
Before construction

Two years after construction

Two major construction methods in soil improvement

○Method1:

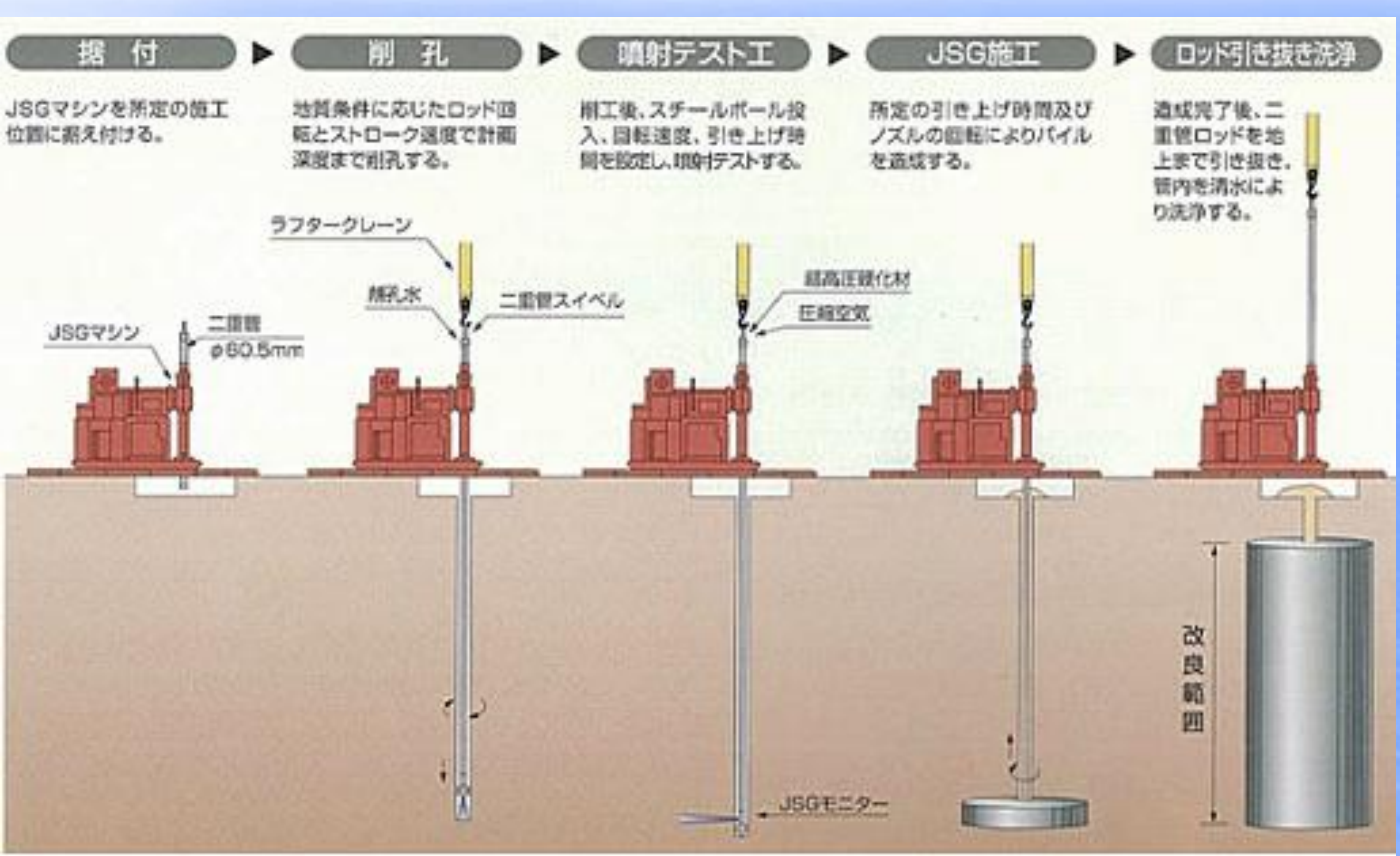
Chemical grouting（materials: sodium silicate and harder)



Two major construction methods in soil improvement

○Method2:

JET grouting (materials: cement and additives)



据　付 ▶ **削　孔** ▶ **噴射テスト工** ▶ **JSG施工** ▶ **ロッド引き抜き洗浄**

据付: JSGマシンを所定の施工位置に据え付ける。

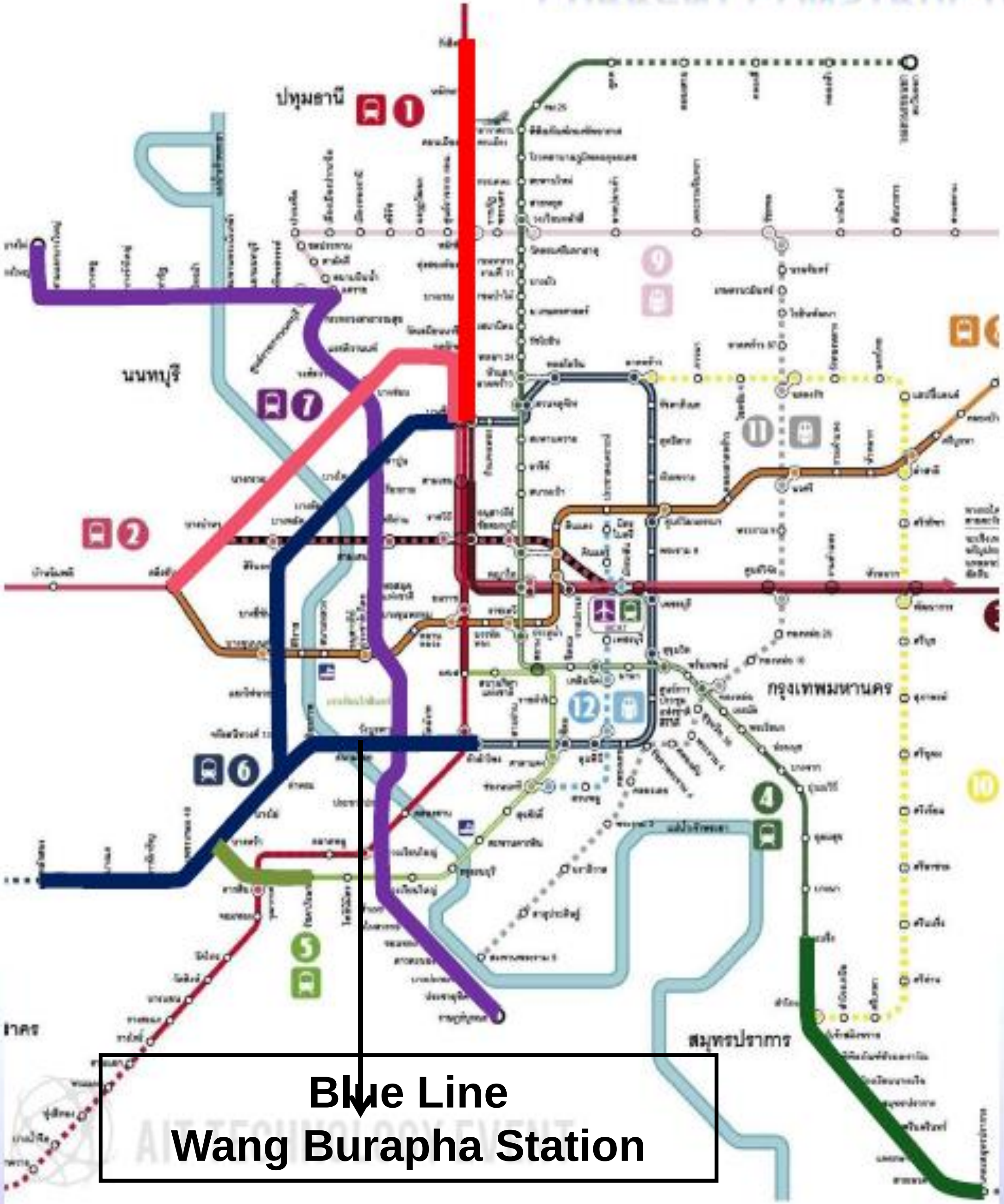
削孔: 地質条件に応じたロッド回転とストローク速度で計画深度まで削孔する。

噴射テスト工: 削孔後、スチールボール投入、回転速度、引き上げ時間を設定し、噴射テストする。

JSG施工: 所定の引き上げ時間及びノズルの回転によりパイルを造成する。

ロッド引き抜き洗浄: 造成完了後、二重管ロッドを地上まで引き抜き、管内を清水により洗浄する。

CURRENT CONSTRUCTION ROUTES

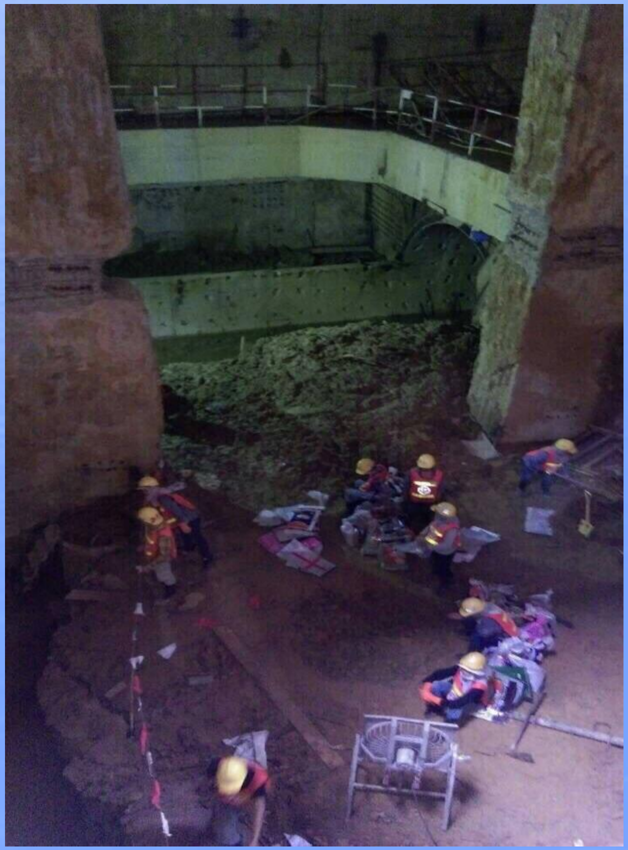


Blue Line
Wang Burapha Station

Agency	Name of Route	Length of Route
SRT	Red Line Bang Sue - Rangsit	26 km 6 stations
SRT	Light Red Line Bang Sue - Taling Chan	15 km 4 stations
MRTA	Purple Line	25.6 km 16 stations
MRTA	Blue Line Ext.	26.9 km 19 stations
MRTA	Green Line Ext. Bearing - Kheha Samut Prakan	13 km 9 stations
BTS	Light Green Line Talat Phlu - Bangwa	~2.7km 2 stations

Pictures: Job site of chemical grouting at Wang Burapha Station in MRT Project

○Injecting materials for stopping underground water



Around 50 meter depth in underground

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