Full-scale Survey on Corrosion Environment and Deterioration of Sulfuric Acid Resistant Coating for Concrete Structures

JS's Approach to Prevent Concrete Corrosion

- 1987: "Guidelines for Coatings for Concrete Anticorrosion Protection (Draft)" established.
- 1991: "Concrete Corrosion Prevention Guidelines (Draft)" established.
- 2001: "Report on Evaluation of Concrete Corrosion Control and Prevention Technology for Sewerage Structures" (Technical Evaluation)
- 2002: Establishment of "Guidelines and Manual for Concrete Corrosion Inhibition and Prevention Technology for Sewerage Structures" → Shift to performance evaluation type
- 2007: The first revision of the JS anticorrosion manual → Performance regulations were established and quality was enhanced
- 2008: "Sulfuric Acid Mortar Corrosion Prevention Technology" (Technology Evaluation)
- 2012: Second revision of the JS anticorrosion manual → Addition of sulfuric acid-resistant mortar method
- 2015: "Corrosion Prevention Technology by Sheet Lining Method (Light Curing)" (Technology Evaluation)
- 2017: JS Corrosion Prevention Manual, Third Revision
  → Prepreg Compression Molding method added (JIS)

JS has been developing various types of anti-corrosion coatings for corrosion of concrete by sulfuric acid, and has been continuously improving the technical standards.

The Position of the Survey

JS 4th R&D Strategy 2017-21

Goal: Establishment of Comprehensive Corrosion Control Technology for sewerage facilities

- Development issues: Ex-post survey of the sulfuric acid protection coating method
- Establishment of corrosion control technology with organic/ carbonic acid
- Research on Metal Corrosion of Sewerage Facilities

Systematization of Corrosion Control Technology for Sewerage Facilities

★Establish **comprehensive anti-corrosion measures for sewerage facilities** through the development and practical application of corrosion prevention technologies for concrete corrosion caused by various factors (sulfuric acid, organic acid, and carbonic acid).

Purpose of the study

Determination of the relationship between actual corrosive environment conditions and deterioration of the corrosion protection layer after execution

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Extraction of Issues in the Sulfuric Acid Prevention Coating Method in the “JS Technical Manual for Corrosion Control"*

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Improvement of corrosion control technology in WWTPs

*Japan Sewage Works Agency, “Technical Manual for Corrosion Inhibition and Corrosion Prevention of Sewerage Concrete Structures" (December 2017).

Research History

2017: Questionnaire Survey about corrosion protection layer

2018: Field survey at 3 sites

→ WWTPs being applied with anti-corrosion layer for more than 10 years had a decrease in the adhesion strength, sulfur intrusion into the building structure, and progressive neutralization.

⇒In 2019, field surveys will be conducted at four WWTPs applied with anti-corrosion layer for exceeding 10 years.

Survey details

Corrosive Environment Survey

Survey item		Details	
Corrosive environment index	Liquid phase	water temperature, pH, ORP, DO concentration	Generation of sulfide
	Gas phase	H_2S concentration, CO_2 concentration, temperature	Generation of hydrogen sulfide gas
		Anti corrosive coating surface pH	Generation of sulfuric acid

Deterioration Survey

Survey item	Details	
visual inspection of surface abnormality	Visual inspection, measurement, record	Swelling, cracking, exfoliation, softening, weakening, wear, etc.
Adhesion Test	Adhesion strength of the anticorrosion coating layer: Tensile strength tester authorized by Building Research Institute	
Neutralization Depth	Concrete neutralization depth (JIS A 1152)	

Survey Details

Detailed investigation (physical property test)）

Test item	Detail
Tensile test*	Tensile strength of the anticorrosion coating layer (JIS K 7164) (indoor test)
Bending test*	Bending strength of anti-corrosion coating layer (JIS K 7017) (indoor test)
Barcol test*	Hardness of the anti-corrosion coating layer (JIS K 7060) (indoor test)
Thickness of anti-corrosion coating layer	Thickness of the anticorrosion coating layer (micrometers) (indoor test)
Sulfur Intrusion Depth	Depth of penetration of sulfate ions into the anticorrosion coating layer and concrete (EPMA analysis) (indoor test)
Neutralization Depth	Concrete Neutralization Depth (JIS A 1152) (Field Survey)

*The tensile test, bending test, and Barcol test were run in the gas and liquid phases of part C

Survey Details

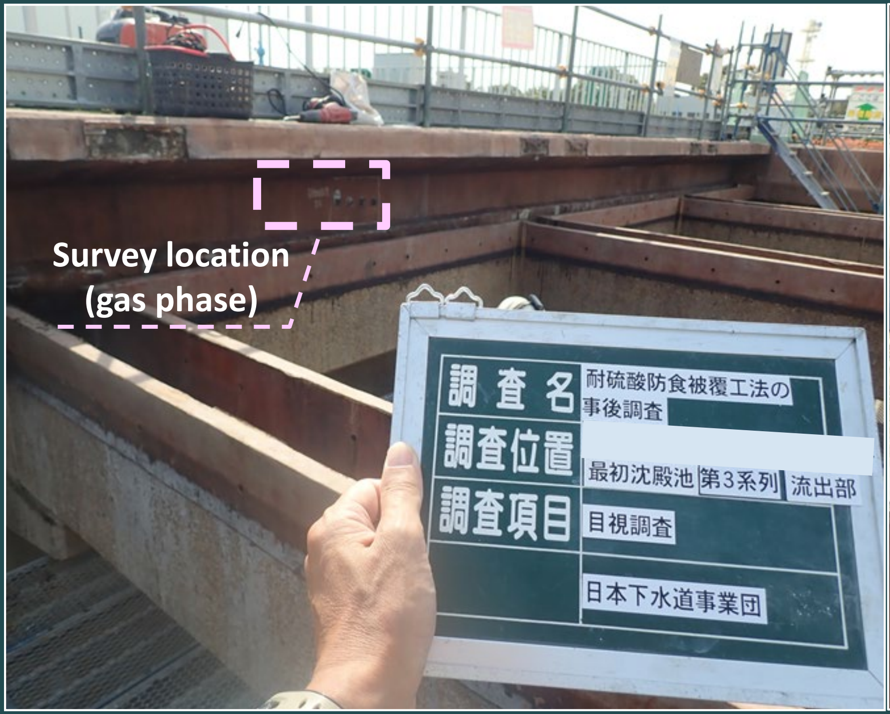
List of Field Survey Locations

Survey destination	WWTP A	WWTP B	WWTP C	WWTP D
Target facilities	Primary settling tank	Gravity thickening tank	Sludge storage tank (Mixing tank)	Primnary settling tank
anti-corrosion coating layer	Coated lining method （Type C）			
	Materials			
	Epoxy resin with ceramic powder	epoxy resin	Vinyl Ester Resin	epoxy resin
Age of coating layer	21 years from 1998	17 years from 2002	17 years from 2002	19 years from 2000
Facilities’ age	51years from 1968	28 years from 1991	23 years from 1996	39 years from 1980

* This survey scoped facilities applied with anti-corrosion coating layer for over 10 years (service life defined in JS Corrosion Control Manual)

Survey Site

WWTP A: Primary settling tank
anti-corrosion coating material: Epoxy resin with ceramic powder



The trough is coated with corrosion protection

Survey Site

WWTP B : Gravity thickening tank
anti-corrosion coating material: epoxy resin

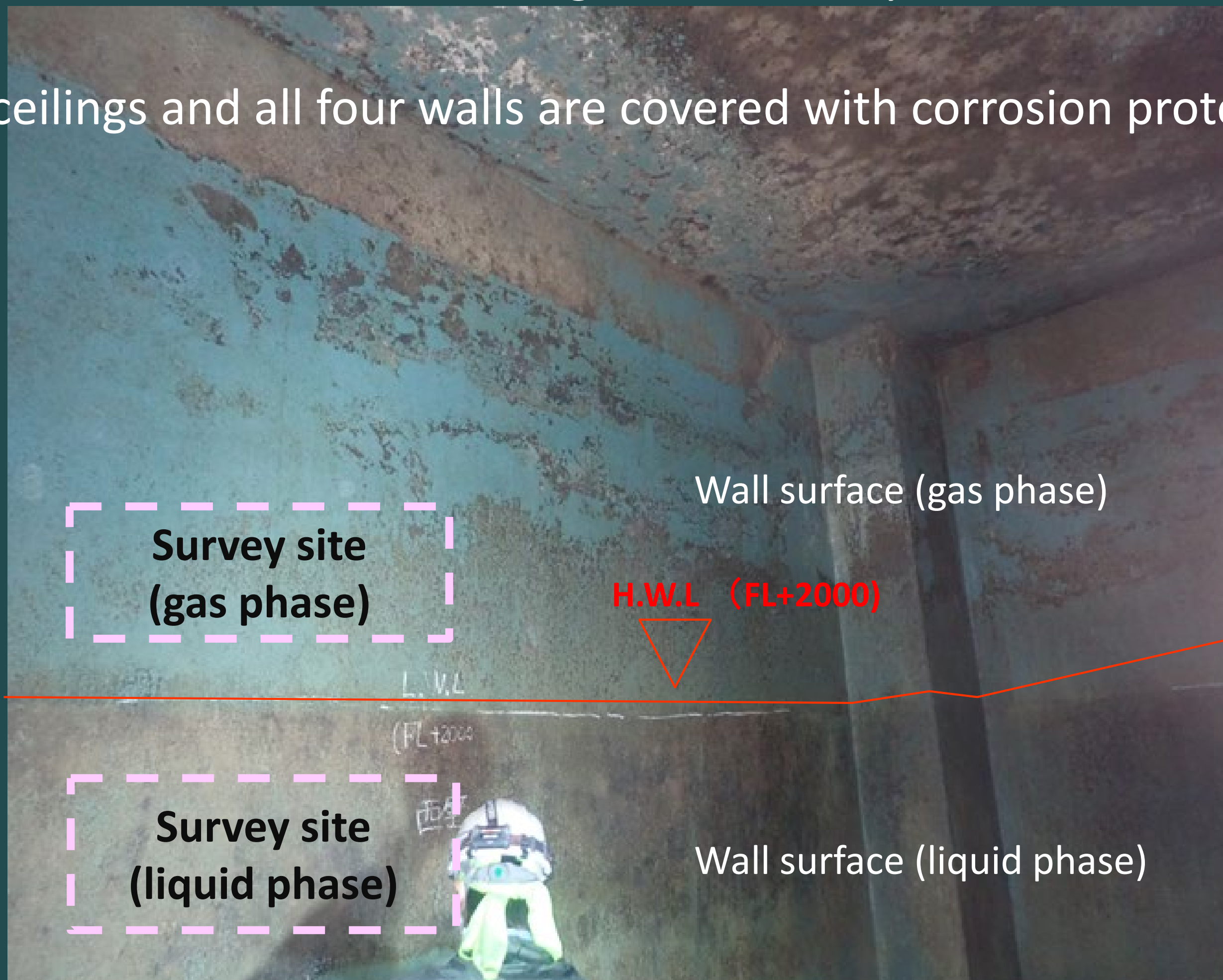
Trough | Scum pit wall

The troughs and scum pits are covered with corrosion protection

Survey Site

WWTP C: sludge storage tank (mixing tank)
anti-corrosion Coating Material: Vinylester Resin

Floors, ceilings and all four walls are covered with corrosion protection



Survey Site

WWTP D: Primary settling tank
anti-corrosion coating material: epoxy resin

Gas phase is covered with corrosion protection

Findings

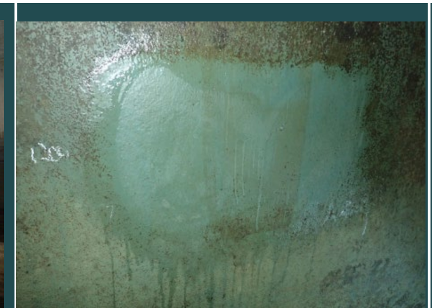
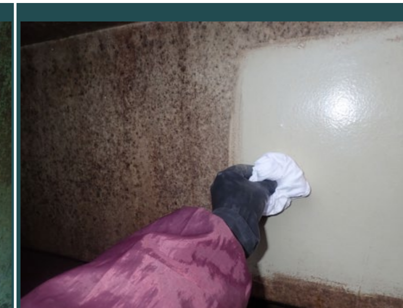
Corrosive Environment Survey

Survey item			WWTP A	WWTP B	WWTP C	WWTP D
			Primary settling tank	Gravity thickening tank	Sludge storage tank (Mixing tank)	Primary settling tank
Corrosive environment index	In liquid phase	Water temperature	17.0℃	17.0℃	18.0℃	17.0℃
		pH	7.3	7.8	4.9	6.7
		ORP	-225	-281	-107	-273
	In gas phase	H_2S concentration	Avg: 8.4ppm Max: 32.0ppm	Avg: 37.0ppm Max: 181ppm	Avg:21.4ppm Max: 150ppm	Avg: 11.4ppm Max: 52.0ppm
		Surface pH	5	3	6	7

→The concentration of H_2S gas at all locations was equivalent to class II corrosive environment which is pronounced concrete corrosion.

Findings

Detailed survey (field test)

Survey item		WWTP A	WWTP B	WWTP C	WWTP D
Visual inspection : surface abnormality					
		Flaking and exfoliation on the wall	Flaking or exfoliation at the outcrop of the beam or trough wall	Healthy conditions	Healthy conditions
Adhesion test	Value	1.66N/mm^2	0.39N/mm^2	4.07N/mm^2	0.96N/mm^2
	Rupture state	Between anti-corrosion coating layer and the building frame	Between the cross-sectional restoration material and anti-corrosion coating layer	Between the anti-corrosion coating and the building frame	Between the anti-corrosion coating and the substrate conditioner

→The bond strength of the WWTP B and C was lower than the quality standard of 1.5 N/mm^2 required by the JS Corrosion Prevention Manual. High adhesion strength area tended to break with the building frame.

* Ratio to quality-standard bond strength of 1.5 N/mm^2

Findings

Detail survey（Property test)

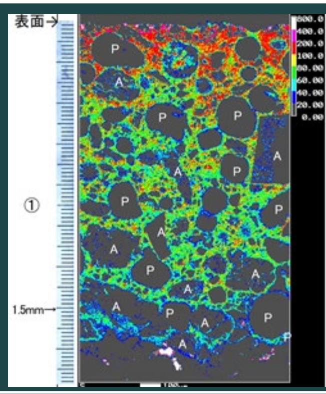
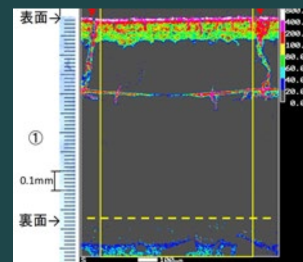
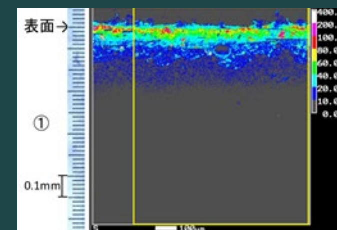
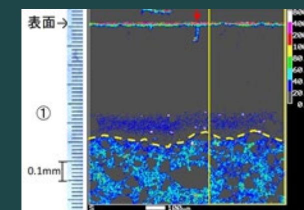
Test item	Gas phase	Liquid phase
Tensile test	Tensile strength ： 32.22MPa Frature displacement ： 1.511㎜ Nominal strain at break ： 1.007%	Tensile strenpgh ： 33.77MPa Fracture displacement ： 1.305㎜ Nominal strain at break ： 0.870%
Bending test	Bending strength ： 61.00MPa Maximum point deflection ： 7.67 ㎜ Maximum point strain ： 2.46%	Bending strength ： 56.15MPa Maximum point deflection ： 2.33 ㎜ Maximum point strain ： 1.09%
Barcol test	38	33

The above three tests were performed in the gas and liquid phases of Part C in the survey in 2019.

→The results of tensile test and barcol test showed no clear difference.
→As a result of the bend test, there was no significant difference in the bending strength, but there was a difference in the maximum point strain. The results of the gas-phase section showed a larger variation among the three specimens than the results of the liquid section.

Findings

Detail survey（Property test）

Test item	WWTP A	WWTP B	C	D
Penetration depth of sulphur (A)				
	1.451mm	0.138mm	0.096mm	0.021mm
Neutralization depth	0.000mm	0.400mm	4.800mm	0.000mm
Thickness of anti-corrosion coating layer(B)	1.856mm	0.800mm	1.167mm	0.760mm
A/B	80.6%	17.3%	8.2%	2.8%

→WWTP B and C showed progressive neutralization of the concrete under their corrosion protection layers.
→Both of them showed no sulfur penetration into the concrete under their corrosion protection layers.

Conclusion

This study was carried out in four WWTPs in corrosive environments of category II or higher, and their anti-corrosion coatings exceeded the service life of 10 years.

- The adhesive strength of the anti-corrosion coating layer showed a tendency to decrease with age.
- None of the areas were found to have progressive sulfur intrusion into the structure, and it was evident that the corrosion protection coating functioned well beyond the standard service life
- The depth of sulfur penetration into the anticorrosion coating layer tended to be greater at higher H_2S gas concentrations in the gas phase and lower surface pH of the anti-corrosion coating layer.

Future plans

- The similar field surveys will be continued at other sewage treatment facilities to determine the relationship between corrosive environment and deterioration status of anti-corrosion coatings.

- In some cases, no abnormality was found in the appearance, but the adhesion strength was below the standard value. Therefore, data accumulation is required to statistically summarize by narrowing down the service years and execution procedure of the anticorrosion coatings when selecting the survey sites.

We would like to express our appreciation to all those involved in the local government for their cooperation in this survey.

Thank you for your attention