37 Technology of repairing the corrosion damage and deterioration to steel structures using newly developed flame coating material

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R&D Objectives and Subjects

Objectives

Objective: To realize safe and secure infrastructure by developing a repair technology that enables easy maintenance and control with the utilization of a newly developed thermal spraying alloy of excellent corrosion durability; the developing repair technology is suitable for solving problems determined through field study on the corrosion damage to steel structures, especially to steel bridges.

Development of a thermal spraying alloy: Developing a thermal spraying alloy with an excellent corrosion prevention performance, especially for dents, the edge portions and the small end faces of steel bridges, as well as with the high durability in severe salt-attack environments.

Development of a thermal spray method in narrow spaces: Accelerating the progress speed of the technology we are developing by utilizing a compact and lightweight plasma arc spraying technique, which was developed by the West Nippon Expressway group and establishing its application to narrow spaces.

Subjects

Field study: To clarify the problem as a repair technology through the investigation of the actual corrosion damage.

Development of a thermal spraying alloy: Developing a thermal spraying alloy excellent in corrosion resistance and self-repairing ability; the alloy composition was designed based on the first - principle calculation and the evaluation of corrosion resistance using electrochemical techniques.

Adaption to the plasma arc spraying method: Carrying out the tests for confirming the adaptability of the plasma arc spraying method, which is considered as an adequate technique for a thermal spraying on a narrow space.

Evaluation of corrosion prevention performance: Performing the verification testing of the developed thermal spray coating by a combined cyclic testing of up to 6,000 hours with a cross-cut sample. Carrying out atmospheric corrosion tests in heavily corrosive salt-attack environments, such as along the coast of the Sea of Japan.

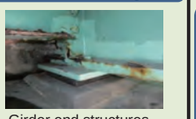
Partial repair as field trial: Preforming a partial repair as a field trial, to the girder end structure of a bridge to verify the workability, the cost and the performance of thermal spray coating with the developed alloy.

Current Accomplishments (1/2)

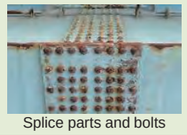
To develop a new thermal spraying alloy with high durability for salt-attack environments, as well as high resistance to the corrosion of dents, edge portions and small end faces.

Problems of damage and deterioration due to corrosion

Examples of corrosion sites in steel bridges



Girder end structures, including shoes



Splice parts and bolts

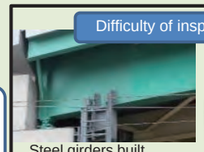
Survey results of corrosion sites in steel bridges

①Girder end structures, including shoes
→ Narrow part and imperfect drainage
②Splice parts, bolts and small end surfaces
→ Decrease in thickness of thermal spray coating.
③Steel girders built across a railway track and a road with a heavy traffic volume → Difficulty of inspection and repair
④Salt-attack environments, such as the seashore
→ Problem of durability

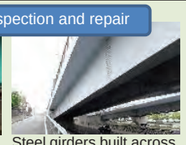
Proposal of a repair method with good workability and a thermal sprayed coating with high durability.

①Development of new thermal spraying alloy exhibits high durability for salt-attack environments and high corrosion resistance for dents, edge portions and small end faces.
②Adapting to plasma arc spraying method capable of easily repairing narrow part.

Difficulty of inspection and repair

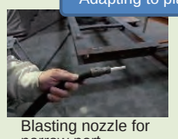


Steel girders built across a railway track



Steel girders built across a road with a heavy traffic volume

Adapting to plasma arc spraying

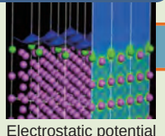


Blasting nozzle for narrow part

Small and lightweight spraying gun

Development of new thermal spraying alloy “Al-Mg-Ca”

Fourteen selected kinds of alloy compositions based on the first-principles calculations.



Electrostatic potential on Al-Mg surface

Al-Mg-Ca was selected from fourteen kinds of alloy compositions based on electrochemical tests.

Measurements of polarization curves

Flame spraying, arc spraying and plasma arc spraying

Thermal spraying of Al-Mg-Ca alloy

Adhesive strength of Al-Mg-Ca thermal spray coating is about 10 Mpa, which is the same as that of conventional Al-Mg in achieving the target strength of 4.5 MPa.

Sprayed coating of Al-Mg-Ca alloy

Fabrication of Al-Mg-Ca alloy wires for various thermal spray methods.

Wire for thermal spraying of Al-Mg-Ca alloy

Current Accomplishments (2/2)

To demonstrate durability of the newly developed thermal spray coating and establish a repair technology using it, based on the results obtained by combined cycle testing and the partial repair as a field trial at an actual steel bridge.

Determination of alloy composition with excellence in corrosion resistance using electrochemical techniques

Target	Problem	Corrosion resistance performance
Salt-attack environment	Rapid dissolution of the coat due to high corrosion rate	Cathodic protection to the coated defective part
Edge portion, small end face	Poor durability resulting from a small thickness of the coat	Anti-self corrosion of the coat
Dent	Rusting from the defect in the coat	Self repairing ability of the coated defective part

		Cathodically protecting performance	Resistance to self-corrosion	Self-recovering performance
Testing method		・Corrosion potential measurement ・Polarization measurement	Polarization measurement	Combined cycle testing
Evaluation criteria		・Level of corrosion potential ・Passivation or de-passivation	Intensity of corrosion current	Appearances
Conventional material	Al	○	○	×
	Al-Mg	○	○	○
New alloy	Al-Mg-Ca	○	○	◎ Improved by 25 %＊

◎ very good, ○ good, × poor (Samples for evaluation were prepared by flame spraying)
＊A time for a start rusting from cross-cut area

Combined cycle testing

Carrying out an accelerated test using the combined cycle testing, which is assumed showing a satisfactory correlation with outdoor exposure.

A time for a start rusting from cross-cut area was improved by 25%.

Al-Mg-Ca

Al-Mg

The appearances of the coats (100 μm thickness) after being subjected to combined cycle testing for 6,000 hours.

Partial repair as field trial at an actual steel bridge

A partial repair as a field trial was carried out on an actual steel bridge of West Nippon Expressway Company Limited by the plasma arc spraying using a newly developed thermal spraying alloy.

The workability of thermal spraying and the quality of the sprayed coat satisfied the in-house quality control provisions of West Nippon Expressway Company Limited.

Steel bridge under repair

Finish state; after repair

Goals

- Development of new thermal spraying alloy with high durability by utilizing state-of-the-art computational materials science and the latest knowledge about corrosion and corrosion protection mechanisms.
- Demonstration of the workability of the repair method and the durability of sprayed coating that uses the developed thermal spraying alloy.

Adapting to JIS thermal spraying : flame spraying and arc spraying

Performance confirming tests
・Workability on thermal spraying
・Electrochemical test

Demonstration tests
・Combined cyclic testing
・Exposure test
・Sliding friction test

To develop new alloy for JIS thermal spraying

Adapting to plasma arc spraying used in West Nippon Expressway Company Limited

Performance confirming tests
・Workability on thermal spraying
・Combined cyclic testing

Test construction work
・Exposure test
・Partial construction work

Establishment of repairing method at end parts of steel girders