University Transportation Research Center - Region 2

Final Report

Subsurface Imaging of Corrosion in Painted Steel Bridges

Performing Organization: New York University

January 2014

Sponsor(s):
University Transportation Research Center - Region 2

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The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

Research

The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center's theme.

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The modern professional must combine the technical skills of engineering and planning with knowledge of economics, environmental science, management, finance, and law as well as negotiation skills, psychology and sociology. And, she/he must be computer literate, wired to the web, and knowledgeable about advances in information technology. UTRC's education and training efforts provide a multidisciplinary program of course work and experiential learning to train students and provide advanced training or retraining of practitioners to plan and manage regional transportation systems. UTRC must meet the need to educate the undergraduate and graduate student with a foundation of transportation fundamentals that allows for solving complex problems in a world much more dynamic than even a decade ago. Simultaneously, the demand for continuing education is growing – either because of professional license requirements or because the workplace demands it – and provides the opportunity to combine State of Practice education with tailored ways of delivering content.

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16. Abstract

According to a comprehensive study conducted in 1998 by CC Technologies, corrosion to the US economy was $276 billion or 3 % of the 1998 GDP (FHWA-RD-01-156). From that amount, $121 billion was spent on corrosion control and $107 billion was spent on protective coatings alone. CC Technologies reported that better corrosion protection could save up 40% of that cost. Improved practices for corrosion protections are: coating quality control and effective inspection at time of coating application; routine/periodic coating inspection during the service life of the structure; an appropriate repair action when coating degradation or delaminate or substrate corrosion is detected. Currently Federal guidelines hold contractors responsible for coating quality. However there is no federal guideline or other practical methodology for evaluating a protective coating quality and subsurface condition.

The objective of this research project is evaluation of infrared thermography as a method for detecting hidden corrosion on steel structures. A previously conducted research validated an infrared thermography as a method for detection of early corrosion onset in gas pipelines beneath the protective coating. The studies indicated that it is possible to detect corrosion at earlier than with current ultrasonic thickness gauges. Also it is possible to detect poor quality coating, such as the presence of air blisters, even in the absence of corrosion. Furthermore thermal imaging is a two dimensional technique and lends itself for improved inspection and documentation of surfaces.

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Final Report
UTRC-RITA/NYSDOT Projects

Project Title: Subsurface Imaging of Corrosion in Painted Steel Bridges

Date of Report: 1/29/2014

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1 Introduction

1.1 Research Motivation

According to a comprehensive study conducted in 1998 by CC Technologies, corrosion cos to the US economy was $276 billion or 3 % of the 1998 GDP (FHWA-RD-01-156). From that amount, $121 billion was spent on corrosion control an $107 billion was spent on protective coatings alone. CC Technologies reported that better corrosion protection could save up 40% of that cost. Improved practices for corrosion protections are: coating quality control and effective inspection at time of coating application; routine/periodic coating inspection during the service life of the structure; an appropriate repair action when coating degradation or delaminate or substrate corrosion is detected. Currently Federal guidelines hold contractors responsible for coating quality. However there is no federal guideline or other practical methodology for evaluating a protective coating quality and subsurface condition.

1.2 Research Objectives

The objective of this research project is evaluation of infrared thermography as a method for detecting hidden corrosion on steel structures. A previously conducted research validated an infrared thermography as a method for detection of early corrosion onset in gas pipelines beneath the protective coating. The studies indicated that it is possible to detect corrosion at earlier than with current ultrasonic thickness gauges. Also it is possible to detect poor quality coating, such as the presence of air blisters, even in the absence of corrosion. Furthermore thermal imaging is a two dimensional technique and lends itself for improved inspection and documentation of surfaces.

1.3 Research Deliverables

We propose to carry out preliminary tests on the applicability of infrared thermography, as a tool in assessing subsurface condition of painted steel bridges. Research deliverables include the results of inspection of bridge steel components using infrared passive and active imaging techniques. The painted components to be imaged include beams, girders, and columns. Results from this work will form the basis for future proposal to the state and the federal government.

2 Performed Research Activities

2.1 Laboratory Testing

Preliminary lab testing included passive and active thermal imaging of steel plate with air blisters or corrosion.

We used the FLIR A320 infrared camera and the Heraeus infrared lights installed as shown Figure 1 and imaged surface temperature of the plate with simulated defects.

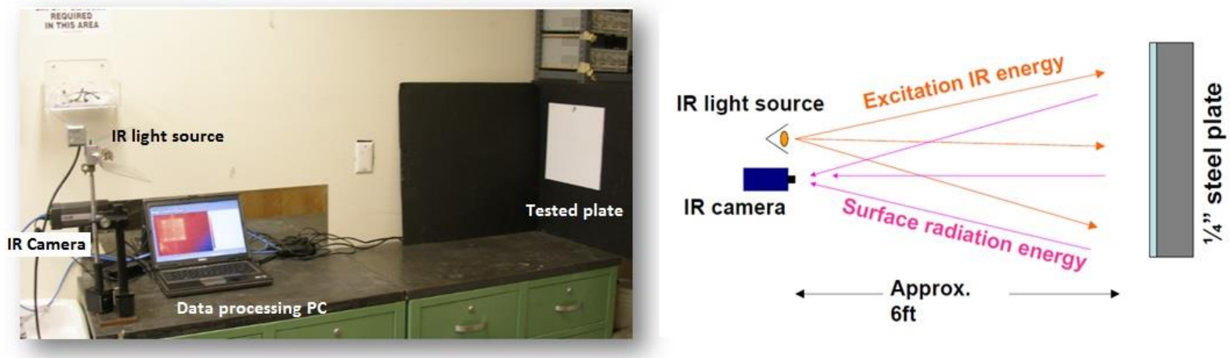
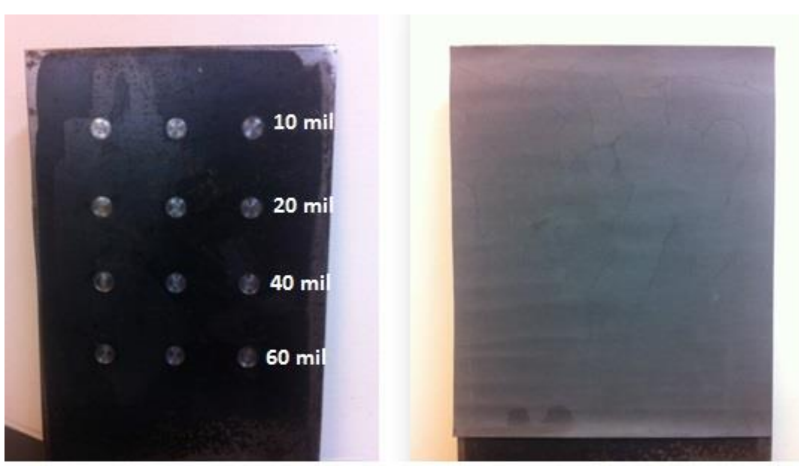


Figure 1. Lab experimental setup.

Surface temperatures and its change were recorded at high frequency (apprx. 5 images per second) and recorded by our data processing PC.

The tested sample plate is structural steel plate ¼" thick. The plate surface was brushed and sanded to remove corrosion and other deposits. We than simulated defects that can be presented under the coating. This procedure was conducted to calibrate defect detection.



a) b)

Figure 2. Steel plate with blind holes and simulated defects covered by protective coating.

Defects were simulated by creating blind holes in three rows with depths ranging from 10 to 60 mils, as shown in Figure 2 a). Each row has 60, 40, 20 and 10 mil deep flat bottom blind holes. Two rows were filled with corrosion compounds. The plate surface was covered with adhesive tape to simulate coating as shown in Figure 2 b).

For corrosion compounds we used are two common forms of iron oxides: Fe3O4 and Fe2O3. Fe3O4 called magnetite is a black “sticky” powder that usually forms undercoating in the presence of acid environment. It usually later transforms to other form of iron oxide. Fe2O3 called hematite is a red-orange “fluffy” powder.

Adhesive tape was chosen as the coating option based on the following factors:

- thermal properties of adhesive tapes are similar to the hardened paints that are usually used for bridge applications;
- thicknesses of the adhesive tapes are relatively uniform and comparable to thicknesses of hardened paints;
- adhesive tapes do not fill the empty blind holes and voids in corrosion, and therefore do not interfere with thermal signatures of the defects.

2.2 Field Testing

Field testing was conducted on a particular steel bridge in the Bronx. This bridge serves as an overpass over Muliner Avenue for the MTA’s number 5 subway line. The bridge was chosen based on the visual inspection of protective paint as it appears to be representative of many locations. We were unable to verify when the bridge columns and beams were last repainted. Figure 3 depicts that protective coating on the columns and girders is in relatively good condition. Figure 3 also shows the paint on the deck beams is significantly deteriorated.

Figure 3. Overall bridge condition

Field testing was performed using the FLIR A320 infrared camera. In the field we used a portable heater instead of electric heaters to stimulate the studied surface. This substitution was made as the electric powered heater was impractical to power in the field.

We performed a few trials to image columns and one trial to image beams.

2.2.1 Column Inspection

The overall condition of the columns paint was good with few local areas of deterioration as shown in Figure 4. It appears to us that the paint on the column base has been repaired several times. Moreover, there is no visible corrosion on the repaired paint surface, except areas close to the interface between column and concrete abutment.

Figure 4. Bridge column typical conditions at base

We inspected the column surface utilizing the active thermography technique. Column inspection setup is shown in Figure 5. Painted surface was stimulated by portable heater. The inspected surface of column was approximately 6 ft away from imaging camera and heater.

Figure 5. Equipment setup for active thermography inspection of bridge steel column

2.2.2 Bridge Deck/Beam Inspection

Bridge deck/beams were inspected from below. The inspected surface of the beams was located at distance of 25 ft. Beams inspection setup is shown in Figure 6.

Figure 6. Equipment setup for thermography inspection of bridge steel beams

3 Results

3.1 Laboratory Test Results

We stimulated the coated surface with controlled remote heat input using the IR heaters and recorded the observed temperatures at the surface. The presence of the defects was pronounced by higher temperatures over defect areas. Figure 7 a) presents locations of simulated defects before the coating was applied Figure 7 b) presents the surface temperature of the plate after 30 seconds heat stimulation. Figure 7 c) presents temperature rise along reference lines after the surface was heat stimulated.

a)

b)

c)

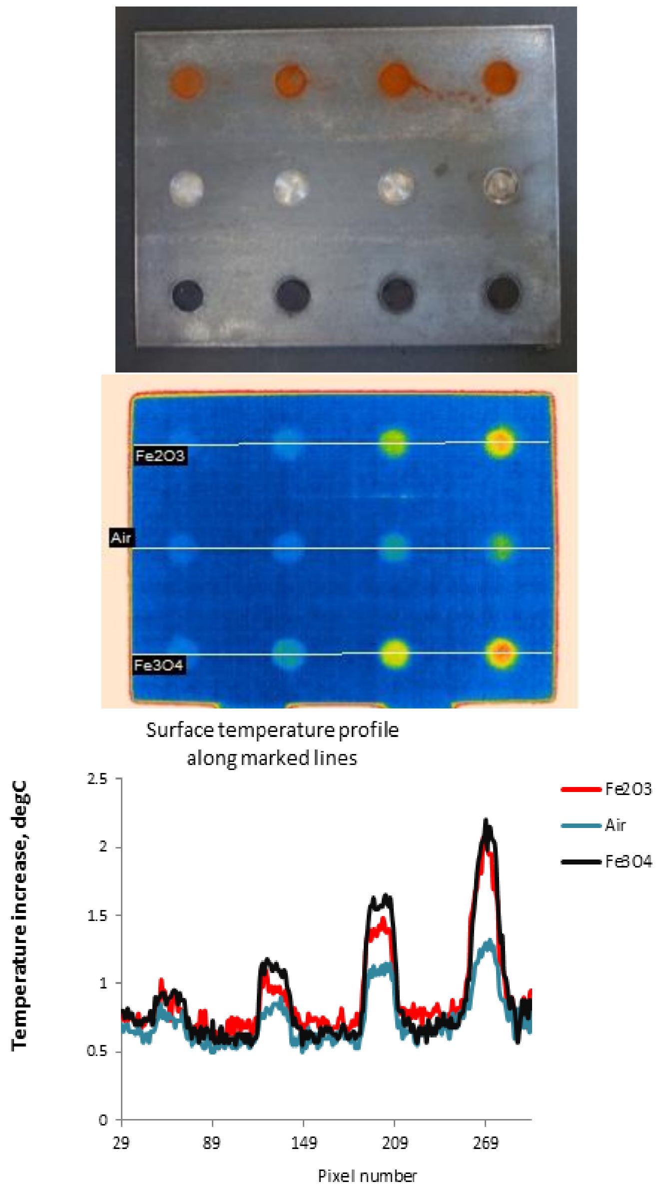


Figure 7. Laboratory test results: a) Plate with simulated defects before coating is applied; b) Surface temperature after heat stimulation; c) Temperature rise profile along the reference lines after heat stimulation

From the data it is clearly seen that defects under coating are detectable by the higher temperature rises. We observed that raised temperature over a defect area is related to the depth of the corresponding blind hole, but there is little differentiation between corrosion types.

Air under the coating resulted in the smaller temperature rise over defect. This is somewhat contradictory to our expectation; but this may be explained by the sagging of the adhesive paper that reduces air gap. Moreover, corrosion compounds are not flush with the plate surface and are on average thickness is the larger than predicted.

3.2 Field Tests Results

We performed the IR field testing during a cold day to amplify results of the active infrared imaging. In absence of the powerful electricity source we used the portable gas heater to stimulate the inspected surface. The heat rate of the heater was unmown and results below are limited to the defects detection only. Quantification of the defect thickness is out of the scope of this research work.

3.2.1 Column Inspection

Column inspection utilizing IR thermography reviled hidden defects under the paint. We imaged the surface temperature after repeating the heat stimulations. Repetitions were needed to cover the proposed inspection surface. Due to limitations of IR camera we divided inspected surface into zones. The IR images were matched to visual images by characteristic features (rivets in this case), which are distinctive in both image types.

Results of column inspection are shown in Figure 8 below. Figure 8 a) shows visual image of inspected surface, inspection zones, area of significant subsurface defects that was identified during IR imaging.

Figure 8 b) shows results of IR inspection of the zone 1 after first heat stimulation. Figure 8 c) shows results of IR inspection of the zone 2 after a second heat stimulation.

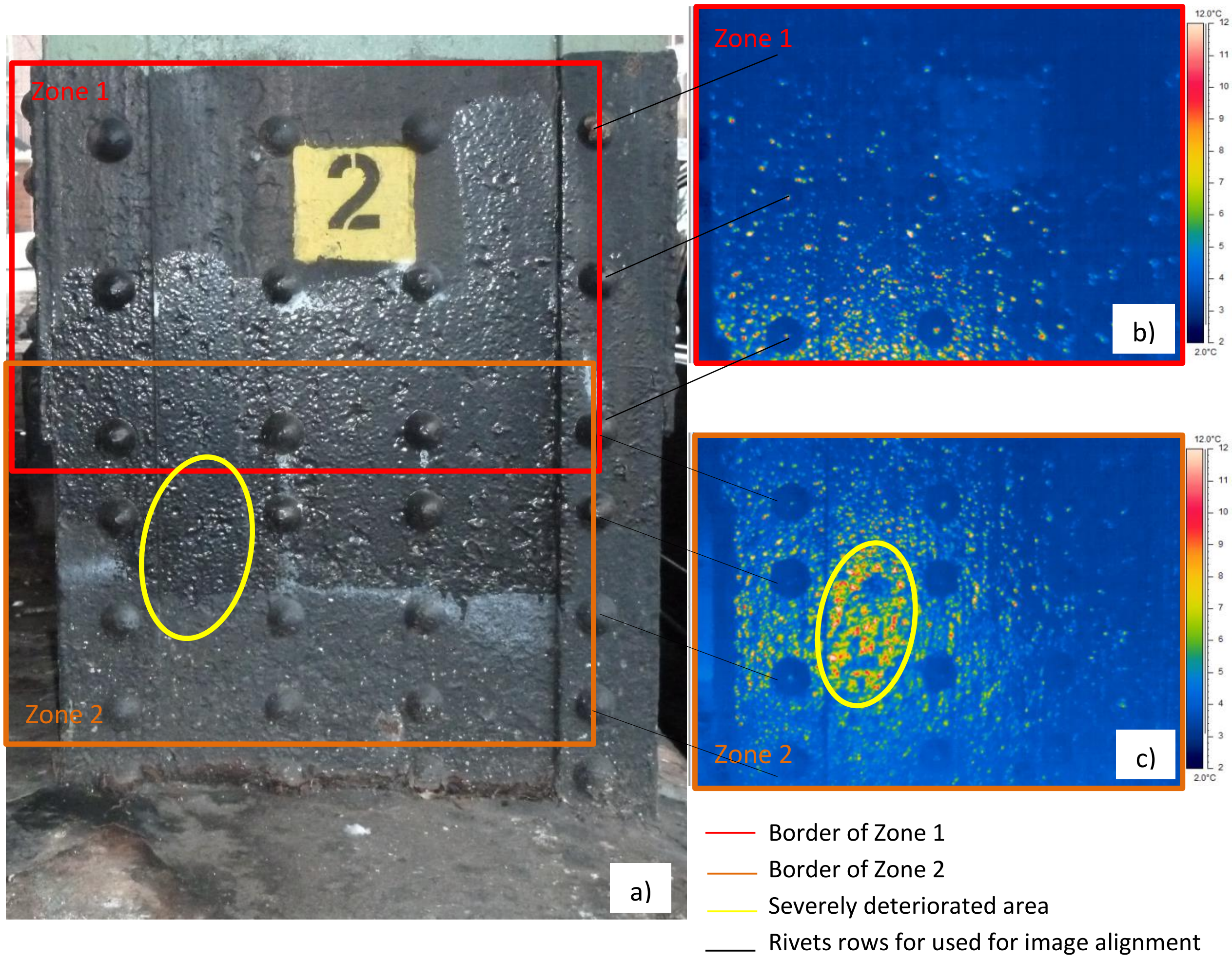


Figure 8. Column inspection: a) Visual image of column base; b) IR image of zone 1 at column base; c) IR image of Zone 2 at column base.

Visual inspection did not suggest any defects under the freshly painted column base. We assume that coating repair was done recently based on presence of shiny black paint. However, the IR inspection revealed a deteriorated area was in zone 2. We believe that the possible cause of defects is due to inadequate surface preparation before fresh paint was applied.

3.2.2 Beams inspection

Beam inspection did not resulted in detectable defects, even though coating deterioration was visibly observable as shown in Figure 9 b). It is attributed to the relatively large distance to inspected surface, low IR camera resolution and inability to stimulate the surface by heat at such remote distance.

a)

b)

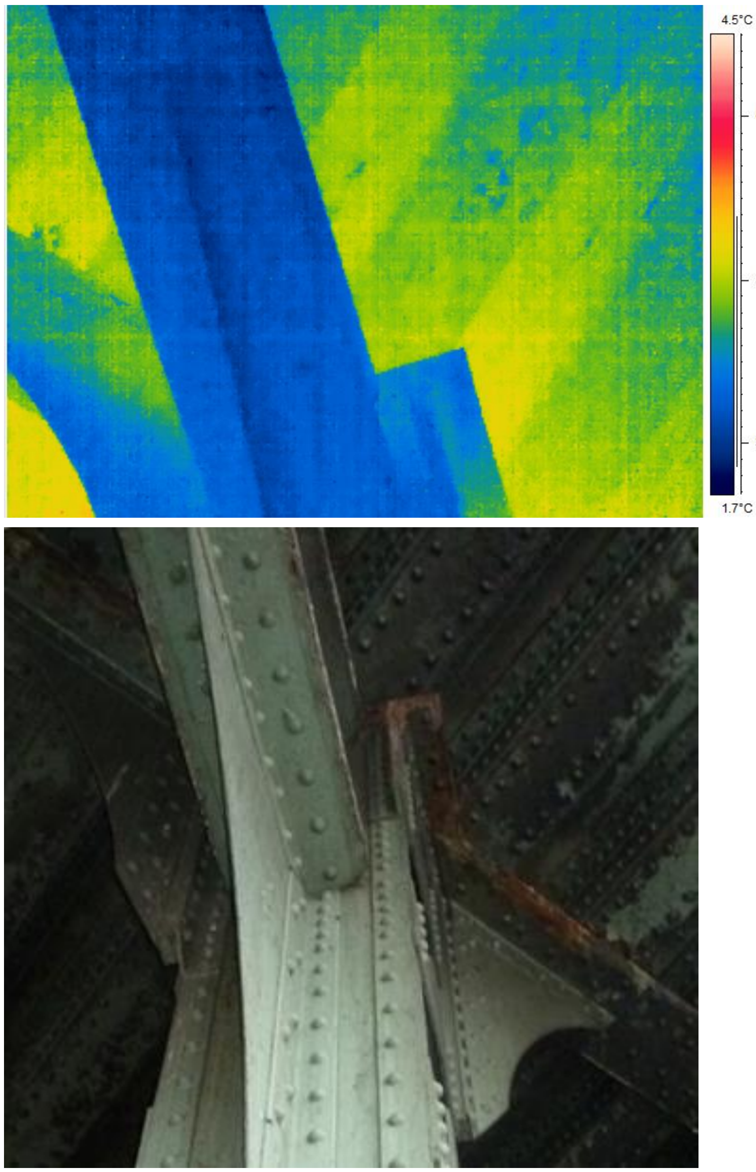


Figure 9. Deck beam IR inspection: a) Surface temperature after heat stimulation; b) Visible image of inspected area

4 Discussion

IR thermography inspection is capable to detect subsurface defects in steel column and beams of bridges. Subsurface defects may be detected remotely, but the distance between imaging system and inspected surface is limited.

It was also revealed that structural element shapes and complex connections of steel bridges create difficulties in surface temperature detection.

While IR thermography demonstrates relatively quick and visually comprehendible results, the post processing for quantities assessment of defects may be complex.

In sum, the current stage of the IR imaging at cannot be employed as the main tool for bridge inspections for defects under protective coatings. This testing will be very valuable tool for quality control after fresh painting of the steel girders or column sides that would have sides with minimal abstractions.

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