Micro-Abrasive Cleaning for Historic Brick

Investigating the Effectiveness of Graffiti Removal and Changes in Surface Characteristics

Ke-An Chiang

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M.S. in Historic Preservation with concentration in Architectural Conservation

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Micro-Abrasive Cleaning
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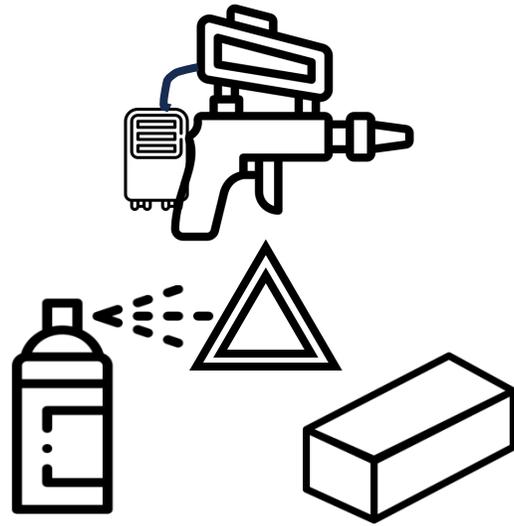Cleaning Test
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INTRODUCTION

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Micro-Abrasive Cleaning / Effectiveness / Historic Brick /
Graffiti Removal / Surface Color / Surface Texture

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GRAFFITI CHALLENGES

SPRAY PAINT GRAFFITI

- Thick paint coating with rapid application and strong adhesion

- May seep into historic masonry pores and become trapped

https://newatlas.com/graffiti-proofing-historic-buildings/12816/

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GRAFFITI CHALLENGES ON HISTORIC BRICK

SPRAY PAINT GRAFFITI

- Thick paint coating with rapid application and strong adhesion

- May seep into historic masonry pores and become trapped

HISTORIC BRICK

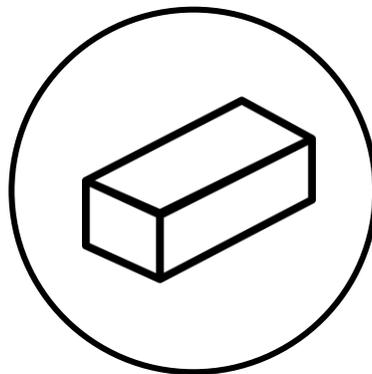- Pre-20th-century bricks with lower hardness, and higher porosity (compared to contemporary bricks), made more vulnerable by prolonged weathering

https://www.youtube.com/watch?v=QW5p-C4BohY
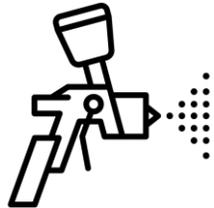
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TRENDS IN CLEANING TECHNIQUES

CHEMICAL CLEANING

- Dissolved paint and chemicals undesirably penetrate cracks
- Potential for direct exposure to toxic or harsh substances

SANDBLASTING (ABRASIVE CLEANING)

- Causes substantial alteration of surface texture
- Generates significant amounts of dust

PRESSURED WATER
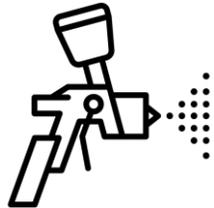
- Limited effectiveness- may leave a residue

POULTICING

- Time-consuming process

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TRENDS IN CLEANING TECHNIQUES

CHEMICAL CLEANING

SANDBLASTING (ABRASIVE CLEANING)

1990s-

MICRO-ABRASIVE CLEANING

PRESSURED WATER

LASER CLEANING

- Time-consuming
- May cause red brick discoloration

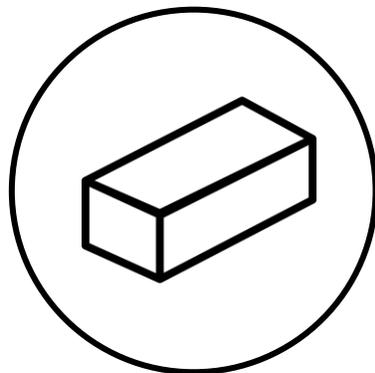**POULTICING**

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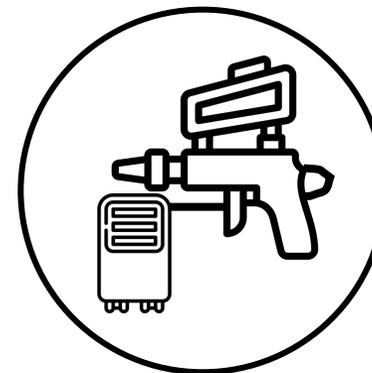
MICRO-ABRASIVE CLEANING FOR HISTORIC BRICK

SPRAY PAINT GRAFFITI

- Thick paint coating with rapid application and strong adhesion
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HISTORIC BRICK

- Pre-20th-century bricks with lower hardness, and higher porosity (compared to contemporary bricks), made more vulnerable by prolonged weathering
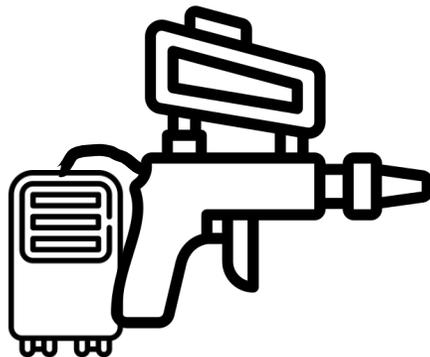
MICRO-ABRASIVE CLEANING

- A mechanical cleaning method using fine particles (typically 20-220 μm) at low pressure (below 50 psi) to remove paint through friction

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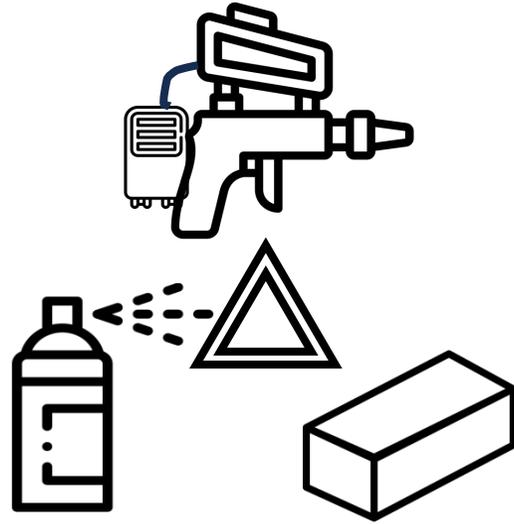# COMBINATION OF CLEANING TECHNIQUES

STEP 1

STEP 2

MICRO-ABRASIVE CLEANING

POULTICING

OR ?

- Alternating cleaning techniques helps reduce the risk of significant surface texture changes from using a single method

- Micro-abrasive cleaning can be used as the **first step** before poulticing or laser cleaning

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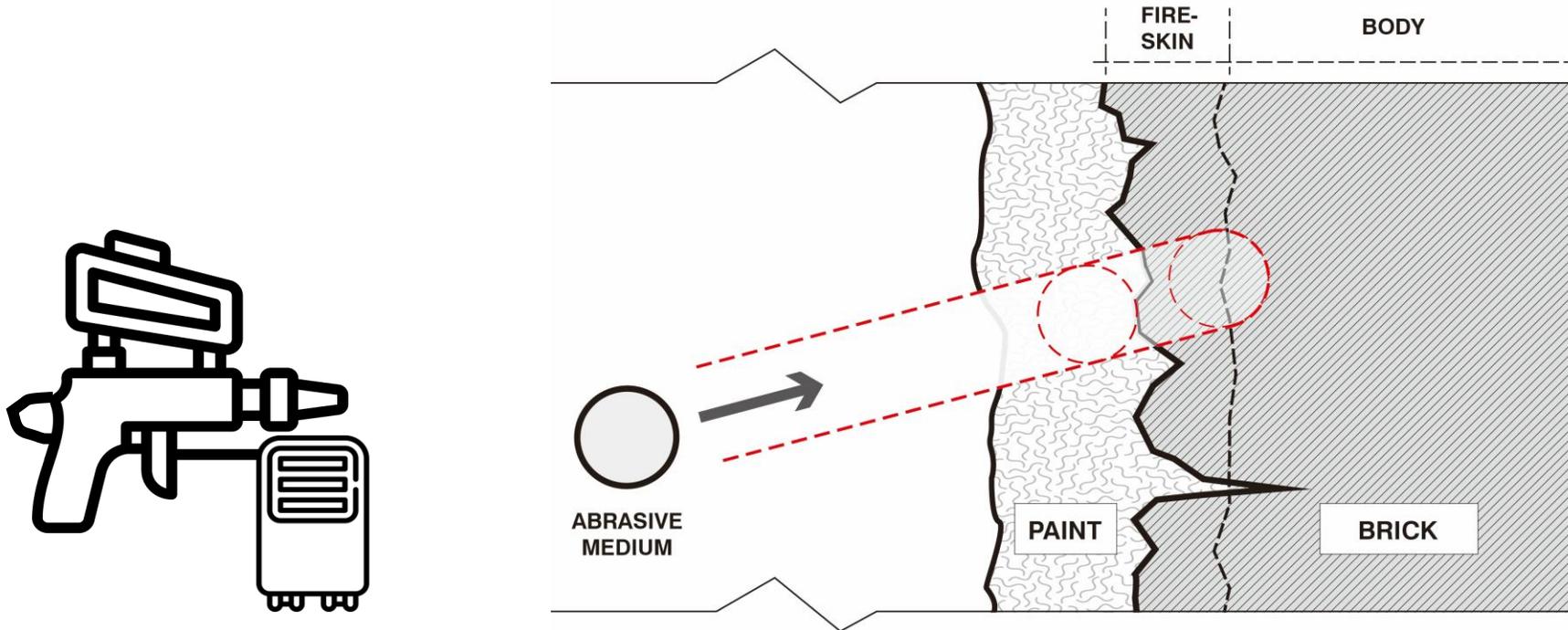SCHOOL OF DESIGN
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RESEARCH FOCUS

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RESEARCH QUESTION

FIRE-SKIN   BODY

ABRASIVE MEDIUM

PAINT   BRICK

How effective are micro-abrasive techniques in removing black spray paint graffiti from late 19th-century weathered machine-made red brick while **achieving visible cleanliness** with **minimal alteration to surface texture**?
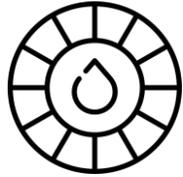
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RESEARCH QUESTIONS

How can spray **paint removal effectiveness** be assessed and defined specifically for late 19th-century weathered machine-made brick?
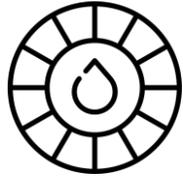
How can **surface texture changes** be measured and defined on historic weathered machine-made brick after micro-abrasive cleaning?

How do **instrumental assessments** correlate with **subjective sensory evaluations**, including tactile and visual assessment, and inform cleaning practices?

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Graffiti Removal / Surface Color / Surface Texture

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RESEARCH QUESTIONS

How can spray **paint removal effectiveness** be assessed and defined specifically for late 19th-century weathered machine-made brick?

- **Color change assessment**: "Testing Methods and Criteria for the Selection/Evaluation of Products for the Conservation of Porous Building Materials" (2006)– Tabasso & Simon
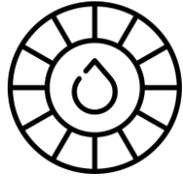
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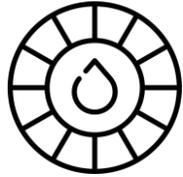
How can **surface texture changes** be measured and defined on historic weathered machine-made brick after micro-abrasive cleaning?

- "Measuring **Surface Roughness** on Stone: Back to Basics" (2000) – Grissom, Charola, et al.
- "A Topographical Assessment and Comparison of Conservation Cleaning Treatments" (2003) –Gaspar et al.

How do **instrumental assessments** correlate with **subjective sensory evaluations**, including tactile and visual assessment, and inform cleaning practices?

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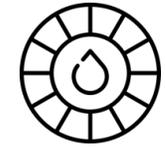
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METHODOLOGY

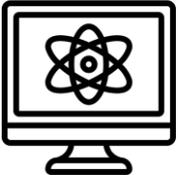| Name	Objective	Test samples	Scale
Spectrophotometric Assessment (Konica Minolta CM-17D)	Examine color changes (E*ab) before and after cleaning	A1a-A12a, A1b-A12b, B1a-B12a, B1b-B12b	3 mm diameter circle area
Surface roughness assessment (Keyence VK-X3100 Profilometer)	Examine surface roughness and 3D topographical changes before and after cleaning	A1a-A12a, A1b-A12b, B1a-B12a, B1b-B12b	36.5 cm² area
Tactile texture assessment	Examine texture changes before and after cleaning	A1a-A12a, A1b-A12b, B1a-B12a, B1b-B12b	3 x 6 cm square area
Visual evaluation	Examine changes in uncleanliness and fire-skin wear level before and after cleaning	A1a-A12a, A1b-A12b, B1a-B12a, B1b-B12b	3 x 6 cm square area

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METHODOLOGY

Name	Objective	Test samples	Scale
Photographic documentation	Record the surface changes before and after cleaning	A1a-A12a, A1b-A12b, B1a-B12a, B1b-B12b	Whole sample
Stereoscopic examination (Zeiss Stemi 305)	Record the surface changes before and after cleaning	A1a-A12a, A1b-A12b, B1a-B12a, B1b-B12b	2.1 mm x 1.8 mm square area
Scanning electron microscopy (SEM) imaging	Record paint layer and fire-skin thickness of brick A through morphology observation	AY1b (cross-section)	550.5 x 480 µm square area
Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS)	Examine the interface between the paint and brick based on elemental composition	AY1b (cross-section)	890 µm line scan

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METHODOLOGY

Name	Objective	Test samples	Scale
Total immersion test	Record the porosity of brick A (following ASTM C97-96 standard)	AX1-4	2 x 2 x 2 inch cube (50.8 x 50.8 x 50.8 mm)
Wet tile saw cutting (Mason-Mite II)	Cut brick A into a small cross-section for SEM evaluation and precise cubes for total immersion tests	AX1-4, AY1a, AY1b	—
Spray paint application			
Micro-abrasive cleaning test (IBIX)	Clean black spray paint on brick samples	A1a-A12a, A1b-A12b, B1a-B12a, B1b-B12b	3 x 6 cm square area

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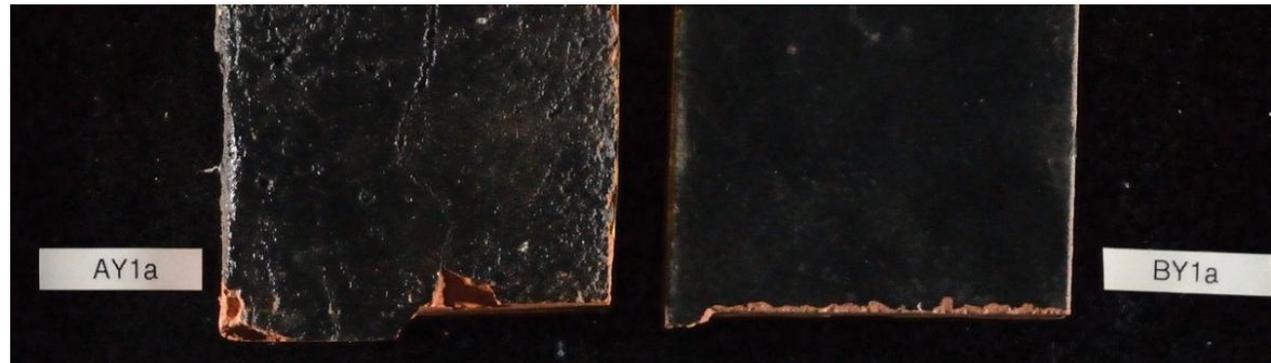Micro-Abrasive Cleaning / Effectiveness / Historic Brick / Graffiti Removal / Surface Color / Surface Texture

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MATERIALS SELECTION

BLACK AEROSOL SPRAY PAINT

Styrene-modified alkyd binder and nitrocellulose formulation

MACHINE-MADE RED BRICK

Sourced from a demolished Bridgeport, PA 1870s residence

CONTEMPORARY RED BRICK

IBIX MICRO-ABRASIVE MACHINE

Employs a mixture of air and micro-grained abrasive mediums

OOLITIC ARAGONITE

Marine-derived spherical crystalline calcium carbonate with a hardness of 3.5–4 (Mohs) as abrasive medium

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MATERIAL SELECTION

**BLACK AEROSOL
SPRAY PAINT**

Styrene-modified
alkyd binder and
nitrocellulose
formulation

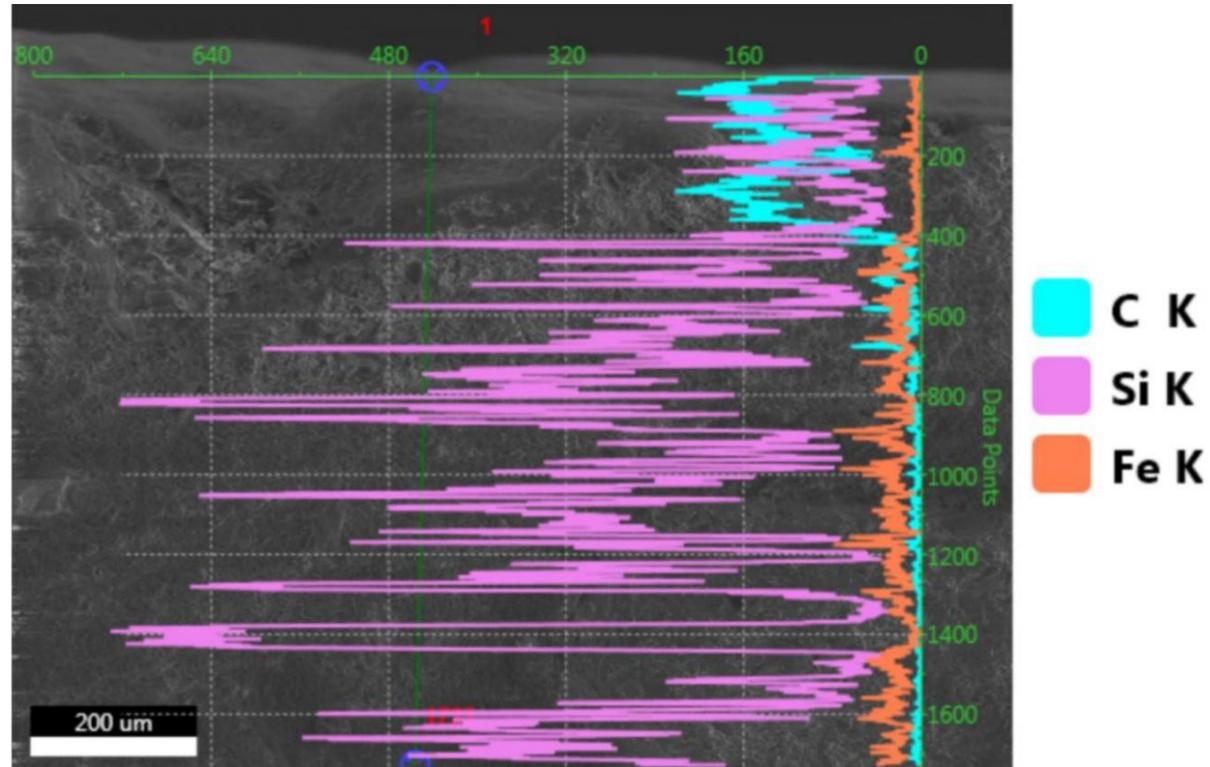| Spray paint	Thickness	Formulation	Elements	Texture
Montana BLACK (BLK409-9001 Black)	90-150 µm	Styrene-modified alkyd binder and nitrocellulose	Carbon (C), oxygen (O), nitrogen (N), silicon (Si), barium (Ba), sulfur (S), aluminum (Al), titanium (Ti), iron (Fe), magnesium (Mg)	Matte with a subtle sheen

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MATERIAL SELECTION

**BLACK AEROSOL
SPRAY PAINT**

Styrene-modified
alkyd binder and
nitrocellulose
formulation

SEM-EDS Line Scan

C K
Si K
Fe K

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MATERIAL SELECTION

MACHINE-MADE RED BRICK
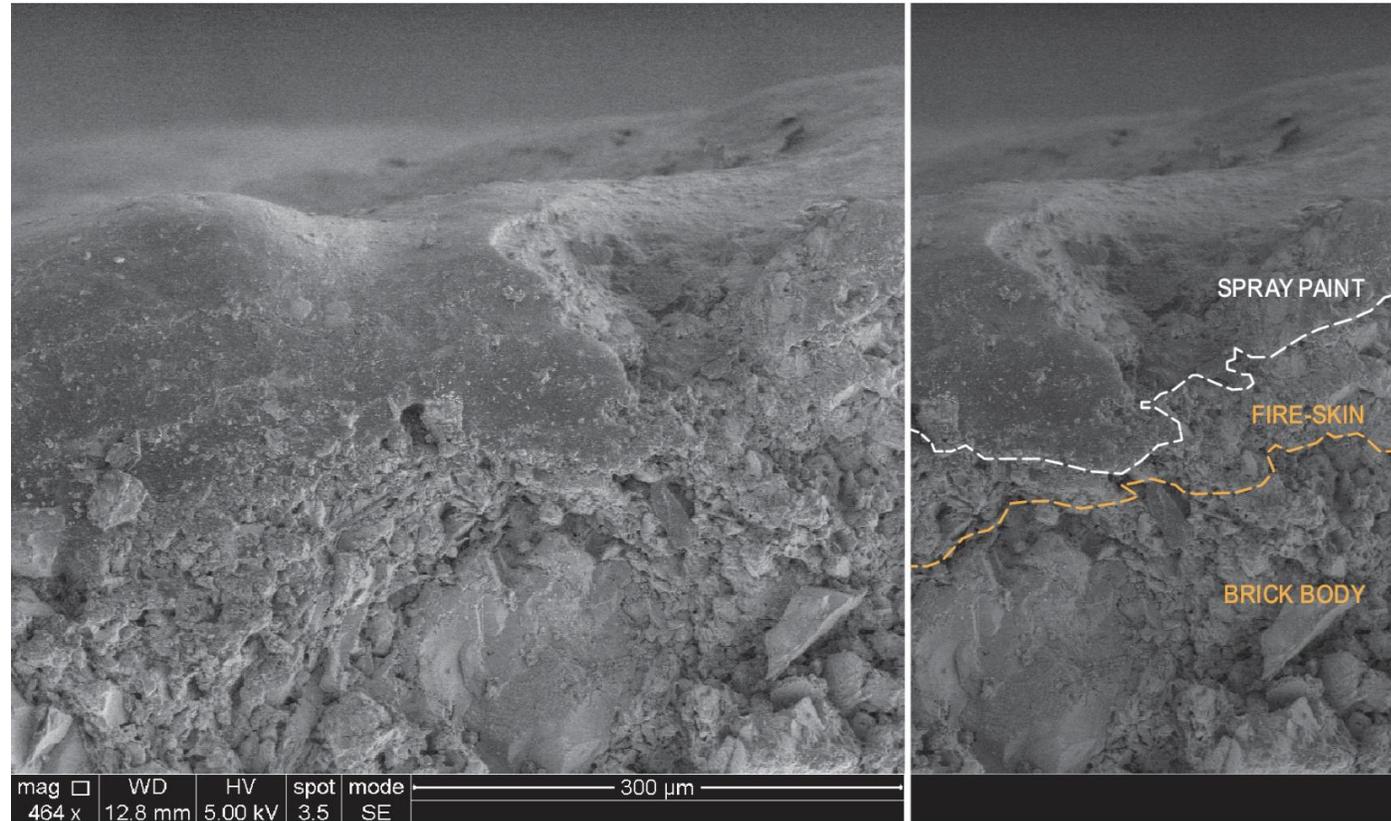
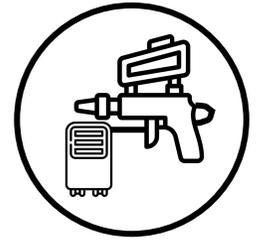Sourced from a demolished Bridgeport, PA 1870s residence

CONTEMPORARY RED BRICK

Brick	Texture (description)	Tactile texture (grit)	Hardness (Mohs)	Porosity	Fire-skin thickness
Brick A (salvage machine-made brick)	Fire-skin is mostly smooth, with minor fissures	320-500	3	Approx. 9.1-9.4%	22-67 μm
Brick B (contemporary brick)	Smooth with slight granularity	500	5	Under 8%	Not determined (focus is on Brick A)

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MATERIAL SELECTION

MACHINE-MADE RED BRICK

Sourced from a demolished Bridgeport, PA 1870s residence

CONTEMPORARY RED BRICK

SPRAY PAINT

FIRE-SKIN

BRICK BODY

| mag □ | WD | HV | spot | mode | 300 µm |
| 464 x | 12.8 mm | 5.00 kV | 3.5 | SE | |

SEM Imaging

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MATERIAL SELECTION

Abrasive medium	Chemical composition	Morphology	Granulometry	Hardness (Mohs)
Oolitic aragonite	CaCO$_3$	Spherical (orthorhombic, bipyramidal crystals)	150-360 µm	3.5-4

IBIX MICRO-ABRASIVE MACHINE

Employs a mixture of air and micro-grained abrasive mediums

OOLITIC ARAGONITE

Marine-derived spherical crystalline calcium carbonate with a hardness of 3.5–4 (Mohs) as abrasive medium

500 µm

Oolitic aragonite paticles under steroscope

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TESTING

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CLEANING TEST PAREMETERS

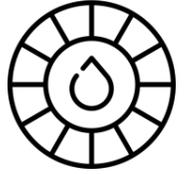| Test substrate	Test parameters					
	Pre-cleaning condition	Micro-abrasive system	Abrasive medium	Distance and angle	Pressure	Cleaning duration
Brick A (salvage machine-made brick)	Dry	IBIX; 2mm cylindrical nozzle	Oolitic aragonite	60 cm (23.5 in), 75°	2 bar (0.2 MPa)	30 s
Brick B (contemporary brick)	Wet (spray with water)				2.5 bar (0.25 MPa)	50 s
2 ×	2 ×	1 ×	1 ×	1 ×	2 ×	2
						= 16
Number of tests:				16 ×	3 =	48

← Visually clean threshold

CLEANING TEST PAREMETERS

Test substrate	Test parameters					
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2	× 2	× 1	× 1	× 1	× 2	× 2
						= 16
Number of tests:				16	× 3	= 48

Visually clean threshold

- "Microblasting Cleaning for Façade Repair and Maintenance: Selecting Technical Parameters for Treatment Efficiency" (2015) – Iglesias-Campos et al.

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CLEANING SETUP

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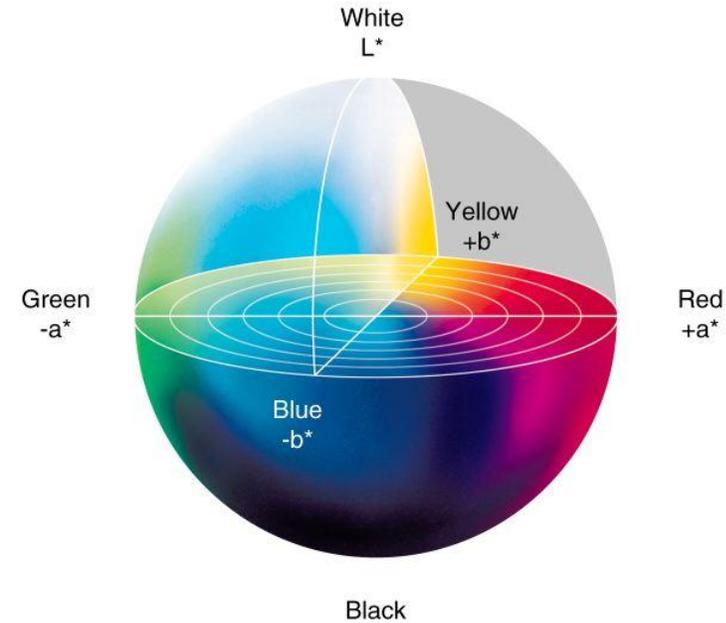
EVALAUATION

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PAINT RESIDUE ASSESSMENT

SPECTROPHOTOMETER & CIELAB COLOR SPACE
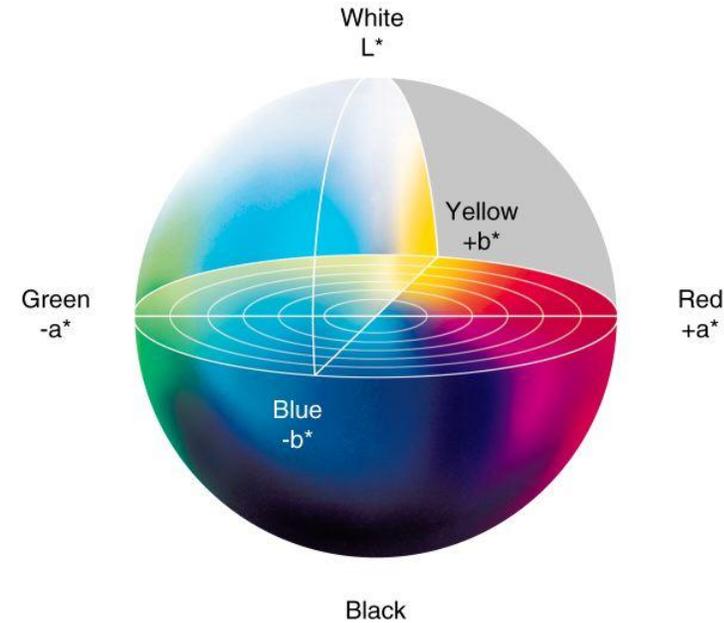
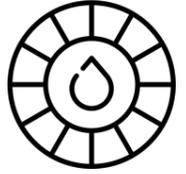It measures color by analyzing light absorption and reflection across multiple wavelengths

$$\Delta E^* = \sqrt{(L_2{}^* - L_1{}^*)^2 + (a_2{}^* - a_1{}^*)^2 + (b_2{}^* - b_1{}^*)^2}$$

Where $L_1{}^*$, $a_1{}^*$, $b_1{}^*$ are the CIELAB values of the original surface before cleaning. $L_2{}^*$, $a_2{}^*$, $b_2{}^*$ are the CIELAB values of the cleaned surface.

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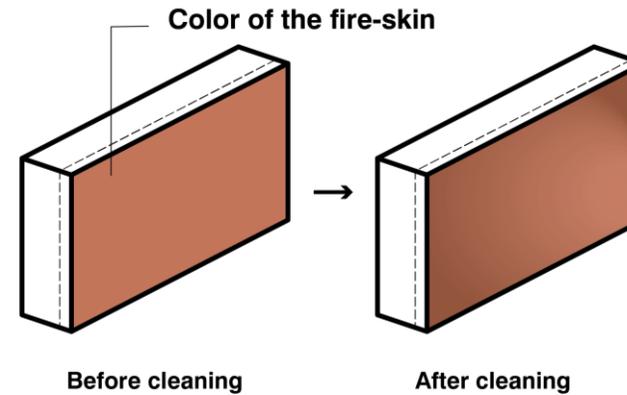
PAINT RESIDUE ASSESSMENT

SPECTROPHOTOMETER & CIELAB COLOR SPACE

It measures color by analyzing light absorption and reflection across multiple wavelengths

$$RS = \frac{(\Delta E *_{ab})_c}{(\Delta E *_{ab})_s} \times 100\%$$

Where $(\Delta E*_{ab})_c$ represents the color difference between the cleaned surface and the unpainted brick surface, and $(\Delta E*_{ab})_s$ represents the color difference between the painted surface and the unpainted brick surface.

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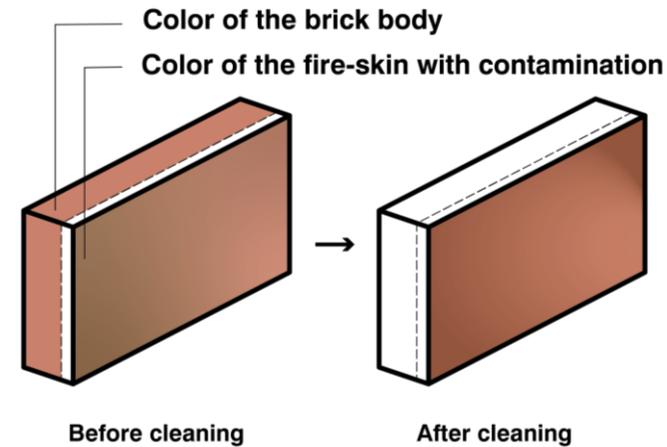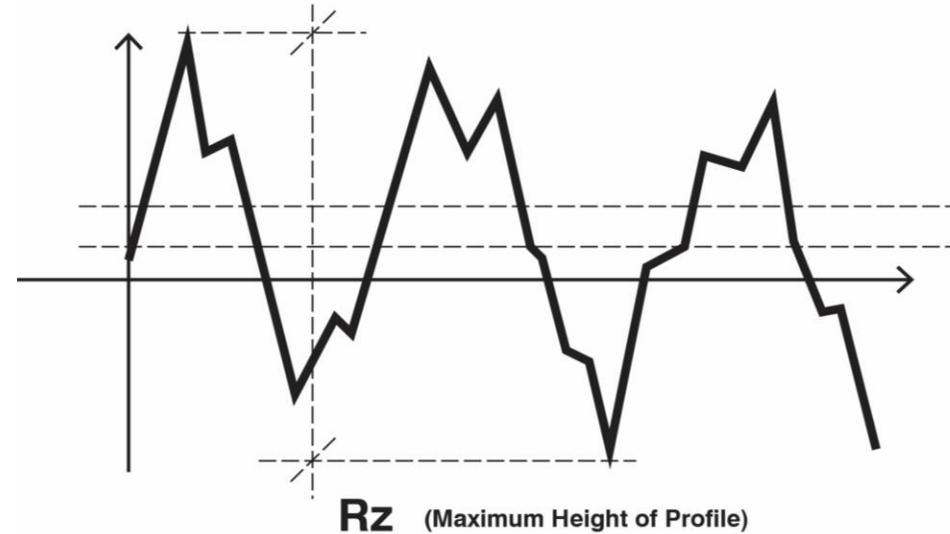
PAINT RESIDUE ASSESSMENT

SPECTROPHOTOMETER & CIELAB COLOR SPACE

It measures color by analyzing light absorption and reflection across multiple wavelengths

IDEAL SITUATION

Color of the fire-skin

Before cleaning → After cleaning

PRACTICAL SITUATION

Color of the brick body
Color of the fire-skin with contamination

Before cleaning → After cleaning

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SURFACE ROUGHNESS ASSESSMENT

(Root Mean Square Roughness)
Rq / Sq
Ra / Sa
(Arithmetic Mean Roughness)

Rz (Maximum Height of Profile)

OPTICAL PROFILOMETER

It measures surface roughness
by scanning height variations
with light-based technologies

$$Sq = \sqrt{\frac{1}{A} \sum_{i=0}^{n} Z_i^2}$$

Where Z_i represents the height of each point, and A is the total measurement area.

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VISUAL & TACTILE ASSESSMENT

VISUAL EVALUATION FRAMEWORK

Fire-skin wear

6	Fully worn	no visible fire-skin remains, exposing the underlying brick structure
5	Largely worn	only small specks of fire-skin remain
4	Locally worn	some scattered areas of fire-skin remain with significant loss
3	Partially worn	fire-skin remains in small areas
2	Minimally worn	fire-skin remains in large areas with some localized loss
1	Mostly intact	fire-skin remains nearly intact with minimal loss

higher level of wear

Uncleanliness

5	Locally Unclean	no visible fire-skin remains, exposing the underlying brick structure
4	Partially Unclean	only small specks of fire-skin remain
3	Mostly Clean	with localized black specks larger than 1mm in diameter
2	Clean (ER)	minor black residue along the edges
2	Clean (TS)	with tiny specks <0.5mm in diameter
1	Clean	no visible black marks

higher level of unclean-liness

TACTILE EVALUATION BASIS

Sandpaper grit	CAMI conversion (µm)
60	268.00
80	192.00
120	116.00
150	93.00
180	78.00
220	66.00
280	44.00
320	36.00
360	28.80
400	23.60
500	19.70

rough

fine

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RESULTS & CONCLUSION

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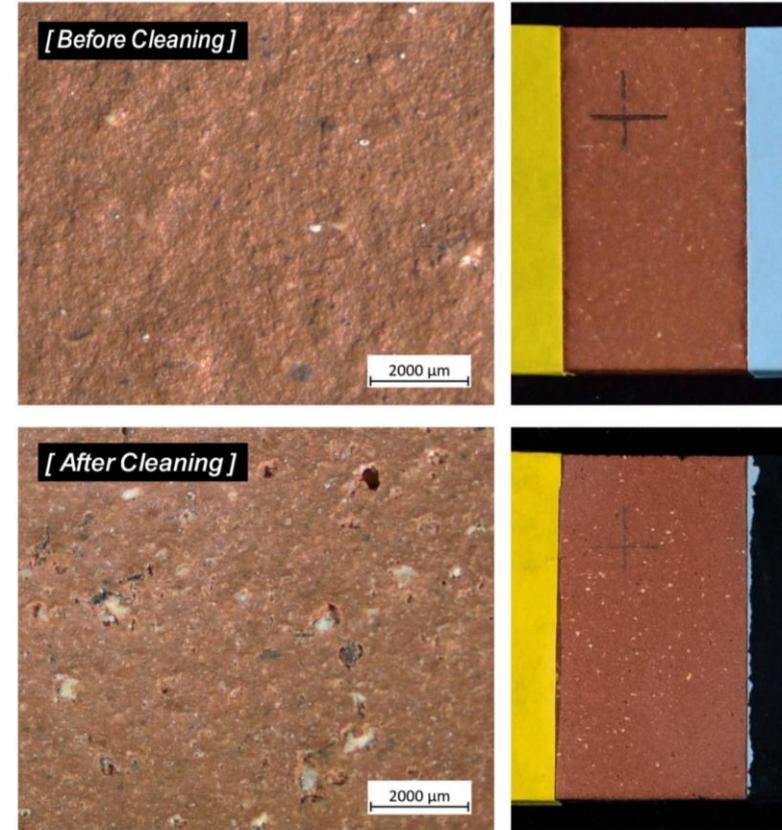Graffiti Removal / Surface Color / Surface Texture

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VISUAL EVALUATION

MACHINE-MADE BRICK
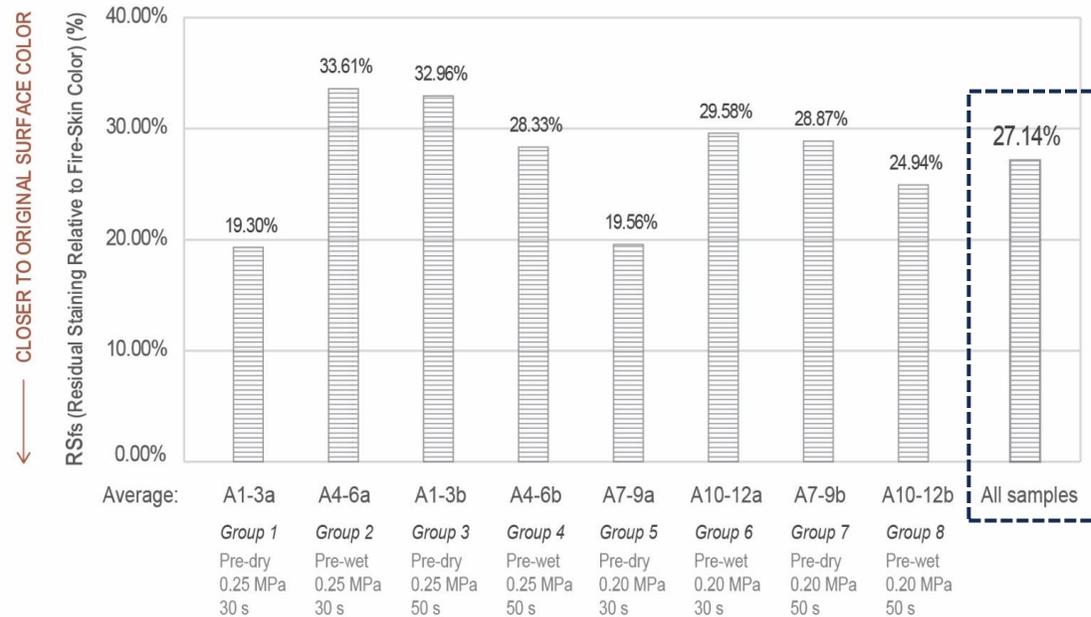

(Sample A3a)

CONTEMPORARY BRICK

(Sample B3a)

- **Fire-skin loss** was significantly greater on historic brick than on contemporary brick

- **Black paint residue** was more visible on historic brick than on contemporary brick
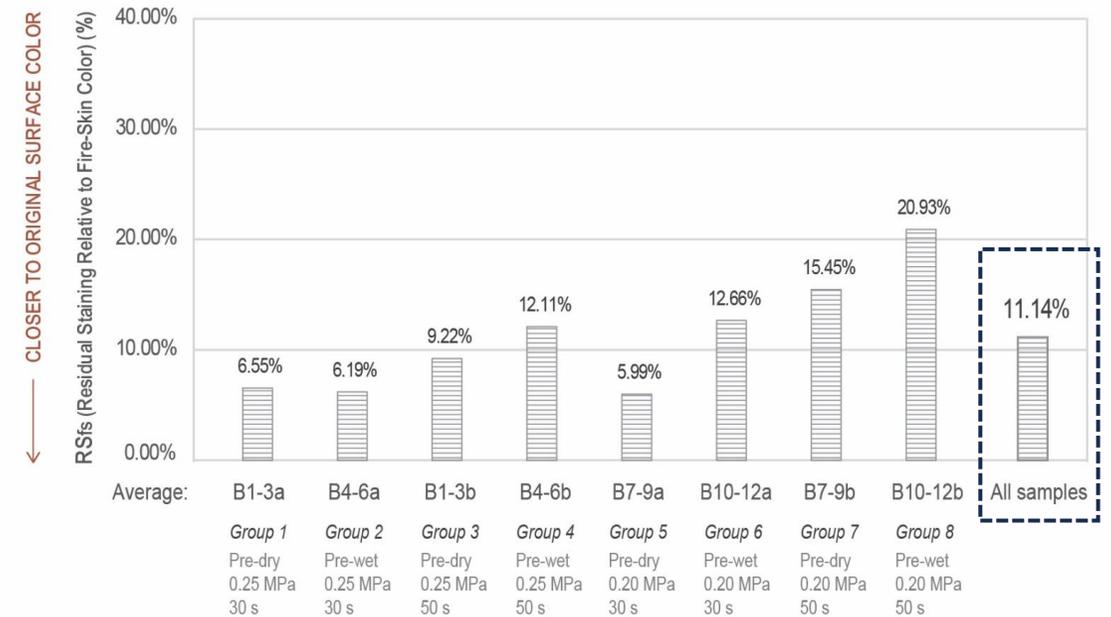
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PAINT REMOVAL EFFECTIVENESS

Brick A (Machine-Made) - Paint Removal Efficacy
Based on Residual Staining Relative to Pre-Cleaning Fire-Skin Color

Brick B (Contemporary) - Paint Removal Efficacy
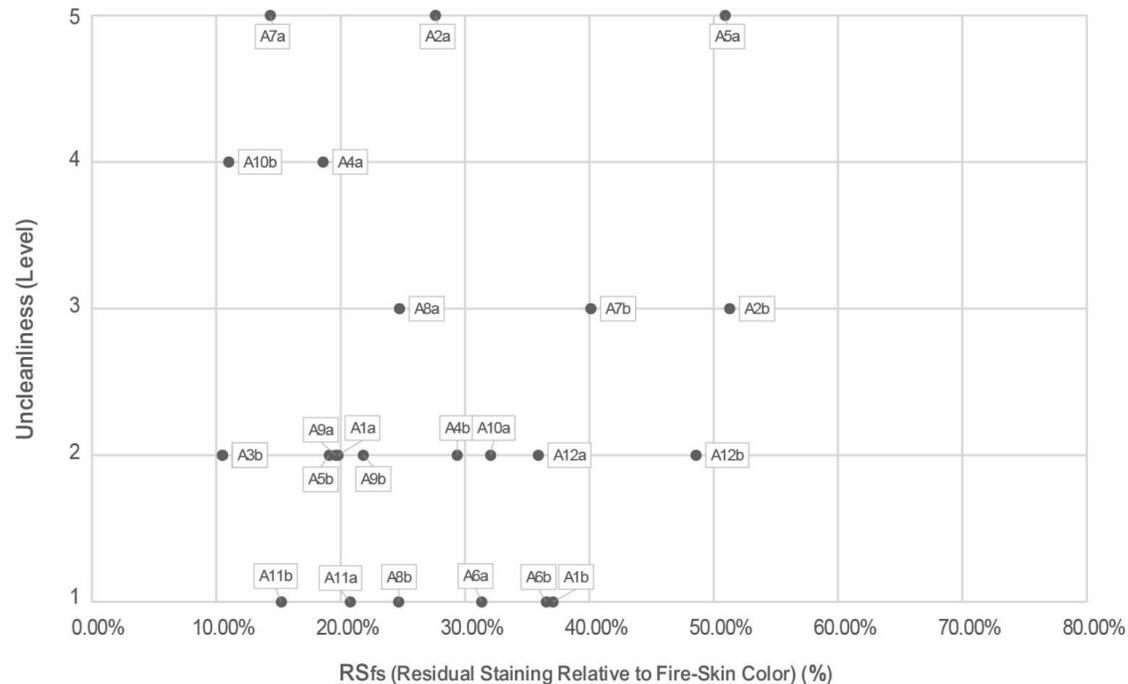Based on Residual Staining Relative to Pre-Cleaning Fire-Skin Color

- RSfs (residual staining referenced to the pre-cleaning surface) on historic brick is approximately 15% higher than that of contemporary brick, averaging around 27%

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PAINT REMOVAL EFFECTIVENESS

REFERENCE VALUE: FIRE-SKIN COLOR

REFERENCE VALUE: BRICK BODY COLOR

Brick A (Machine-Made) - Cleaning Evaluation
Unclear Relationship of Residual Staining (Relative to Fire-Skin Color) and Visual Uncleanliness

Brick A (Machine-Made) - Cleaning Evaluation
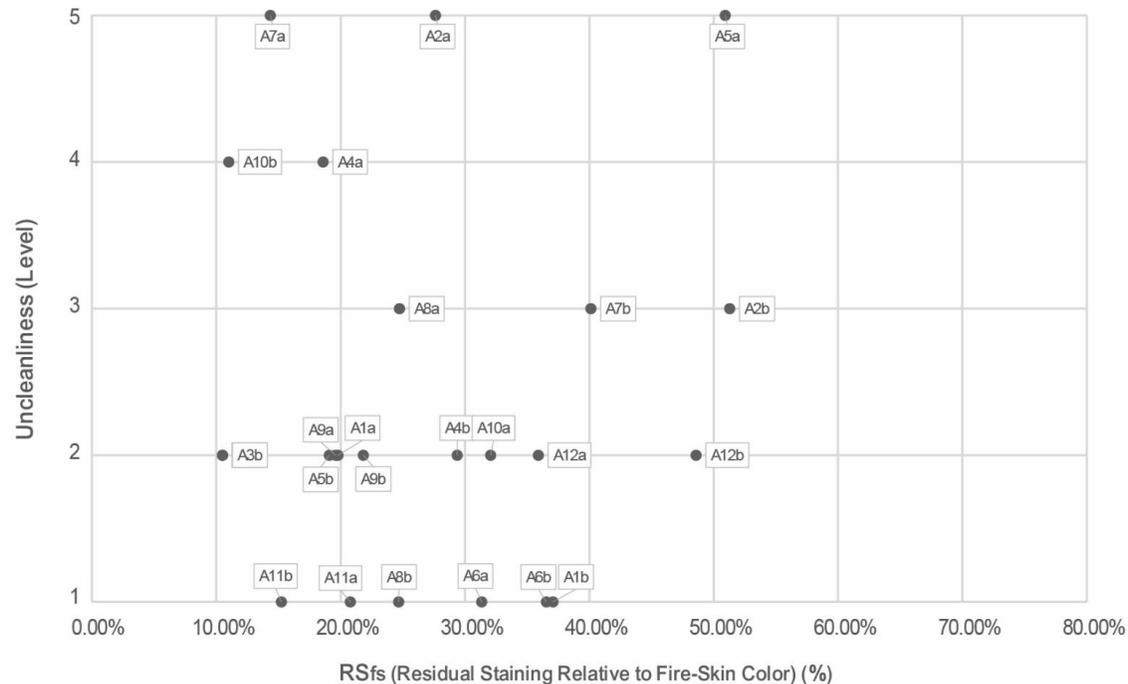Direct Relationship of Residual Staining (Relative to Brick Body Color) and Visual Uncleanliness

$y = 6.6199x + 1.5406$

- RSfs (residual staining referenced to the pre-cleaning surface) may have been influenced by long-term soiling and weathering

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PAINT REMOVAL EFFECTIVENESS

REFERENCE VALUE: FIRE-SKIN COLOR
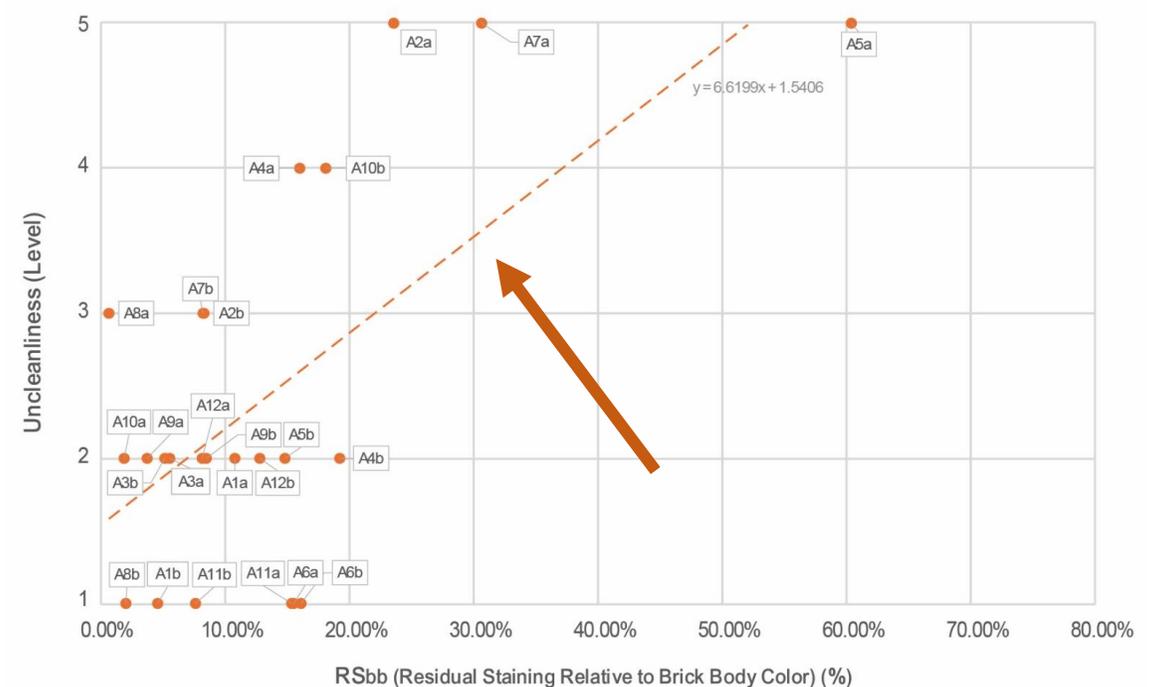

Brick A (Machine-Made) - Cleaning Evaluation
Unclear Relationship of Residual Staining (Relative to Fire-Skin Color) and Visual Uncleanliness
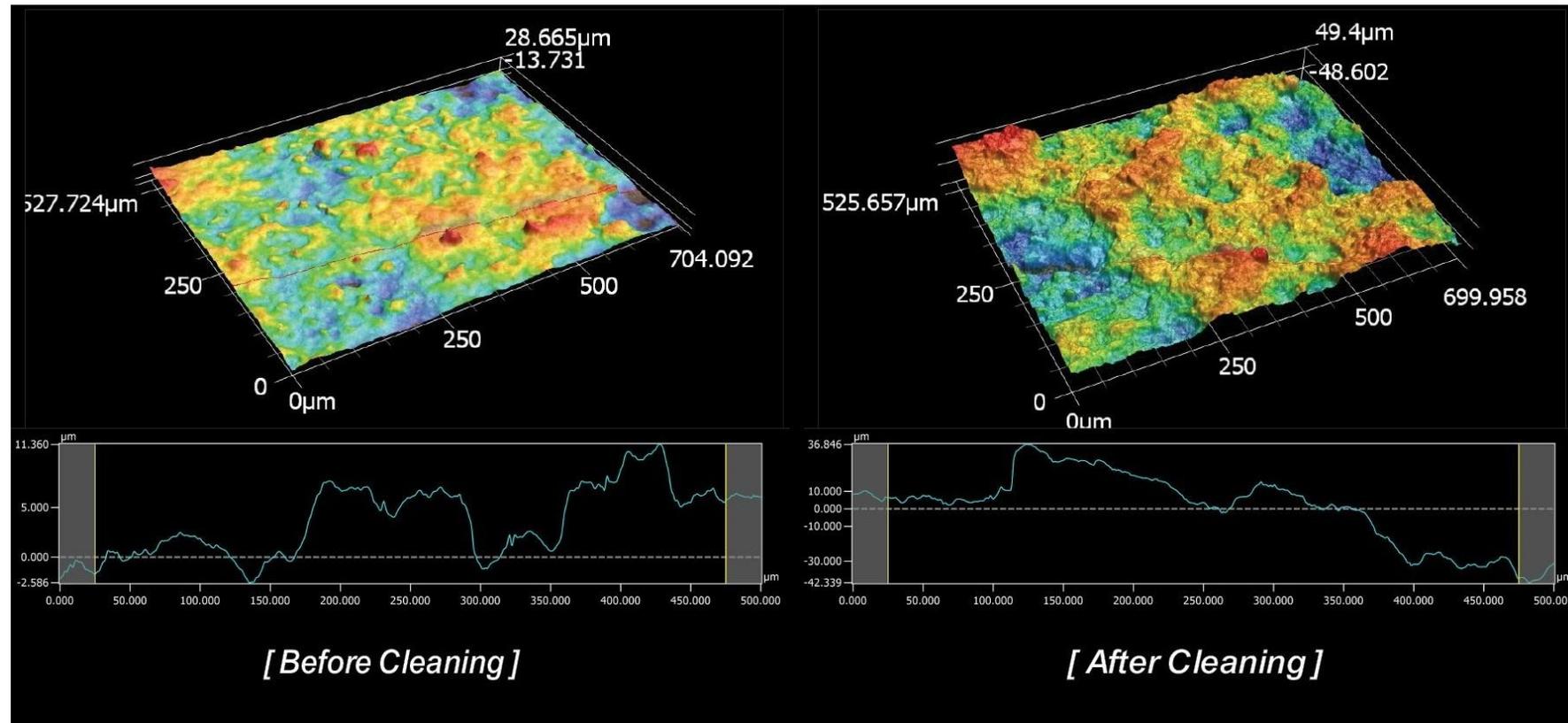
REFERENCE VALUE: BRICK BODY COLOR

Brick A (Machine-Made) - Cleaning Evaluation
Direct Relationship of Residual Staining (Relative to Brick Body Color) and Visual Uncleanliness

$y = 6.6199x + 1.5406$

- RSfs (residual staining referenced to the pre-cleaning surface) may have been influenced by long-term soiling and weathering

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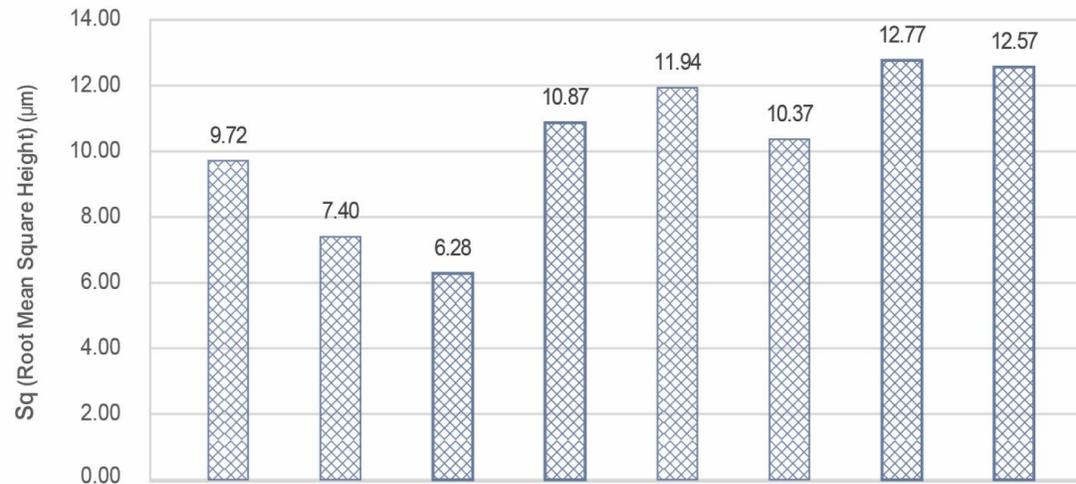Micro-Abrasive Cleaning / Effectiveness / Historic Brick /
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SURFACE ROUGHNESS CHANGE EVALUATION

[Before Cleaning]   [After Cleaning]

(Sample A8a)

- Surface roughness (Rq/Sq) increased by $\sim$6–13 μm after reaching visual cleanliness

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SURFACE ROUGHNESS CHANGE EVALUATION

Brick A (Machine-Made) - Surface Roughness Change
Based on Sq (Root Mean Square Height) Area Measurement

Brick B (Contemporary) - Surface Roughness Change
Based on Sq (Root Mean Square Height) Area Measurement

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SURFACE ROUGHNESS CHANGE EVALUATION

Brick A (Machine-Made) - Surface Roughness Change
Based on Sq (Root Mean Square Height) Area Measurement

Brick B (Contemporary) - Surface Roughness Change
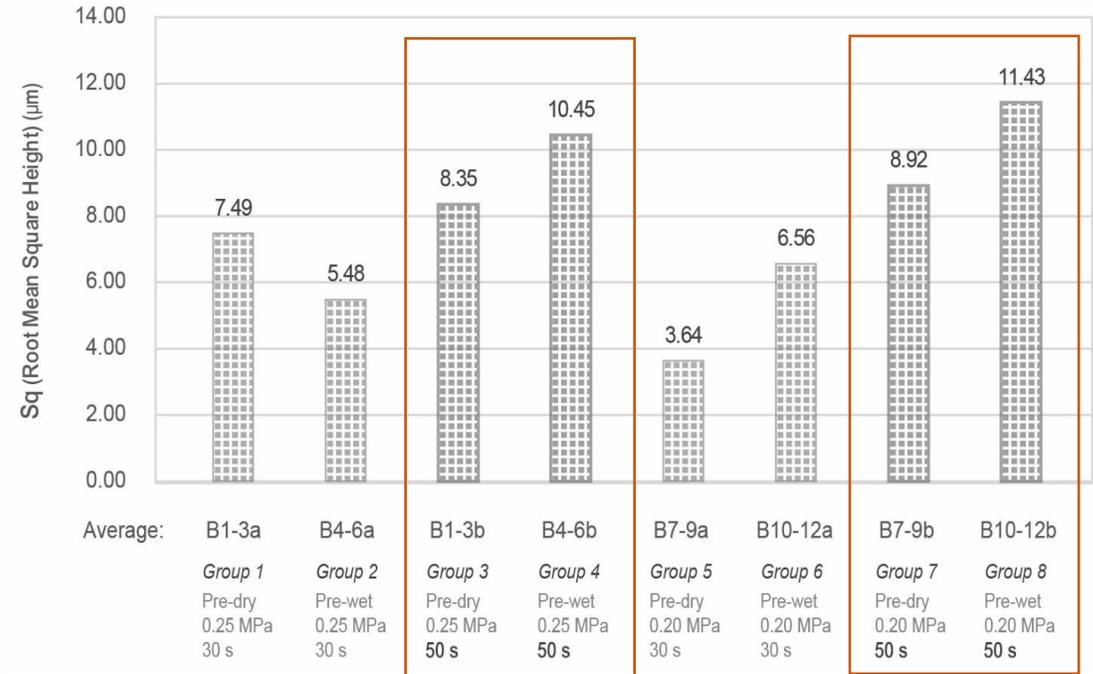Based on Sq (Root Mean Square Height) Area Measurement

- Longer cleaning (+20s) increased surface roughness more than pressure changes (±0.05 MPa) or pre-wetting

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SURFACE TEXTURE EVALUATION

Brick A (Machine-Made) - Roughness Change Evaluation
Unclear Relationship of Sq Roughness Change and Visual Fire-Skin Wear

Brick B (Contemporary) - Roughness Change Evaluation
Unclear Relationship of Sq Roughness Change and Visual Fire-Skin Wear

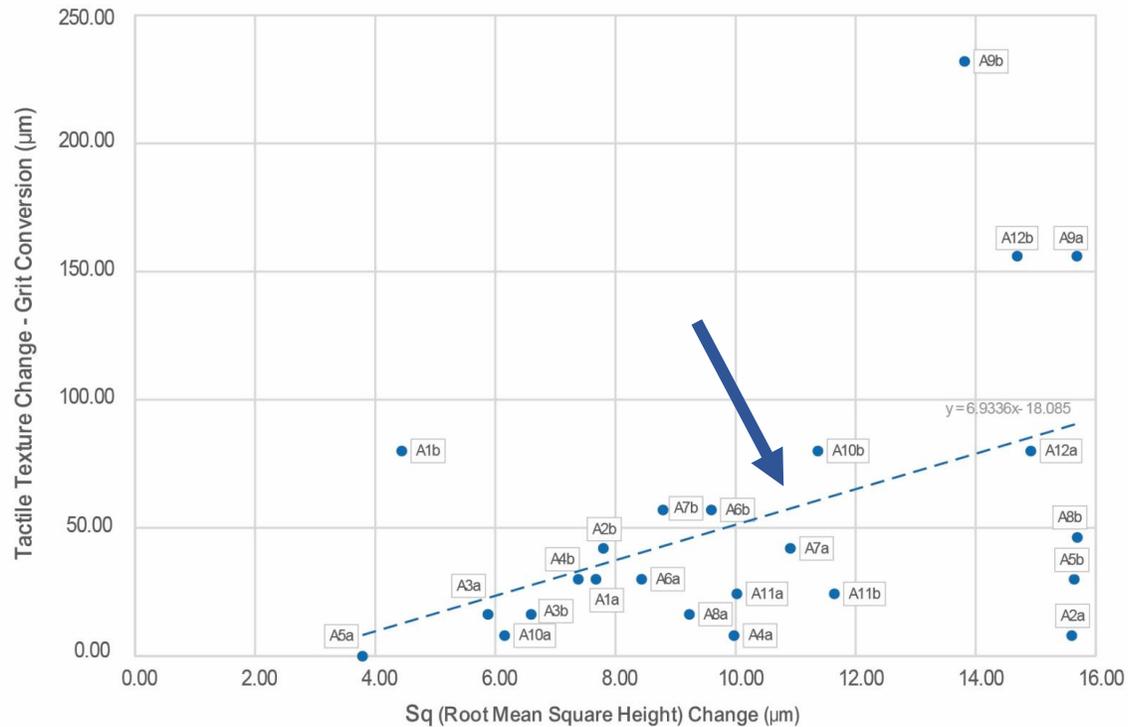- Surface roughness change values may not indicate the extent of fire-skin loss

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SURFACE TEXTURE EVALUATION

Brick A (Machine-Made) - Texture Change Evaluation
Direct Relationship of Sq Roughness Change and Tactile Texture Change

Brick A (Machine-Made) - Fire-Skin Wear Evaluation
Direct Relationship of Visual Fire-Skin Wear and Tactile Texture Change

- Tactile assessment may be effective in detecting both subtle roughness changes and visible fire-skin wear

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SURFACE TEXTURE EVALUATION

TACTILE ASSESSMENT

Brick A

	Difference
	Δ CAMI conversion (μm)
A1a	30.00
A1b	80.00
A2a	8.00
A2b	42.00
A3a	16.30
A3b	16.30

Brick B

	Difference
	Δ CAMI conversion (μm)
B1a	0.00
B1b	0.00
B2a	0.00
B2b	0.00
B3a	0.00
B3b	3.90

- Tactile differences in two brick texture may relate to the spacing of surface irregularities

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SURFACE TEXTURE EVALUATION

TACTILE ASSESSMENT

Brick A

	Difference
	Δ CAMI conversion (μm)
A1a	30.00
A1b	80.00
A2a	8.00
A2b	42.00
A3a	16.30
A3b	16.30

Brick B

	Difference
	Δ CAMI conversion (μm)
B1a	0.00
B1b	0.00
B2a	0.00
B2b	0.00
B3a	0.00
B3b	3.90

Surface Texture Change of Brick A and B
Based on Sa, Sq, Sz, Spd Area Measurement/ Keyance Profilometry

- Tactile differences in two brick texture may relate to the spacing of surface irregularities
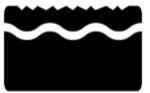
SUMMARY OF FINDINGS

- Fire-skin loss was significantly greater on historic brick than on contemporary brick

- RSfs (residual staining referenced to the pre-cleaning surface) on historic brick is approximately 15% higher than that of contemporary brick, averaging around 27%
- RSfs (residual staining referenced to the pre-cleaning surface) may have been influenced by long-term soiling and weathering

- Surface roughness (Rq/Sq) increased by $\sim$6–13 μm after reaching visual cleanliness
- Longer cleaning (+20s) increased surface roughness more than pressure changes ($\pm$0.05 MPa) or pre-wetting
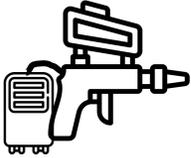- Surface roughness change values may not directly indicate the extent of fire-skin loss

- Tactile differences in two brick texture may relate to the spacing of surface irregularities
- Tactile assessment may be effective in detecting both subtle roughness changes and visible fire-skin wear

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RECOMMENDATIONS FOR FUTURE RESEARCH

- Broaden parameter testing and sample numbers to improve consistency and reliability of results

- Investigate equipment-related factors to enhance pressure stability during cleaning

- Study the effects of paint aging on adhesion and penetration to inform more effective graffiti removal strategies

- Investigate alternative or complementary surface assessment methods beyond roughness metrics to better capture material texture and condition

- Identify complementary techniques to remove residual paint with minimal surface impact

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Thank you for listening!

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