Evaluating Non-Invasive and Micro-Invasive Analytical Techniques for Investigating Twentieth-Century Architectural Finishes

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The Berlin Modernism Housing Estates, recognised as UNESCO World Heritage Sites, were built during the interwar period and profoundly influenced twentieth-century modernist architecture. Restoration of these surfaces today raises a key question for the monument conservation practice: **"What did the colours and finishes look like at the time of construction?"** Stemming from this question, this study addresses two central issues: **(1) the composition of the construction phase paints and (2) the most suitable analytical protocol for their comprehensive investigation.**

Our approach is based on archival research and conservation practice. Analytical results from non-destructive methods applied on-site were compared with micro-destructive laboratory methods to **investigate the paint systems and pigments within their architectural context, and to compare them to the archival evidence by Bruno Taut.** As a case study, we examined a terraced house in the Waldsiedlung Zehlendorf in Berlin, designed by Bruno Taut and built in 1929.

Non invasive methods

Exposure

Fig. 1: Left: colour plan from the Brenne Architekten documentation (photo credit: Brenne Architekten). Right: Exposure from HS81Ex01WZ, showing 3 paint layers (photo credit: Jana Hainbach).

Handheld Raman with SSE[1] (Bruker Bravo)

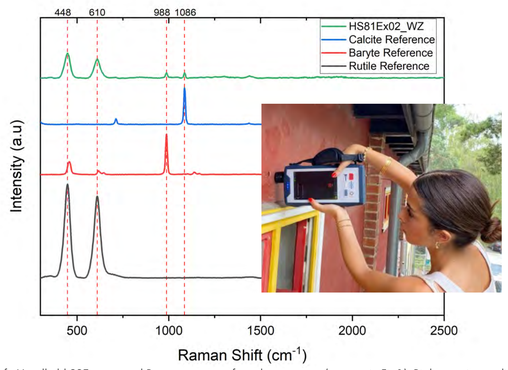
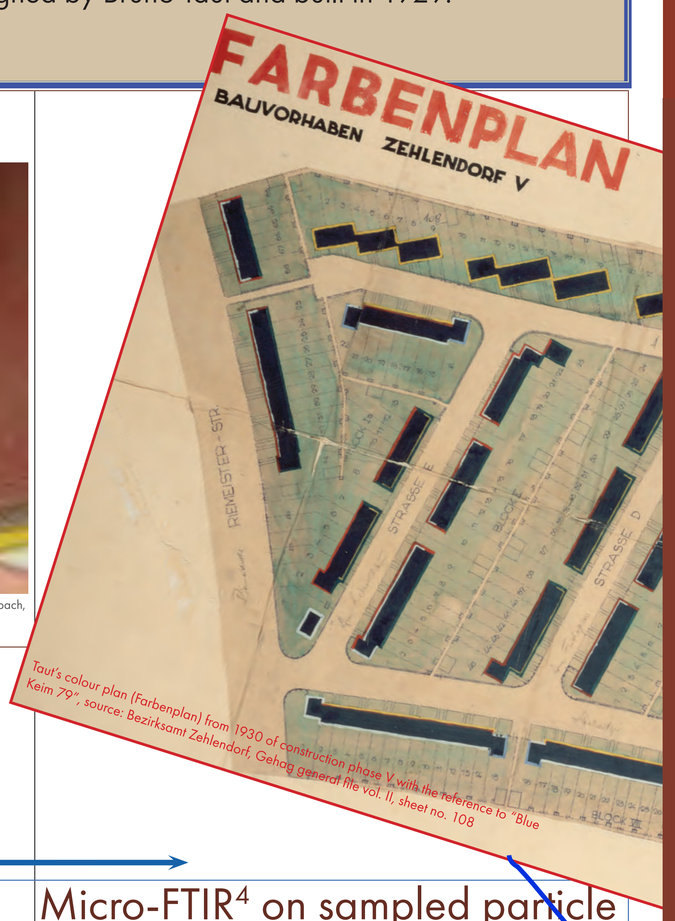


Fig. 2: Left: Handheld SSE processed Raman spectrum from the exposure (as seen in Fig1). Right: on-site application of the handheld Raman instrument (representative facade). Credit: Jana Hainbach, 2024.

p-XRF[2]

Fig. 3: On-site application of the portable XRF instrument (representative facade). Credit: Jana Hainbach, 2024.



Taut's colour plan (Farbenplan) from 1930 of construction phase V with the reference to "Blue Keim 79", source. Bezirksamt Zehlendorf, Gehag general file vol. II, sheet no. 108

Results

Layer 3: beige
Layer 2: beige
Layer 1: yellow (NCS: S 0550-G90)

Layer 5 (tentative): calcite, baryte and rutile

Layer 2: Zn, Pb, Ba, Sb, (Sr, Fe): lead antimonate, zinc oxide, calcite, barium sulfate.

Micro-invasive & laboratory methods

Vis-light microscopy on cross-section

Fig. 4: Cross section made from the on-site sample, HS81Ex02 (Fig.1), showing 5 paint layers under visible light microscope with 50x magnification. Credit: Zeynep Alp, 2024.

Micro-Raman Spectroscopy on cross-section

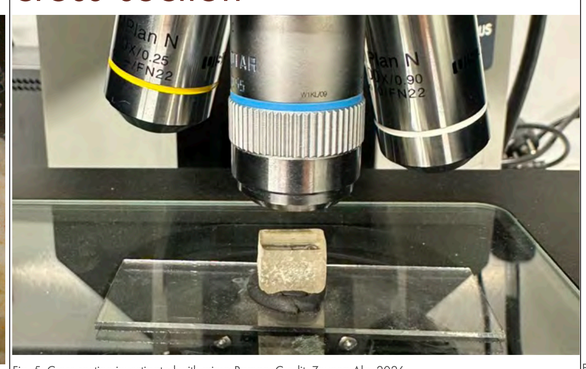


Fig. 5: Cross section investigated with micro-Raman. Credit: Zeynep Alp, 2026.

SEM-EDX[3] on cross-section

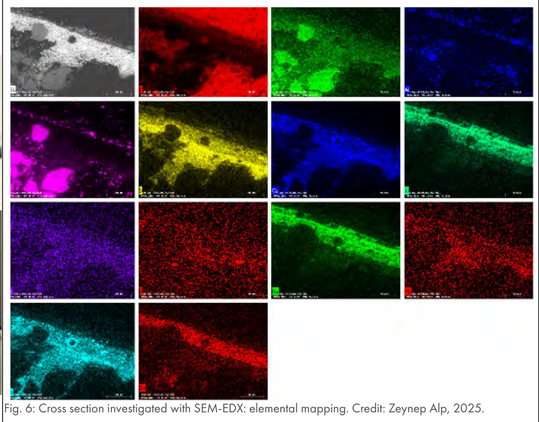


Fig. 6: Cross section investigated with SEM-EDX: elemental mapping. Credit: Zeynep Alp, 2025.

Micro-FTIR[4] on sampled particle

Fig. 7: Sampling for FTIR in transmission mode. Micro-sample is placed on the diamond and measured in transmission for binder, pigment and filler analysis. Credit: Zeynep Alp, 2025.

Results

Layer:
- 5: beige, reconstruction
- 4: pink, reconstruction
- 3: pink, reconstruction
- 2: yellow, reconstruction
- 1: yellow, construction phase

Layer:
- 5: rutile, hematite
- 4: goethite, calcite, rutile
- 3: goethite, calcite, gypsum, baryte, rutile
- 2: goethite, lead antimonate, calcite, gypsum, baryte
- 1: goethite, lead antimonate, calcite, gypsum

Layer
- 5: Si, S, Ca, Ti, Zn, Al, Ba (Fe, Na)
- 4: Si, S, Ca, Ti, Zn, Al, Ba (Fe, Pb, Na)
- 3: Si, S, Ca, Ti, Zn, Al, Ba (Fe, Pb, Na)
- 2: Si, S, Ca, Ba, Pb, Al, (Fe, Zn, Na)
- 1: Si, S, Ca, Pb, Ba, Al, (Fe,F, Zn, Na)

Layer:
- 5: PVAC, barium sulfate, calcium carbonate, gypsum
- 4-5: acrylic binder, gypsum, barium sulfate, talk
- 2-3: PVAC, barium sulfate, quartz, calcium carbonate
- 1: gypsum, calcium carbonate, quartz, barium sulfate

Discussion

Exposure area determined the non-invasive investigation results. However, sampling was necessary to reveal the complete stratigrapghy.

It was not possible to measure with colourimetry due to the minimally exposed layer and high surface roughness.

Handheld Raman only measured the pigment and filler composition of the top layer (layer 5). Whereas micro-Raman could be applied to selected layers on the cross-section. It revealed the pigment and filler compositions of individual layers that the handheld Raman could not reach and detect.

p-XRF revealed the elements in the underlying paint. However, it was not clear from which underlying layer this signal came from. It´s on-site combination with handheld Raman helped choosing sampling area.
SEM-EDX complemented Raman and XRF results by locating the elemental distribution of pigments, degradation products and fillers. In layer1 Sb could not be detected since K and Sb have the same emission lines. It also characterised the paint as "Keim'sche Mineralfarben"[1].

FTIR provided negative confirmation for any organic binder in the first layer, confirming the silicate paint binder evidence from SEM-EDX. It detected polymeric binder for the subsequent layers, however, indicating their later date of origin.

Conclusions

- **There is no single ideal analytical method or standard workflow** for investigating architectural finishes.
- **Sampling is essential** for comprehensively identifying historic paint layers.
- The advantages and limitations of each analytical method depend on **instrumental characteristics**.
- Each case requires a **tailored approach shaped by targeted research questions, archival evidence, and conservation priorities**.
- The transfer from monument conservation to analytical investigation lies in **translating key questions into suitable analytical strategies** (and the other way round). Based on the results, monument conservation can determine their **practical approach**.
- **Keim´sche Mineralfarbe** as the paint product, as indicated by archival evidende of Bruno Taut, is confirmed by analytical investigations.

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References: [1] Z. Alp, J.Hainbach, C. Herm, T. Danzl,'Keim'sche Mineralfarben' marker: Is it a myth? A comprehensive analytical study of its detection methods and true nature, Construction and Building Materials 475 (2025).

Footnotes: 1: Sequentially Shifted Excitation System, **2:** X-Ray Fluorescence Analysis, **3:** Scanning Electron microscopy coupled with Electron Dispersive X-Ray Analysis, **4:** Fourier Transform Infrared Spectroscopy