Deterioration Evaluation of Reinforced Concrete Materials in Highway Bridges

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Introduction

This study aims to detect and monitor the deterioration behavior of concrete for highway bridges in New England via characterizations of the samples collected from the field and laboratory accelerated aging tests. The evolutions of components, reaction products, and chemical bonds in the aged materials were investigated with a purpose to develop enough data for condition assessment.

Objectives

- Condition assessment of the existing infrastructure via multiple material characterizations
- Understanding the development of reaction products and chemical bonds in aged concrete materials

Experiments

Four locations on three different reinforced concrete (RC) piers of I-495 bridge in Chelmsford, MA were chosen, and the samples were collected frequently (on a monthly basis) (Fig. 1).

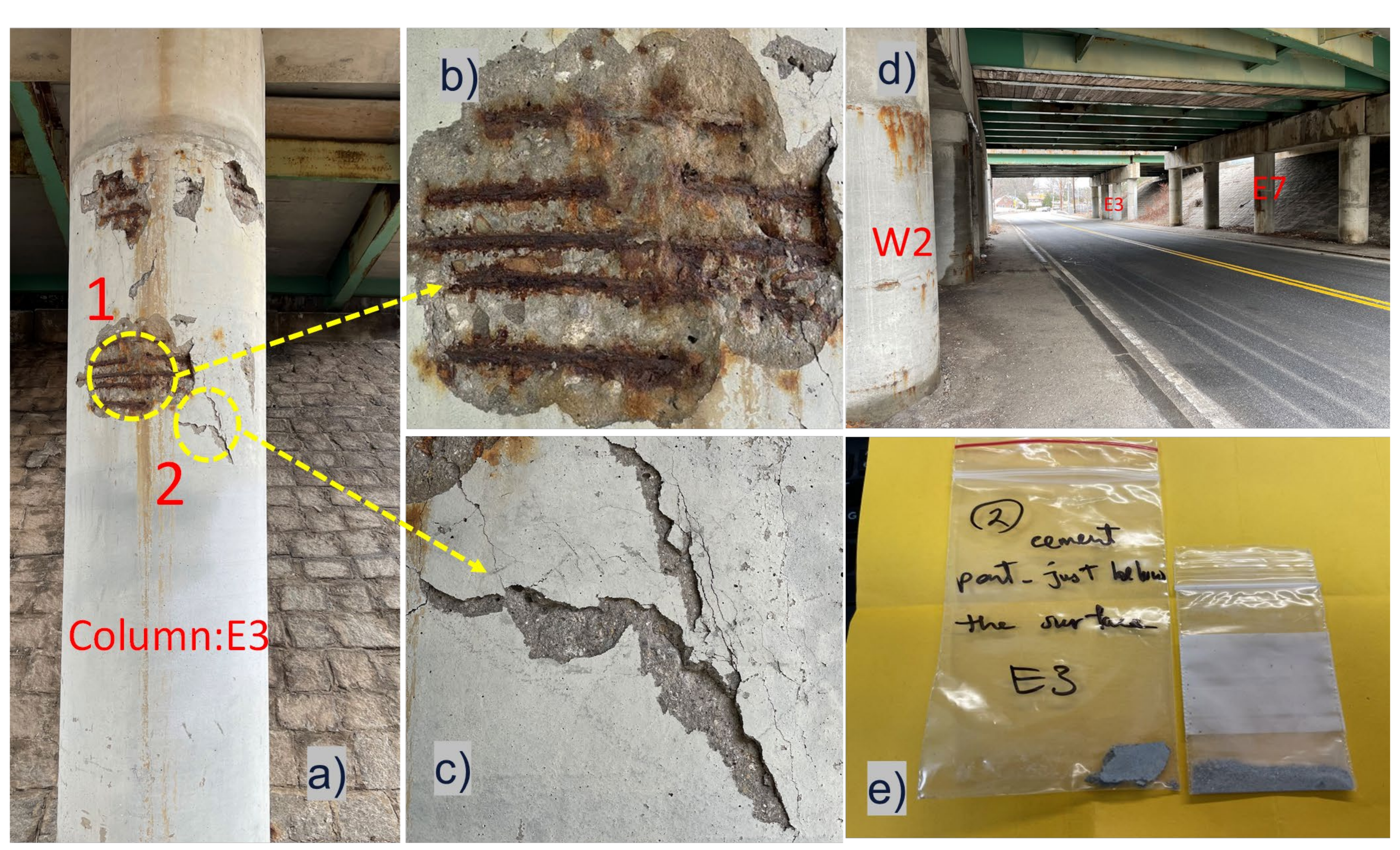

Fig. 1: a) One selected bridge pier (E3); b) Enlarged deterioration region (sample collection location 1); c) Enlarged deterioration region (sample collection location 2); d) RC piers of I-495 bridge in Chelmsford, MA; e) Collected samples for characterization

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Results

Fig. 2 shows the X-ray diffraction (XRD) analysis of collected samples between 09/22/22 and 10/26/23, and the phases quantified via Rietveld refinement. Quartz and calcite were observed as the main crystalline components with a gradual increment of calcite over time.

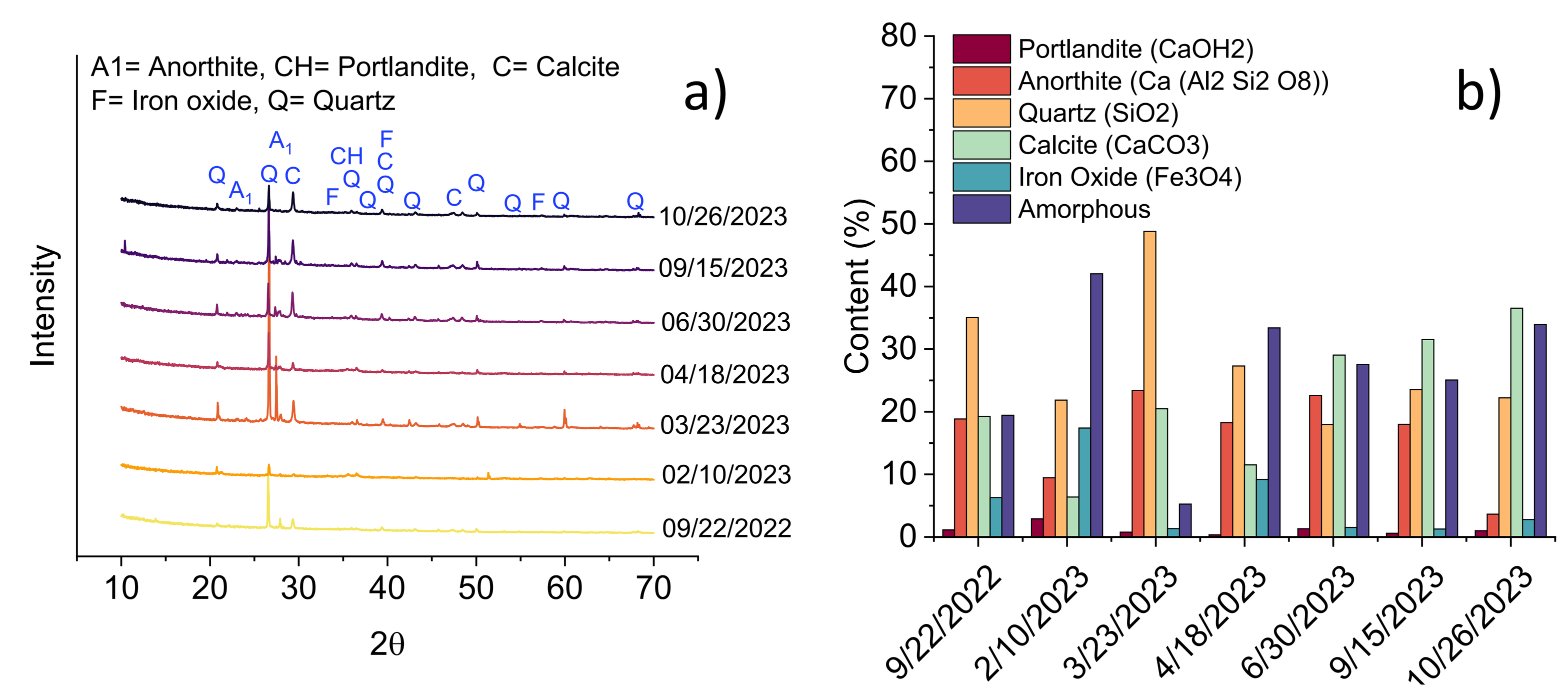
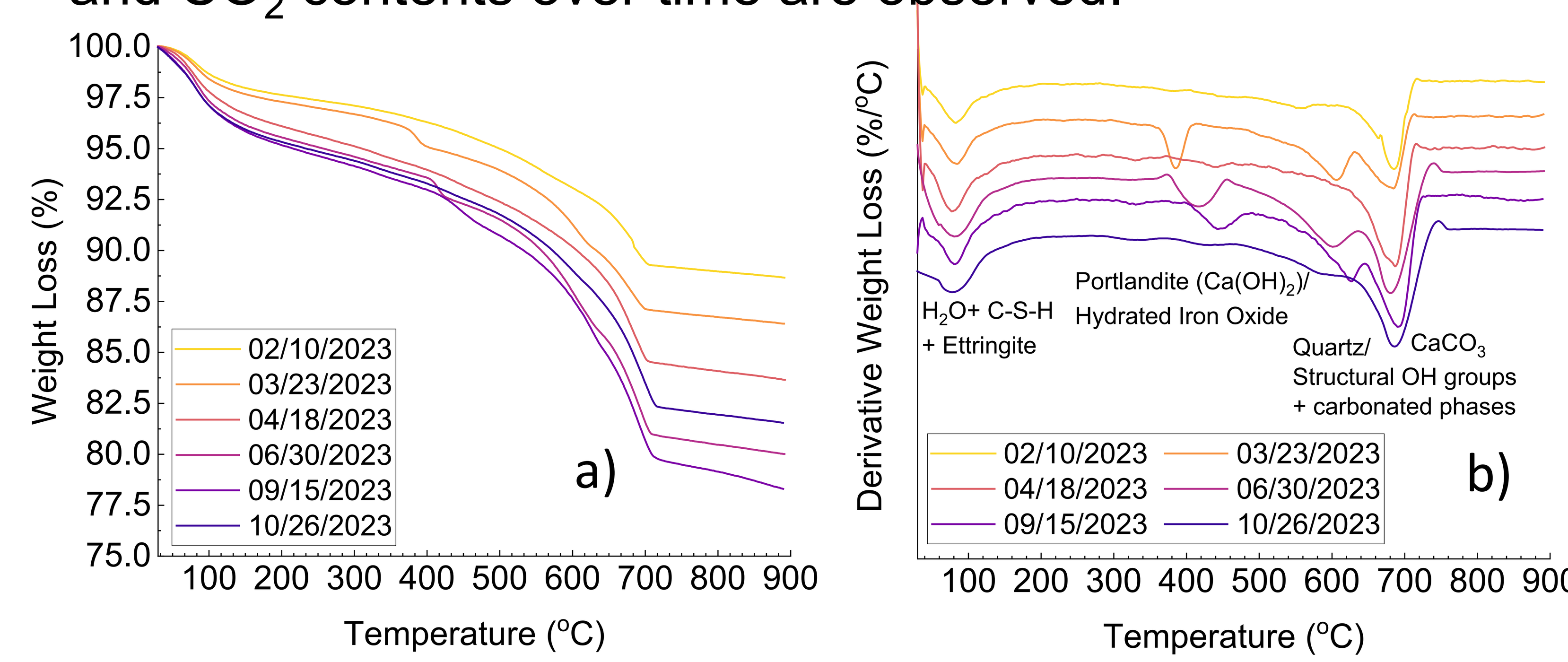


Fig. 2: XRD results of samples collected from E3 column (sample collection location 1).

Fig. 3 shows the thermogravimetric analysis of the samples collected from the E3 column, where increases in C-S-H and CO_2 contents over time are observed.



Specimen	Water Evaporation (%) (30–105 °C)	Bound water and C-S-H (%) (105–300 °C)	OH (%) (300–500 °C)	CO2 (%) (550–893 °C)
2/10/2023	1.44	1.46	2.10	5.41
3/23/2023	1.69	1.62	2.79	6.51
4/18/2023	2.35	2.54	2.71	7.77
6/30/2023	2.82	2.58	3.10	10.22
9/15/2023	3.06	2.79	4.62	11.22
10/26/2023	3.06	2.60	2.57	9.09

Fig. 3: Thermogravimetric analysis of collected samples from E3 column (sample collection location 2).

Iron oxide was also detected from XRD, which can be originated from the rust in the collected concrete samples due to the corrosion of reinforcing rebars. The overall increasing trend of this phase indicates the proceeded corrosion in the RC bridge piers.

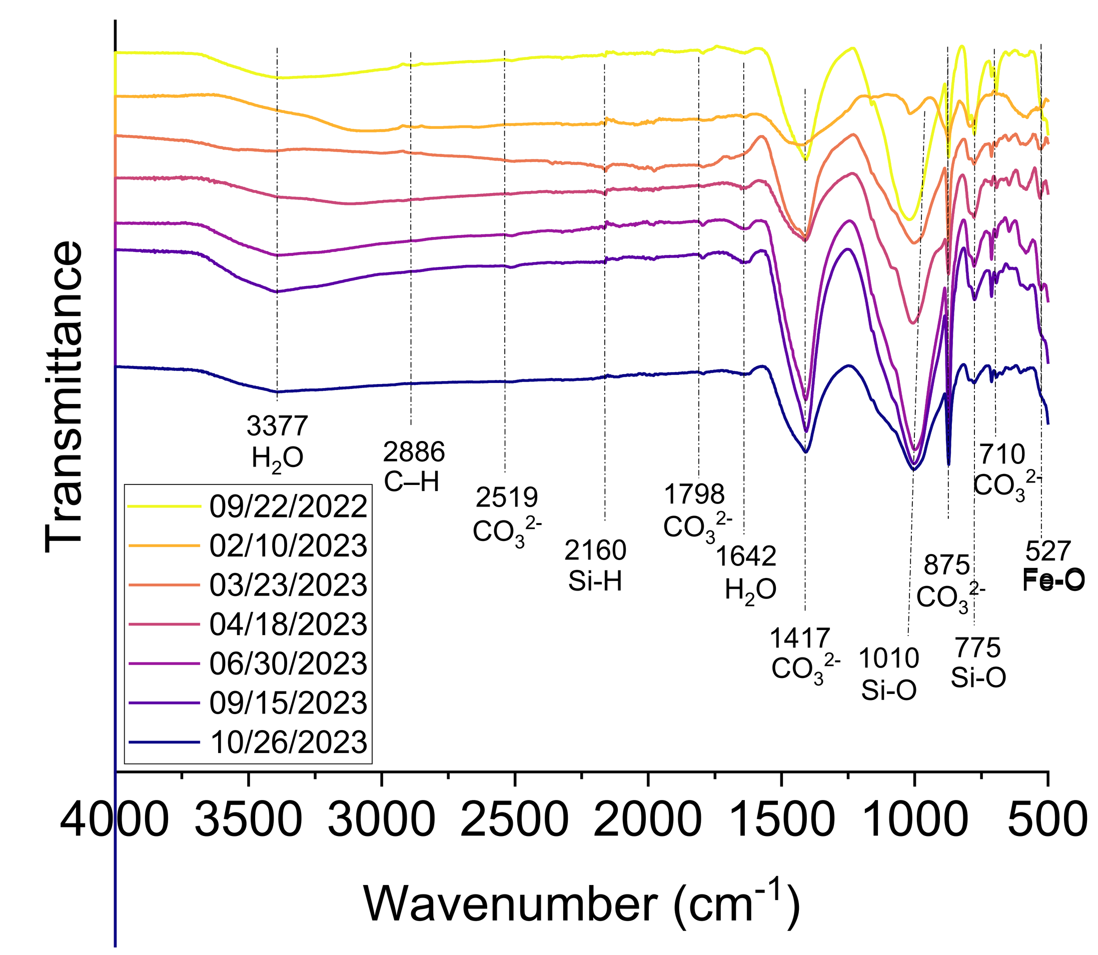


Fig. 4: FTIR results of samples collected from E3 column (sample collection location 1).

From the FT-IR spectra in Fig. 4, the increases in intensity of the Si-O peak at 1010 cm^{-1} and the Fe-O stretching at 527 cm^{-1} indicate an increase of C-S-H and iron oxide respectively, as seen in TGA and XRD data.

The increasing intensity of the CO_3^{2-}-related peaks at 710 cm^{-1}, 875 cm^{-1}, 1417 cm^{-1}, 1798 cm^{-1}, and 2519 cm^{-1} indicate the proceeded carbonation over time in the aged region, which can induce further deteriorations in the RC structure.

Conclusion

- The XRD analysis indicated that the main crystalline components of the collected samples are quartz and calcite where a gradual increment of calcite and iron oxide was observed over time.
- The TGA and FT-IR results showed increases in C-S-H and carbonation products over time.
- The FT-IR data indicated increases in rust content by presenting increases of Fe-O bond intensity over time.