

# The Role of Material Porosity on Ozone Uptake for Metakaolin-Concrete Surfaces

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## 1 Introduction

Metakaolin-cement systems hold promise for both the reduction of carbon dioxide emissions associated with cement manufacturing and indoor ozone uptake. Cement is an essential component in the building industry used in formulating concrete. The cement industry is responsible for 3.4% of the global anthropogenic CO<sub>2</sub> emissions (Marland and Boden, 2003; Hanle et al. 2009). The usage of calcined clay as a cement substitute can reduce up to 280 lbs of CO<sub>2</sub> per ton of cement produced (U.S. Environmental Protection Agency, 2010).

In addition to a diminished environmental impact, clay may cause increased removal of ozone, an important indoor pollutant. Previous investigations have correlated non-calcined clay with high ozone reaction probabilities, reducing indoor ozone concentrations (Hoang et al. 2009). Epidemiological studies have shown up to 0.87% increase in mortality per 10-ppb increase in daily ozone, proving that the removal ozone from indoor environments could have a beneficial effect on human health (Bell et al. 2005; Levy et al. 2005).

The effect of including metakaolin in concrete on the ozone deposition velocity is unknown in both sign and magnitude. Usage of metakaolin in concrete systems results in the reduction of pore structure in the concrete (Khatib and Wild, 1996) potentially reducing the ozone deposition velocity. Therefore, this experimental investigation reports on the ozone deposition velocity of concrete mixtures with and without 15wt.% replacement of cement with metakaolin and with varied porosities.

## 2 Methods

The primary materials used in this study include (i) ground kaolinite [Al<sub>2</sub>Si<sub>2</sub>O<sub>5</sub>(OH)<sub>4</sub>] (Wards Natural Science Establishment, INC.), (ii) Type I portland cement, from the Lehigh Valley Cement Plant, Texas processed in June of 2009, (iii) ASTM C109 grade Cube Test Ottawa Silica Sand (Humboldt) and, (iv) deionized water. Specimens of size 14 cm x 14 cm x 3.8 cm were prepared. Table 1 summarizes the composition of the samples.

Table 1: Sample compositions

Sample	W/CM Ratio <sup>1</sup>	Metakaolin wt. %
Cement-high water	0.57	None
Cement-low water	0.48	None
Clay-high water	0.48	15
Clay-low water	0.38	15

<sup>1</sup>water to cement ratio

The water to cement ratio was varied in samples to change the concrete porosity. Mixing procedures followed ASTM C305 specifications. Specimens were taken out of the molds after 24 hrs and placed in a lime water bath at 23°C until curing maturity. Specimens were stored at 23°C and a relative humidity of 50% until testing.

Four 48-L electro-polished stainless steel chambers (25 cm x 38 cm x 50 cm) were used to test ozone deposition velocities on the concrete specimens. Carbon-filtered room air was conditioned to achieve the desired (1) relative humidity (TSI, Inc., Q-Trak 8551), (2) ozone concentration (generated by a modified zero air generator, Perma Pure LLC) and, (3) air exchange rate (controlled by mass flow controllers, Aalborg, USA). Air

flow rates were checked using a bubble flow meter (Gilibrator 2, Gilian, Sensidyne, LP) and ozone concentrations were measured using a single UV absorbance cell ozone monitor (Model 202, 2B Technologies). Tests were run for over 3.5 hours allowing steady-state ozone concentrations to be achieved in each chamber. Uncertainty was taken as the larger of the experimental standard deviation or the uncertainty of the ozone analyzer.

Two different testing conditions were used with the following experimental conditions:

Test 1 (cement-high water, clay-low water):  $49 \pm 2.2$  % RH,  $150 \pm 6$  ppb average inlet ozone concentration, 1.75 air exchanges per hour,  $23.8 \pm 3$  °C.

Test 2 (cement-low water, clay-high water):  $33 \pm 2$  % RH,  $145 \pm 5$ ppb average inlet ozone concentration, 1.2 air exchanges per hour,  $26 \pm 3$  °C.

### 3 Results

The deposition velocity ( $v_d$ ) was calculated using a steady state mass balance equation, accounting for the deposition to the chamber surfaces. Figure 1 shows the deposition velocity for the bare concrete samples.

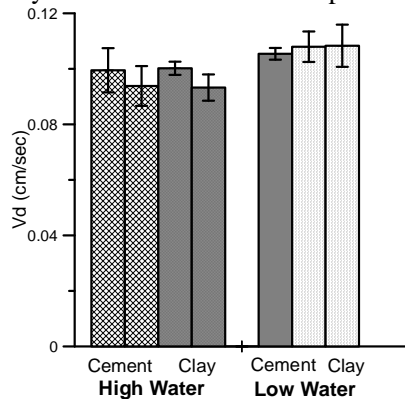


Figure 1. The deposition velocity ( $\text{cm s}^{-1}$ ) of all samples.

The results showed that the substitution of 15wt.% metakaolin for cement had no effect on the deposition velocity for concrete. Mixtures with more mixing water average  $0.097 \pm 0.008 \text{ cm}\cdot\text{s}^{-1}$  (high water) whereas mixtures with less mixing water average  $0.11 \pm 0.007 \text{ cm}\cdot\text{s}^{-1}$  (low water). More experimentation is needed to determine the statistical significance of concrete mixing water to ozone uptake. Recorded  $v_d$  for

concrete from literature, ranges from  $0.05 \text{ cm}\cdot\text{s}^{-1}$  to  $0.58 \text{ cm}\cdot\text{s}^{-1}$  (Simmons and Colbeck, 1990; Cano-Ruiz et al. 1993).

### 4 Conclusions

The results confirm the deposition velocity was not influenced by adding calcined clay. Preliminary results show mixing water may slightly influence ozone uptake. Overall, these findings suggest use of metakaolin as a partial cement replacement will not amplify or improve existing ozone indoor air quality problems.

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