Application of Coated Time Domain Transmission (TDT) Sensors for Measurement of Moisture Content in Dielectrically Lossy Clay Slurries

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Abstract: Digital time domain transmission (TDT) sensors have become widely accepted as accurate and economical alternative to time domain reflectometry for moisture content measurements in moderately conductive soils. However, their applicability for dielectrically lossy clays has not been investigated thoroughly. Two types of coatings, a silicone coating (SC) and a high-dielectric coating (HDC), were applied to commercially available TDT sensors. The sensors were used for calibration experiments in highly dispersive bentonite slurries and less dispersive kaolinite slurries at a range of moisture contents and electrolyte concentrations. Because the apparent permittivity measured with the coated sensors consists of two components (permittivity of the soil and permittivity of the coating), the standard Topp relationship cannot be applied directly to infer water content from apparent permittivity. Individual calibration of the coated sensors yielded good results for kaolinite slurries with gravimetric water contents higher than 0.37 kg kg^{-1}. But, dielectric dispersion in the bentonite-water mixtures resulted in reduction of the effective measurement frequency, making it impossible to obtain a satisfactory calibration. As a result, we conclude that coated TDT sensors can be calibrated for moisture content measurement in heavy natural clay soils if the dominating clay mineralogical fractions do not exhibit highly dispersive behavior.

Keywords: Time domain transmissiometry (TDT), TDT waveform, Clay slurry, Water content

1. Introduction

Photo1 Heavy clays in a lowland field.

Technical problem of moisture measurement using TDT sensor in clays

Applicability of TDT sensors for dielectrically lossy clays has not been investigated thoroughly.

The aim of present study is to demonstrate the performance limit of an uncoated and coated TDT sensors for moisture content measurements in dielectrically lossy clays.

2. Experimental method

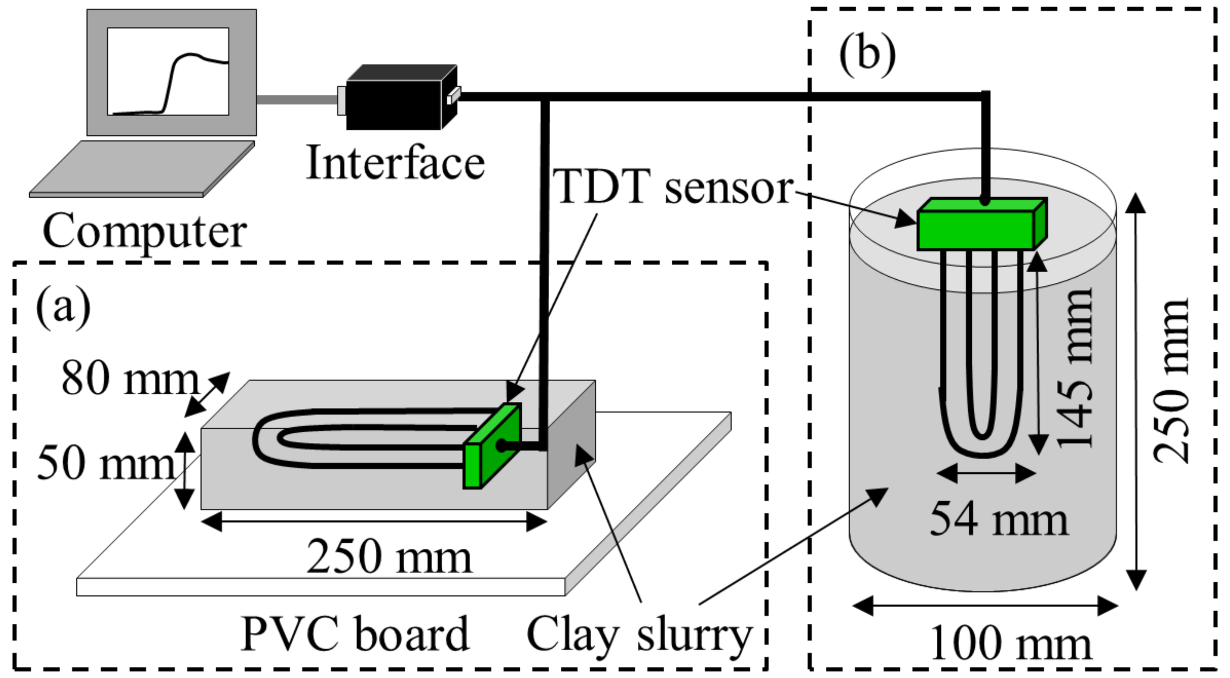

Fig.1 Schematic of laboratory experiments.

Silicone coating (SC)

High-dielectric coating (HDC)

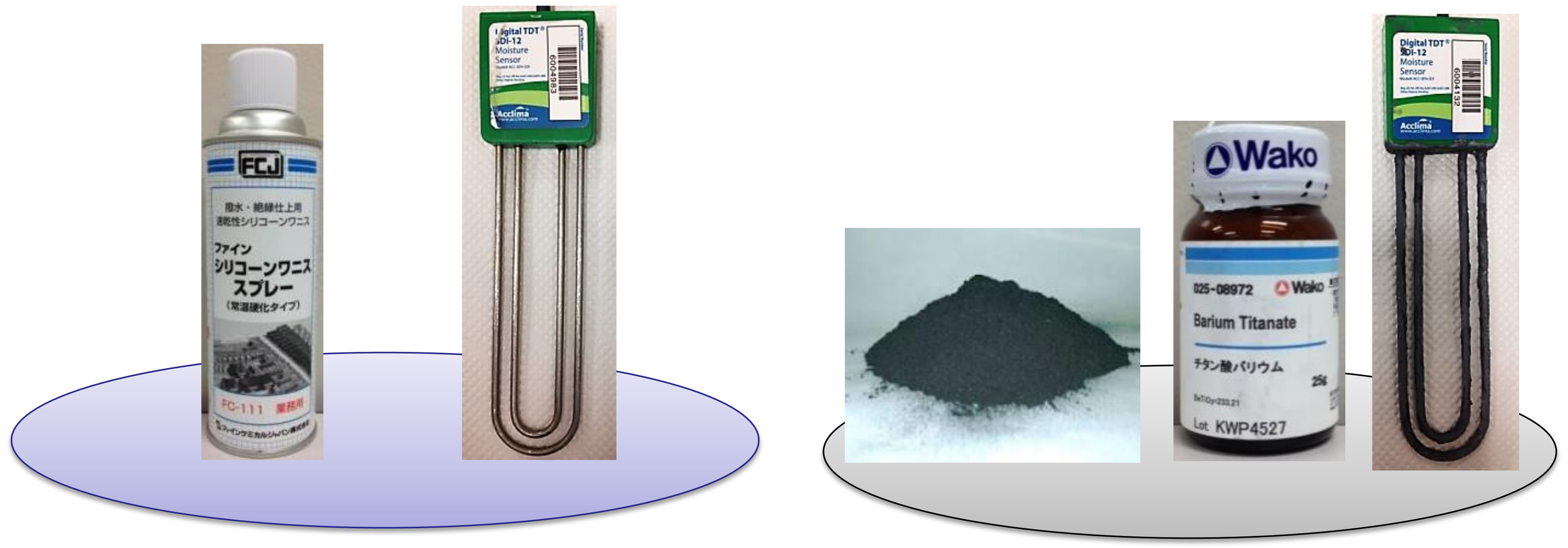

Photo2 Two different coated TDT sensors.

- Materials under test: Kaolinite - $CaCl_2$ solution mixtures
  Bentonite - $CaCl_2$ solution mixtures
- Concentration of $CaCl_2$ solutions: 0.0 (Distilled water, DW), 0.05, 0.1, 0.5 M
- TDT sensors: Uncoated (UC) sensor,
  Two types of coated sensors
- Measured data sets : TDT waveforms
  Apparent permittivity (ε_{TDT})
  Propagation time

3. TDT waveforms

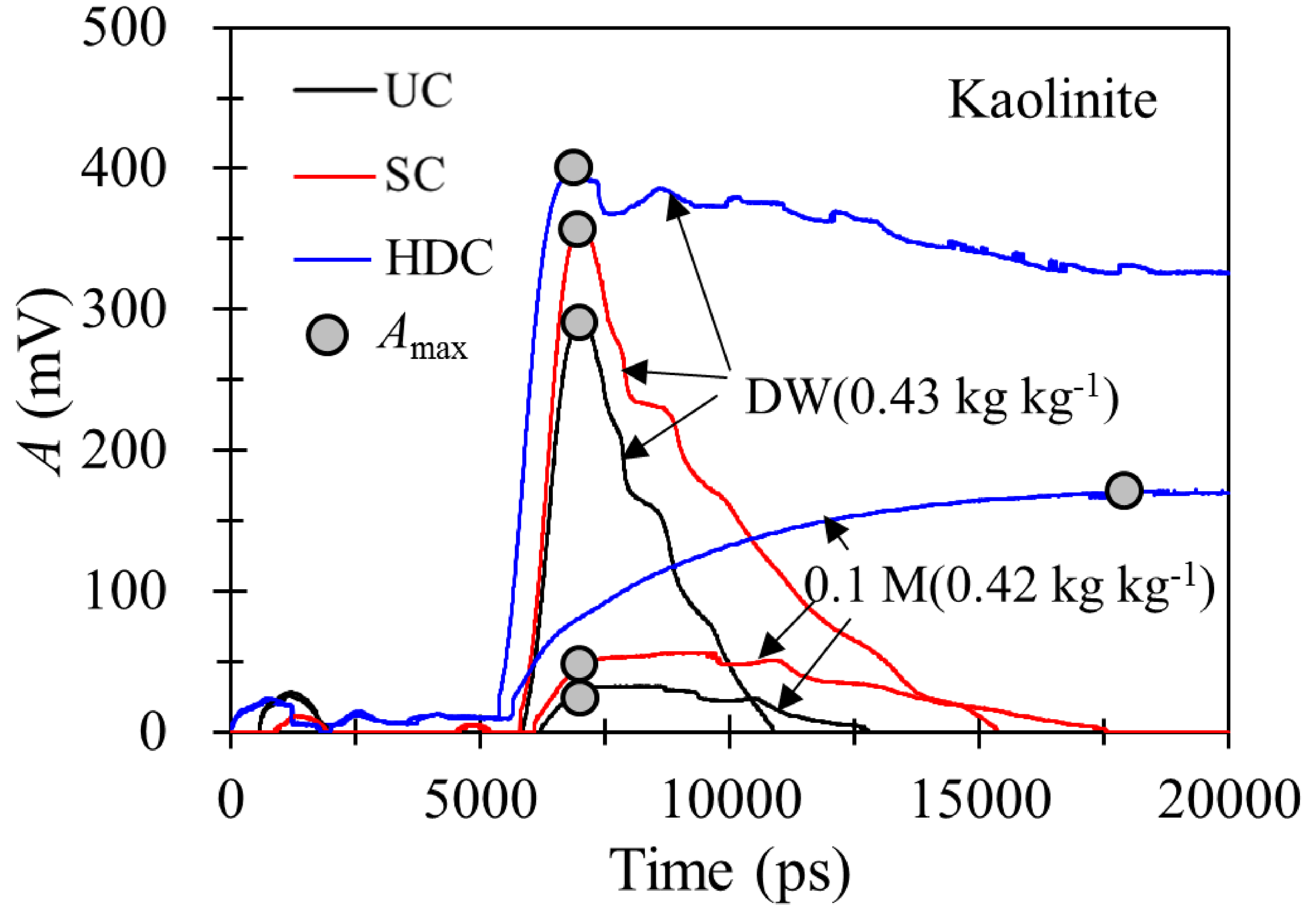

Fig.2 TDT waveforms for kaolinite slurries.

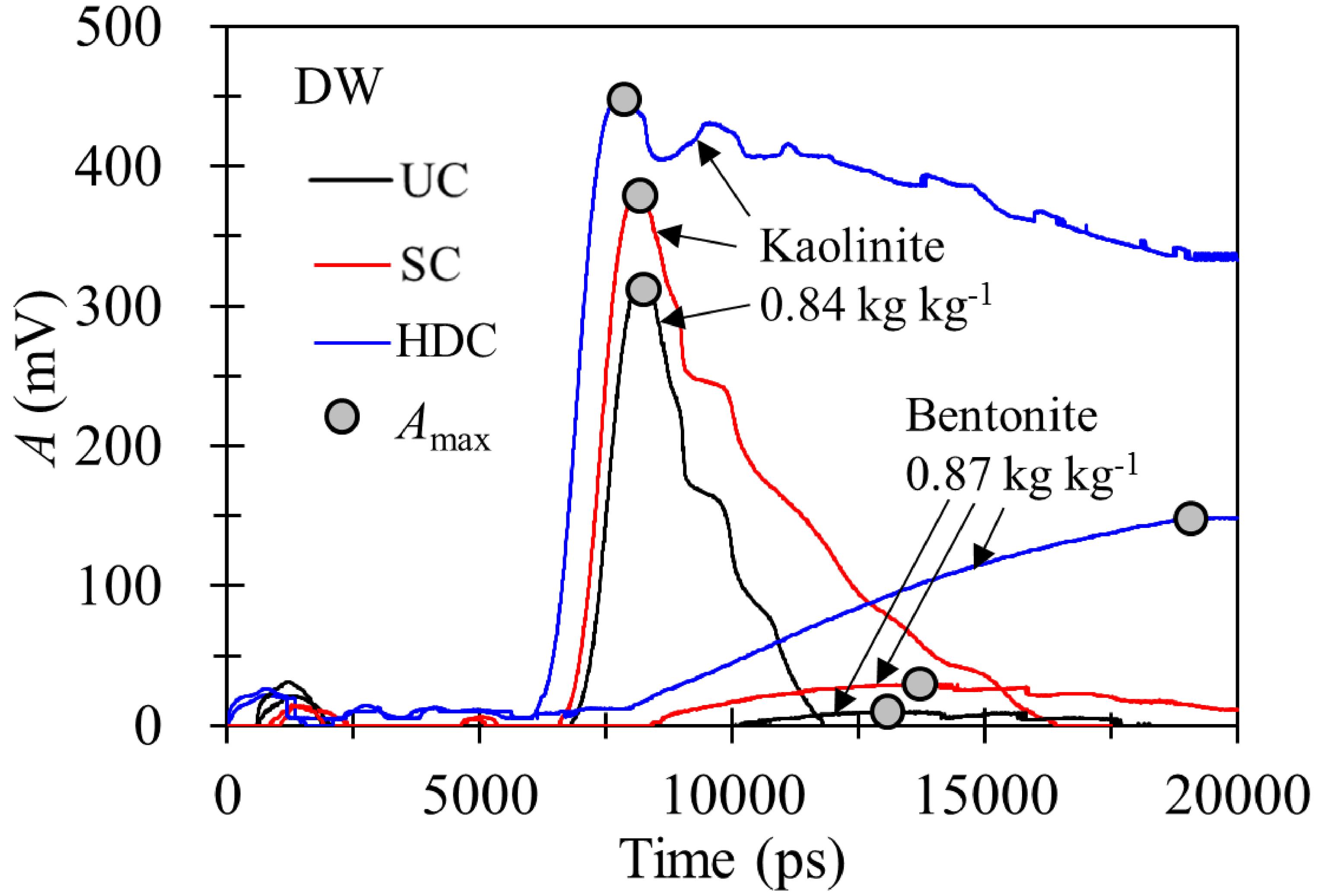

Fig.3 TDT waveforms for kaolinite and bentonite slurries.

4. Moisture content measurements

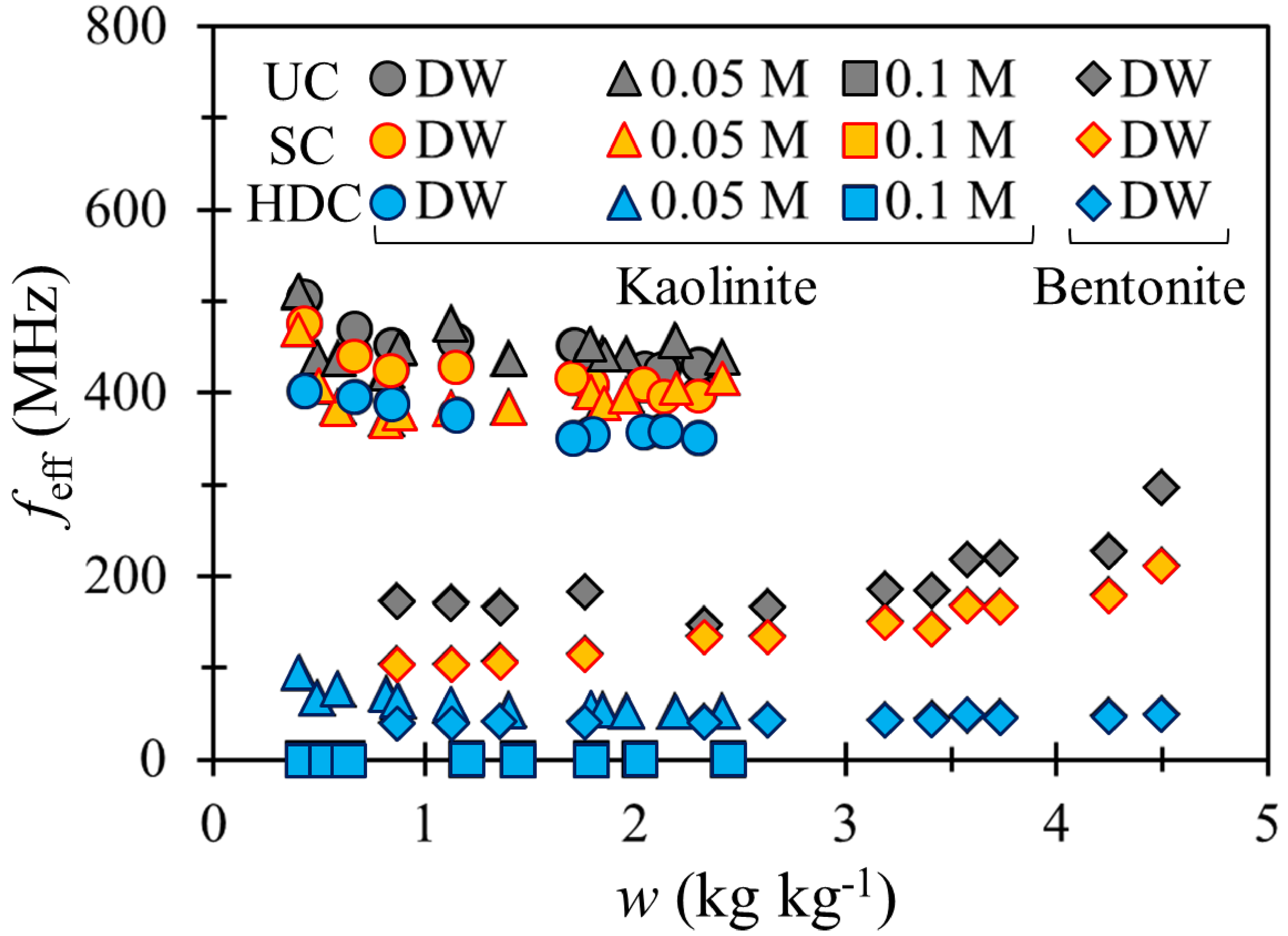

Fig.4 Effective frequency (f_{eff}) vs. gravimetric water content (w).

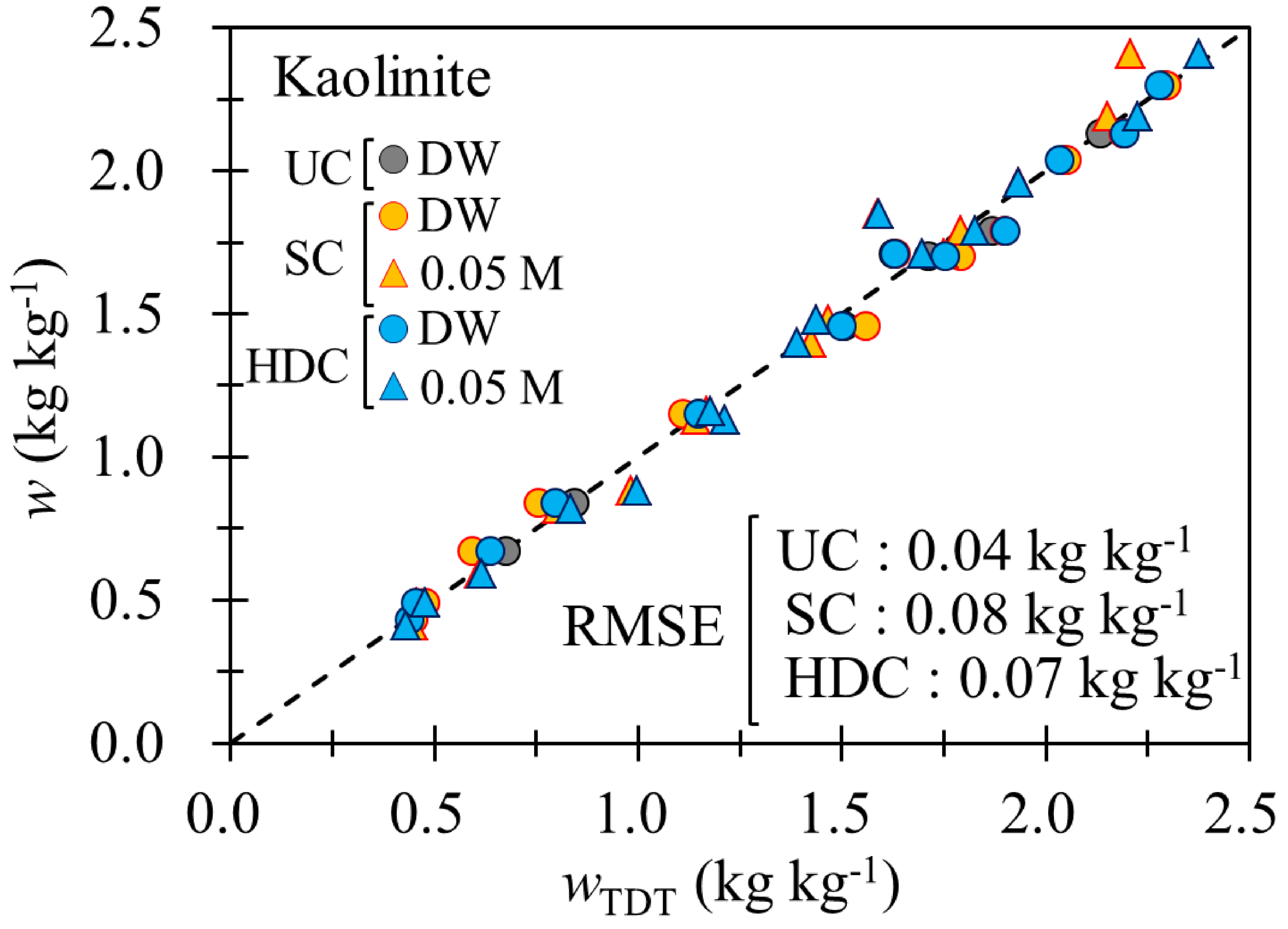

Fig.6 Gravimetric water content (w) vs. gravimetric water content measured by TDT sensor (w_{TDT}) for kaolinite slurries.

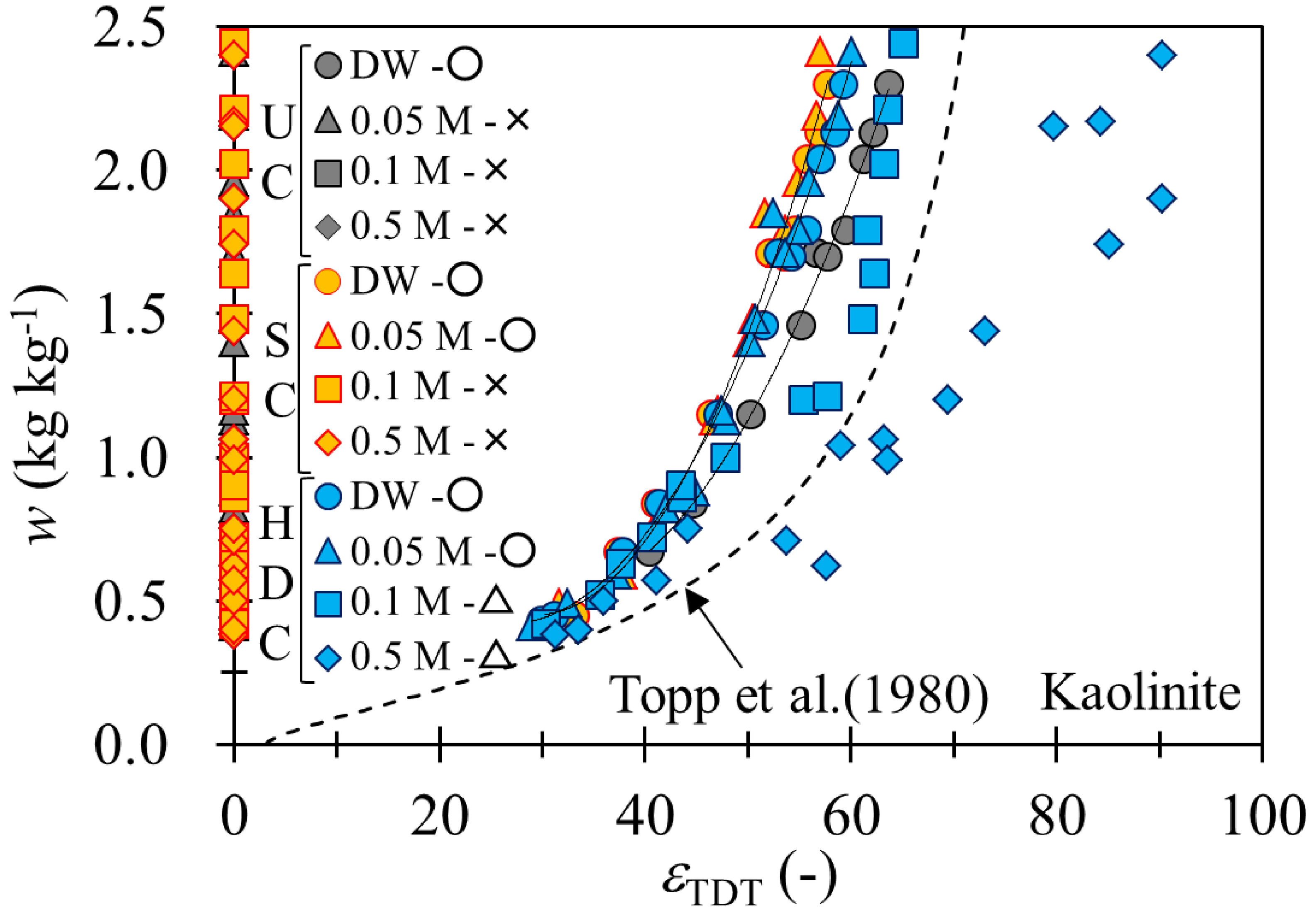

Fig.5 Gravimetric water content (w) vs. apparent permittivity (ε_{TDT}) for kaolinite slurries.

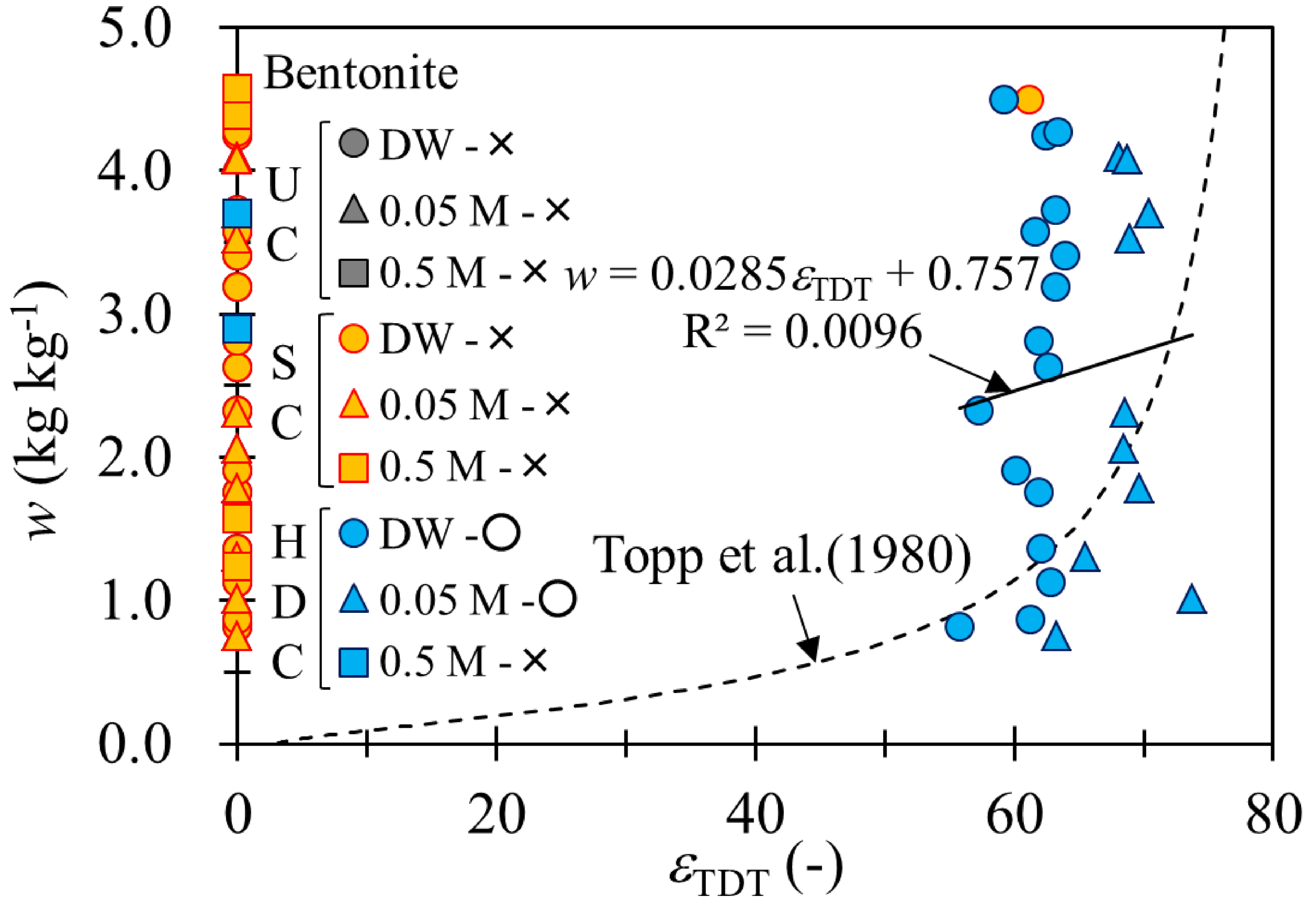

Fig.7 Gravimetric water content (w) vs. apparent permittivity (ε_{TDT}) for bentonite slurries.

5. Conclusion

We conclude that coated TDT sensors can be calibrated for moisture content measurement in heavy natural clay soils if the dominating clay mineralogical fractions do not exhibit highly dispersive behavior.

References:

Topp et al.(1980): Electromagnetic determination of soil water content: measurements in coaxial transmission lines, Water Resources Research, 16: 574-582.