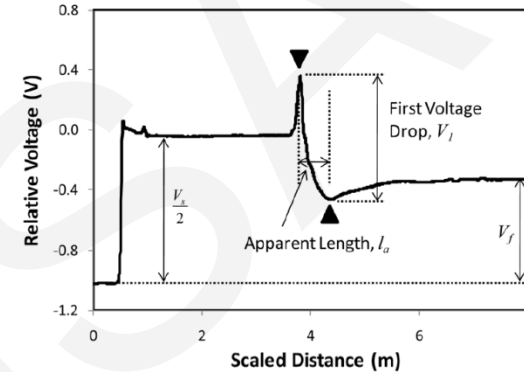


# Study on calibration equation for soil water content in field tests using time domain reflectometry

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# Application of TDR



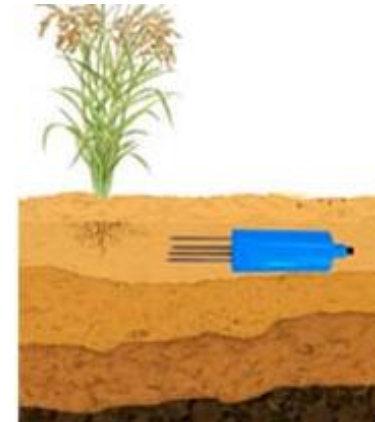
TDR technology



Environmental geotechnics



Geotechnical engineering



Agriculture

# Limit of Application in Field Fest

## Existing models:

1) Topp equation:  $\theta = 4.3 \times 10^{-6} K_a^3 - 5.5 \times 10^{-4} K_a^2 + 2.92 \times 10^{-2} K_a - 5.3 \times 10^{-2}$

2) Two-step method:  $\sqrt{K_a} \frac{\rho_w}{\rho_d} = a + bw$

3) One-step method:  $\sqrt{K_a} \frac{\rho_w}{\rho_d} = a + bw$

$$\sqrt{\sigma} \frac{\rho_w}{\rho_d} = c + dw$$

$$\sqrt{\sigma} = f + g\sqrt{K_a}$$

$$w = \frac{c\sqrt{K_a} - a(f + g\sqrt{K_a})}{b(f + g\sqrt{K_a}) - d\sqrt{K_a}}$$

$$\rho_d = \frac{d\sqrt{K_a} - b(f + g\sqrt{K_a})}{ad - cb} \rho_w$$

## Limitation of Existing models:

- 1) Topp equation expressed in volumetric water content;
- 2) Two-step method takes time and energy;
- 3) Both two-step and one-step methods need calibration first;
- 4) Heterogeneous soil and different soil types in the field.

# Method of this paper

Derivation of equation:

$$v = \frac{c}{\sqrt{K_a}} \quad t = t_s + t_w + t_a \quad v = \frac{2l}{t}$$

$$l\sqrt{K_a} = l_s\sqrt{K_s} + l_w\sqrt{K_w} + l_a\sqrt{K}$$

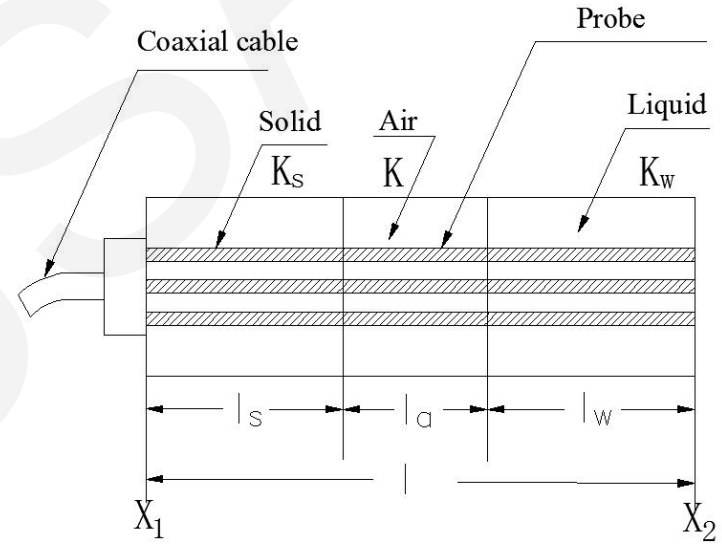
$$s = \frac{l_w}{l_a + l_w}$$

$$w = \frac{\rho_w l_w}{G_s l_s \rho_w}$$

$$\sqrt{K_a} = \frac{s\sqrt{K_s} + (sG_s\sqrt{K_w} + (1-s)G_s\sqrt{K})w}{s + G_s w}$$

$$w = \frac{\sqrt{K_a} - \sqrt{K_s}}{G_s\sqrt{K_w} + (1/s - 1)G_s\sqrt{K} - (G_s/s)\sqrt{K_a}}$$

$$w = \frac{A + \sqrt{K_a}}{B + C\sqrt{K_a}}$$



Analysis model

# Data collect and regression analysis

■ Total 45 kinds of soil samples and 418 data points from our own tests and literatures are collected

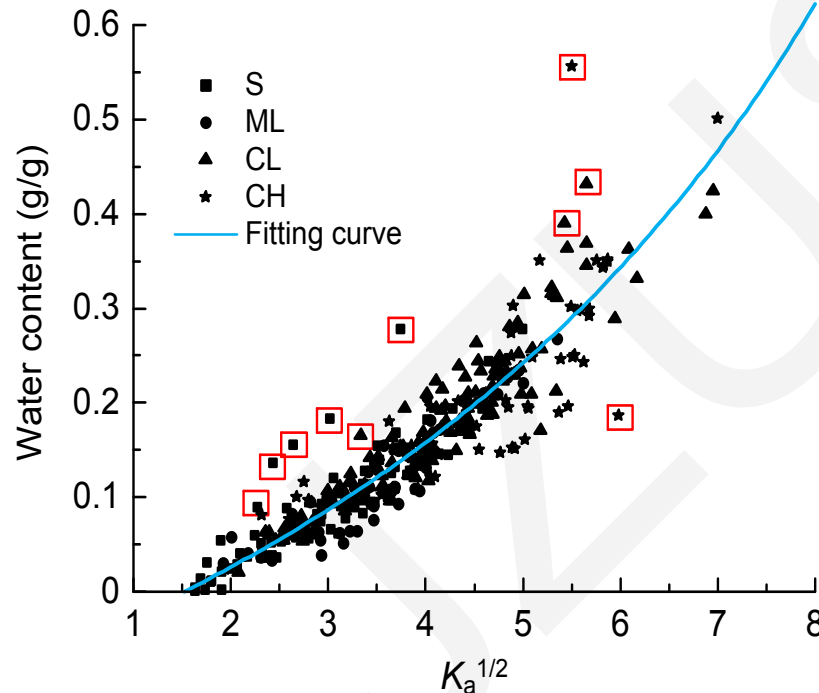


Fig. 2 Result of regression analysis by Eq. (10)

$$w = \frac{-1.4637 + \sqrt{K_a}}{22.1373 - 1.4606\sqrt{K_a}}$$

# Analysis of Influence Factors

■ Influence of soil type, dry density, compaction energy, pore fluid conductivity and temperature are studied

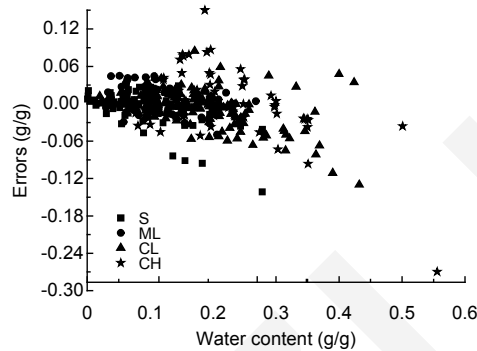


Fig. 3 Errors of water content by Eq. (10) vs gravimetric water content for different soil types

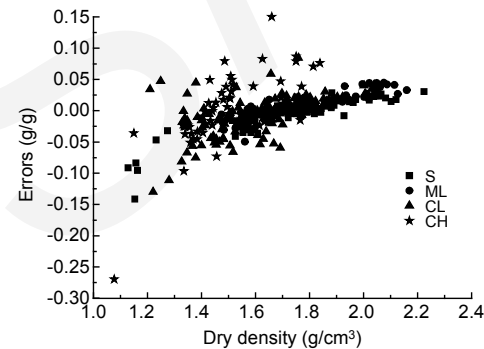


Fig. 4 Errors of water content by Eq. (10) vs dry density

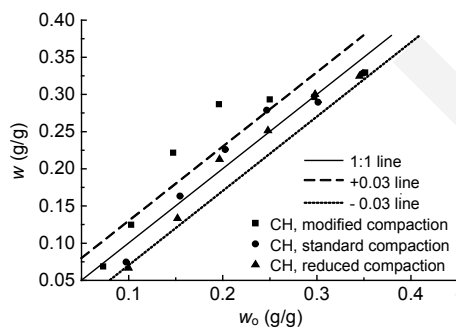


Fig. 5 Comparisons of water content by Eq. (10) and the oven dry method for ASTM-CH soil at different compaction energy levels

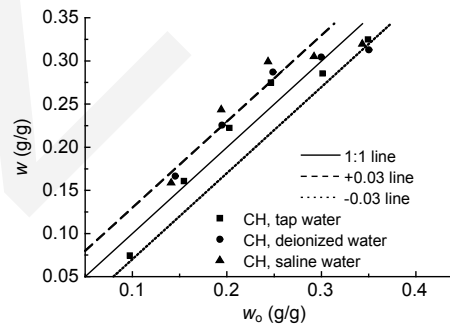


Fig.6 Comparisons of water content by Eq. (10) and the oven dry method for ASTM-CH soil at different pore fluid conductivities

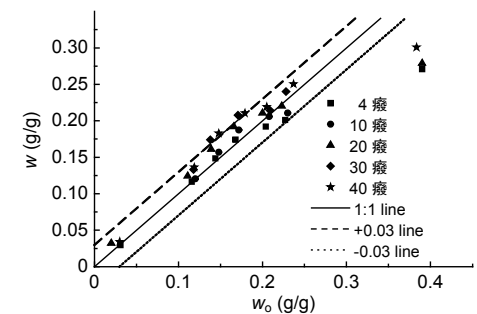


Fig. 7 Comparisons of water content by Eq. (10) and the oven dry method for Crosby Till soil at different temperatures

# Conclusions

## Conclusions:

1. The accuracy of the new empirical calibration equation is within  $\pm 0.05$  g/g for commonly encountered soils.
2. For dry density ranging between 1.3–2.3 g/cm<sup>3</sup>, the new empirical calibration equation shows a good accuracy.
3. For the commonly encountered ranges of compaction energy and pore fluid conductivity, the new empirical calibration has a good accuracy.
4. Temperature has no sensible influence on the results from the new empirical calibration equation when it is used within 4–30 ° C.