COMPUTEDPARAMETERS

Moisture Content for Unbound Materials at Seasonal Monitoring Program Sites

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Introduction

Moisture content plays a significant role in the performance of pavements. Variation in the amount of moisture in the subgrade can change the volume of swelling soil, which may result in detrimental deformation of the pavement structure. An increase in moisture in the subgrade and unbound base can weaken the bearing capacity of these materials, affecting the pavement's response to loads and, ultimately, pavement service life.

The moisture content of unbound materials at LTPP Seasonal Monitoring Program (SMP) sites is computed based on the dielectric constant determined through the use of time-domain reflectometry and soil property data contained in the LTPP Information Management System (IMS) database. A discussion of the use of time-domain reflectometer (TDR) probes and the values derived from them can be found in the computed parameters document, "An Input for Moisture Calculations—Dielectric Constant From Apparent Length" (Publication No. FHWA-RD-99-201), which can also be found on this web site.

Benefits

With computed moisture content data available, a user can proceed directly with analysis that requires this information from seasonal monitoring sites, without having to perform the intermediate interpretation and calculation steps.

Process Implementation

The computed moisture content can be found in two IMS tables: **SMP_TDR_AUTO_MOISTURE** and **SMP_TDR_MANUAL_ MOISTURE**. The **SMP_TDR_AUTO_ MOISTURE** table contains moisture content data computed from automated TDR measurements, while the **SMP_TDR_MANUAL_MOISTURE** table contains moisture content data interpreted from TDR traces recorded on paper.

For each measurement date, time, and TDR probe for which a trace could be interpreted, the tables contain the volumetric moisture content (VMC), a code indicating the model used to obtain the VMC, and the gravimetric moisture content. The inputs to the models other than the dielectric constant are found in **SMP_TDR_MOISTURE_SUPPORT**.

The research has identified four models for use: (1) the Coarse-K_a model, (2) the Fine-K_a model, (3) the AllSoil-K_a model, and (4) the Fine-Gradation model. In the first three models, the only independent variable is the dielectric constant. In the last model, both the dielectric constant and soil properties are needed.

After a model has been selected as a function of soil type and dielectric constant, both the volumetric and gravimetric moisture content can be determined, as illustrated in figure 1 below.

NOTES

Coarse-K_a model:
Coarse-grained soil model with only dielectric constant as independent variable.

Fine-K_a model:
Fine-grained soil model with only dielectric constant as independent variable.

AllSoil-K_a model:
Generic soil model with only dielectric constant as independent variable.

Fine-Gradation Model:
Fine-grained soil model with gradation and other parameters as independent

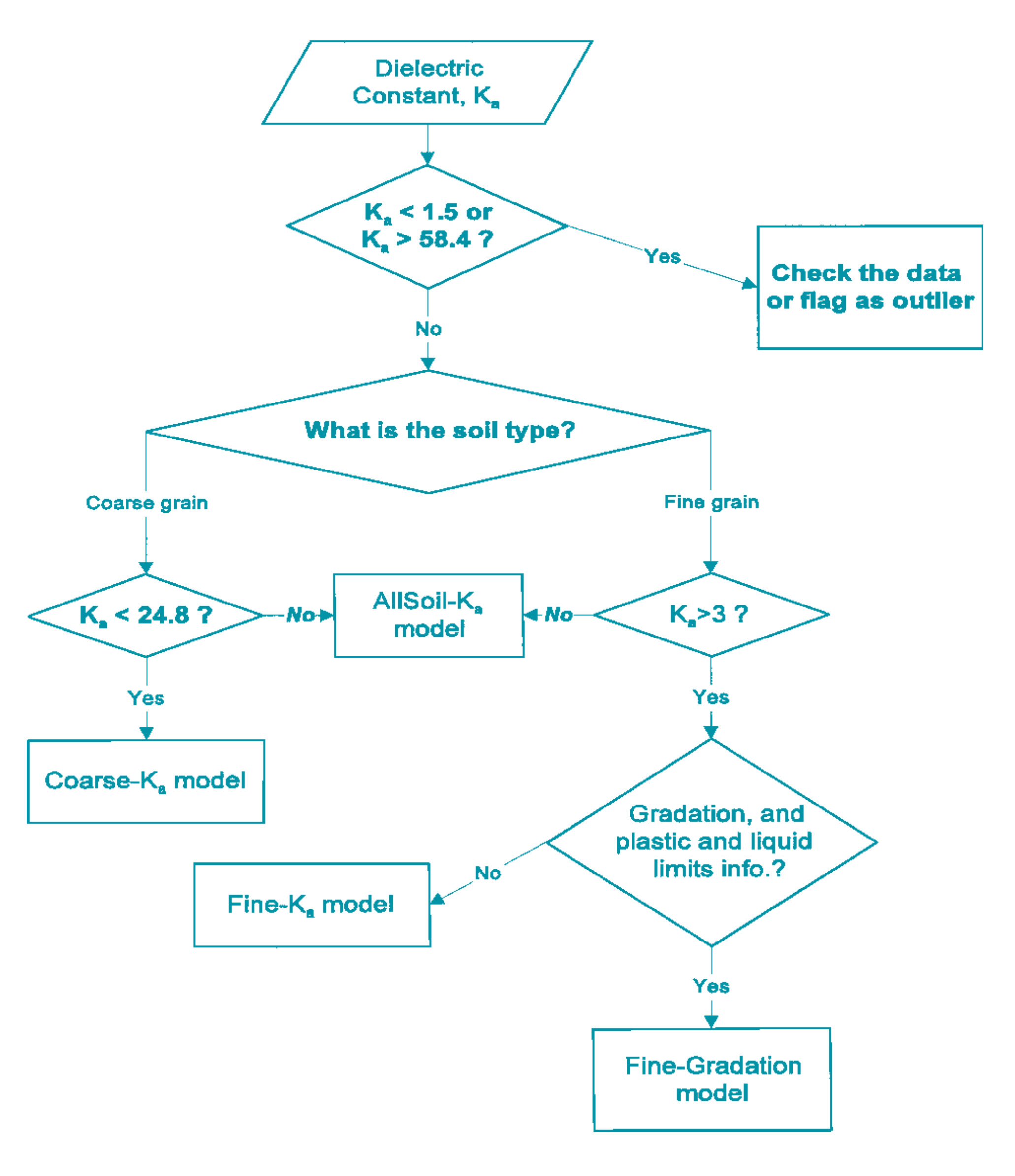

Figure 1. Selection of model for determining volumetric moisture content.

Analysis Steps

1. Obtain dielectric constant for TDR probes and survey dates of interest.

2. Collect the information stored in **SMP_TDR_MOISTURE_SUPPORT**. The information includes soil type, dry density of the soil surrounding a given probe, percentage of the soil passing a 1 1/2'', 1/2'', No. 4, No. 10, and No. 200 sieve and the plastic and liquid limits. The source of the first two values is also documented. Other useful information can be found in the SMP installation report for the site or in one of the following LTPP tables:

- **TST_L05B, SMP_TDR_DEPTHS_LENGTH**
- **SMP_DRY_DENSITY, TST_ISD_MOIST**
- **TST_UG05_SS05, INV_SUBGRADE**
- **TST_SS01_UG02, TST_SS04_UG08**
- **TST_UG04_SS03**

The moisture content data are computed for TDR probes installed at various depths. Drawing a diagram of the pavement structure with the installed TDR probes and their depths will help to verify the material type surrounding each probe. Units for the various values should be checked. The LTPP database currently contains data in both the U.S. customary units (English units) and the International System of Units (S.I.) (metric units). The models described were developed for S.I. unit inputs and some conversion of inputs may be necessary.

3. Select a volumetric moisture model using the process shown in figure 1 and compute volumetric moisture for each probe.

The Coarse-K_a model, the Fine-K_a model, and the AllSoil-K_a model are all third-order polynomials of the form:

$$V_w\% = a_0+a_1 K_a+a_2 K_a^2+a_3 K_a^3$$

where:
a_0, a_1, a_2, a_3= regression coefficients as shown in table 1.
K_a= the dielectric constant.

When a fine-grained soil with a dielectric constant and gradation, plastic limit, and liquid limits within the specified range, as shown in table 2, is encountered, the Fine-Gradation model should be used. The model is of the form:

$$V_w = a_0 + a_1K_a + a_2K_a^2 + a_3K_a^3 + a_4AVG\_ONE\_AND\_HALF\_PASSING + a_5AVG\_ONE\_HALF\_PASSING + a_6AVG\_NO\_4\_PASSING + a_7AVG\_NO\_10\_PASSING + a_8\ AVG\_NO\_200\_PASSING + a_9AVG\_PLASTIC\_LIMIT + a_{10}AVG\_LIQUID\_LIMIT$$

where:
K_a is the dielectric constant and the remaining variables are defined in the relevant IMS data tables. The coefficients and input data ranges are shown in table 2 on the following page.

Model Name	a_0	a_1	a_2	a_3
Coarse-K_a model	-5.7875	3.41763	-0.13117	0.00231
Fine-K_a model	0.4756	2.75634	-0.06167	0.00048
AllSoil-K_a model	-0.8120	2.38682	-0.04427	0.00029

Table 1. Volumetric moisture model parameter estimates for coarse-grained soils and selected fine-grained soils.

Variable	Coefficient	Value	Input Range
Intercept	a_0	1761.78	n/a
K_a	a_1	2.9145	3 - 58.4
K_a^2	a_2	-0.0767	–
K_a^3	a_3	0.0007	–
AVG_ONE_AND_HALF_PASSING	a_4	-19.6649	99 - 100
AVG_ONE_HALF_PASSING	a_5	4.3667	97 - 100
AVG_NO_4_PASSING	a_6	5.1516	90 - 100
AVG_NO_10_PASSING	a_7	2.7737	84 - 100
AVG_NO_200_PASSING	a_8	0.0606	12.6 - 94.6
AVG_LIQUID_LIMIT	a_9	-0.2057	0 - 45
AVG_PLASTIC_LIMIT	a_{10}	0.1023	0 - 69

Table 2. Coefficients and input range of the Fine-Gradation model.

4. Compute the gravimetric moisture content using the equation:

$$GV_w = \gamma_w / \gamma_d * V_w\%$$

where:

γ_w = 9.81 N/cm^3, the unit weight of water.

γ_d = unit weight of dry soil, N/cm^3.

$V_w\%$ = volumetric moisture content, %.

Researcher: This monograph was based on the report *LTPP TDR Moisture Database Schema and QC Specifications*, prepared by ERES Consultants, Inc., July 1998. Contract No. DTFH61-96-C-00003.

Availability: This publication is available in pdf format from the LTPP home page at *httpp://www.tfhrc.gov.* Copies are also available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Key Words: Time-domain reflectometry (TDR), moisture content.