International Association of Chinese Infrastructure Professionals

Implementing the LWD for MoDOT Construction Acceptance of Unbound Material Layers

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INTRODUCTION

- Conventional density-based methods of unbound materials compaction quality assurance (QA) using nuclear density gauges (NDG) become less desirable because of safety, regulatory, and cost concerns.
- The density is not a direct input to the structural design of pavements and is not directly linked to the long-term performance of pavements, instead the modulus is.
- Modulus-based compaction QA of unbound materials is gaining attention, several devices were proposed in the last decades.
- Modulus-based compaction QA method using the lightweight deflectometer (LWD) has been employed by a few state DOTs and countries.
- Missouri DOT is interested in shifting from the NDG to LWD in unbound materials compaction QA.

Modulus-Based Devices


Nuclear Density Gauge


Briaud Compaction Device


Clegg Hammer


Zorn Lab 3.0 LWD


GeoGauge

Dynamic Cone Penetrometer

OBJECTIVES

- To classify four soils and determine their optimum moisture contents (OMC) and maximum dry densities (MDD).
- To determine field target moduli for tested soils through laboratory LWD tests on Proctor mold on corresponding samples at acceptable moisture contents (MC). (OMC-3% to OMC for MoDOT)
- To evaluate compaction acceptance of tested soils using MC and field-to-target LWD modulus ratio criteria successively.

METHODOLOGY

Laboratory and field tests

Lab/field	Tests	Results
Lab	Soil classification	Soil type
	Compaction test	OMC and MDD
	LWD test on Proctor mold	Lab LWD moduli (E_{lab}), lab MCs (MC_{lab}), lab applied stresses (P_{lab}) and coefficients (α_i)*
Field	LWD test in the field	Field measured LWD moduli (E_{field}), field MCs (MC_{field}), and field applied stresses (P_{field})

*α_i is determined with MC_{lab}, P_{lab}, and E_{lab} via Eq. (1).

Compaction acceptance evaluation

if OMC-3% ≤ MC_{field} ≤ OMC: ← **Criterion [1]:** Moisture content
  if E_{field}/E_{target}** ≥ 100%: ← **Criterion [2]:** Field-to-target LWD modulus ratio.
    Compaction is acceptable
else:
  Compaction is unacceptable

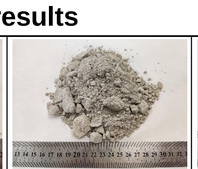
** E_{target} is determined with MC_{field}, P_{field}, and α_i via Eq. (2).

$$E_{lab} = a_0 + a_1 \times MC_{lab} + a_2 \times MC_{lab}^2 + a_3 \times P_{lab} + a_4 \times P_{lab}^2 \quad (1)$$

$$E_{target} = a_0 + a_1 \times MC_{field} + a_2 \times MC_{field}^2 + a_3 \times P_{field} + a_4 \times P_{field}^2 \quad (2)$$

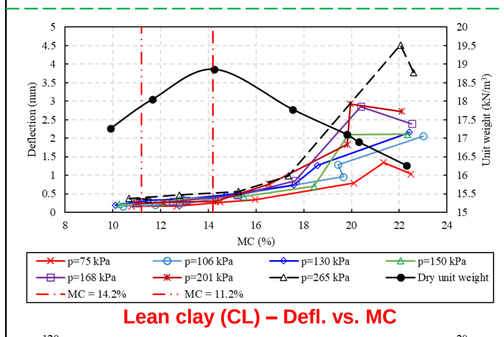
SOIL PROPERTIES

Soils classification and compaction results

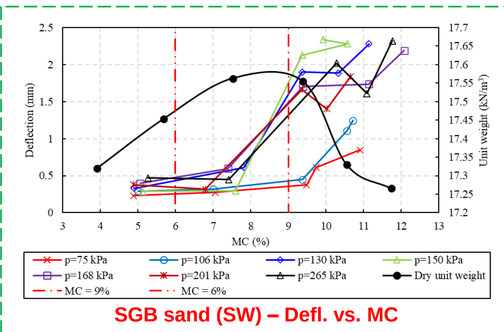
Soils				
	Lean clay	**SGB sand**	**Base agg.**	**Silty clay**
USCS	CL	SW	SW	CL
OMC (%)	14.2	7.5	9	12.5
MDD (kN/m³)	16.1	17.6	21.6	18.7

LWD TESTS ON PROCTOR MOLD

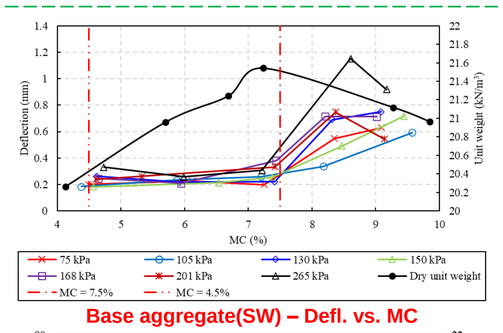
- LWD tests on Proctor mold were conducted, using Zorn Lab 3.0 LWD shown in the INTRODUCTION, on the four types of soils compacted at a range of MCs depending on their OMCs.
- Results of LWD tests on Proctor mold, including deflection vs. MC and lab LWD modulus vs. MC, were plotted along with compaction curves.
- Coefficient α_i were determined by fitting results to Eq. (1) using Excel Solver, which were used in Eq. (2) later.



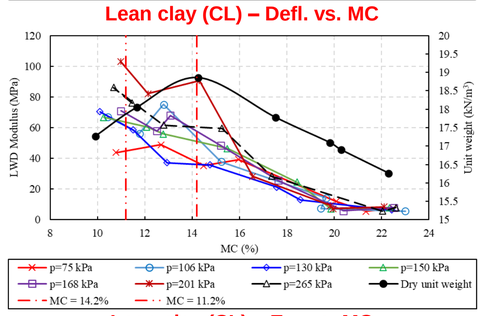
Lean clay (CL) – Defl. vs. MC



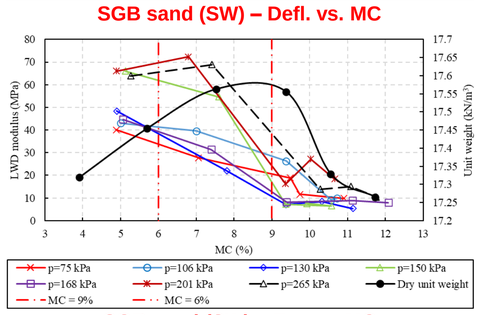
SGB sand (SW) – Defl. vs. MC



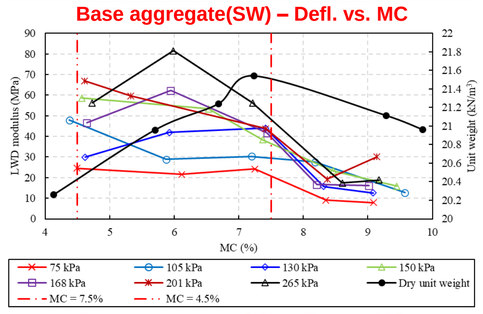
Base aggregate(SW) – Defl. vs. MC



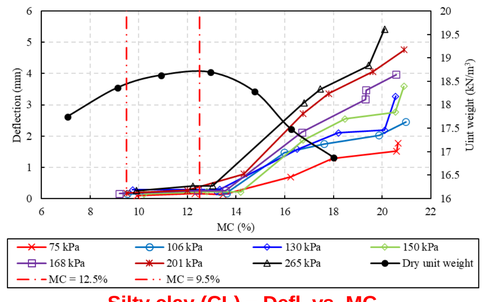
Lean clay (CL) – E_{lab} vs. MC



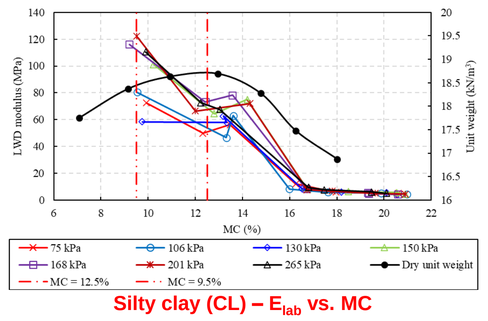
SGB sand (SW) – E_{lab} vs. MC



Base aggregate (SW) – E_{lab} vs. MC



Silty clay (CL) – Defl. vs. MC

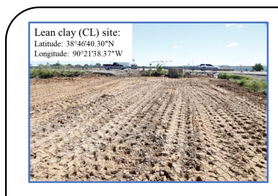


Silty clay (CL) – E_{lab} vs. MC

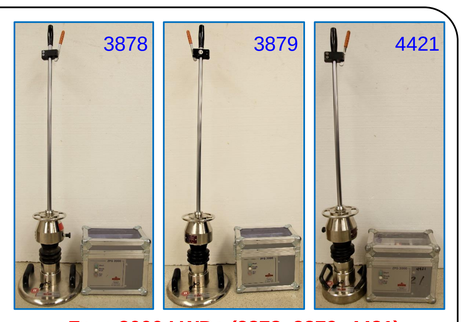
Coefficients α_i

Soils	Lean clay (CL)	SGB sand (SW)	Base agg. (SW)	Silty clay (CL)
α_0	101.5083	72.34699	-35.96733	270.54287
α_1	-3.54272	-4.63602	17.988002	-25.59477
α_2	-0.09918	-0.21032	-1.869550	0.5445991
α_3	148.8916	35.00368	402.13784	287.61439
α_4	-128.78	223.637	-751.2629	-663.0138

FIELD LWD TESTS AND COMPACTION ACCEPTANCE EVALUATION

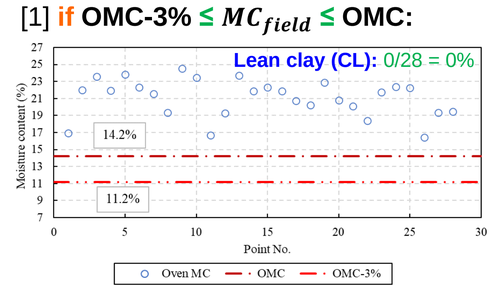


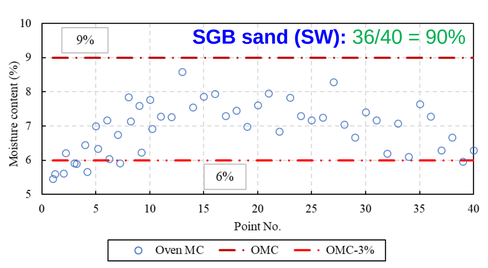
- Field LWD tests were conducted at four corresponding sites (shown above) using three field-version Zorn 2000 LWDs (shown on the right).
- Results of field LWD tests were plugged into Eq. (2) to determine E_{target}.
- Compaction acceptance was evaluated according to moisture content and modulus ratio (E_{field}/E_{target}) criteria, successively.

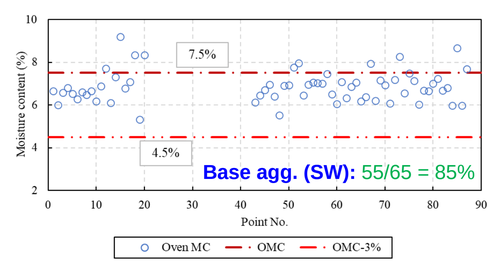


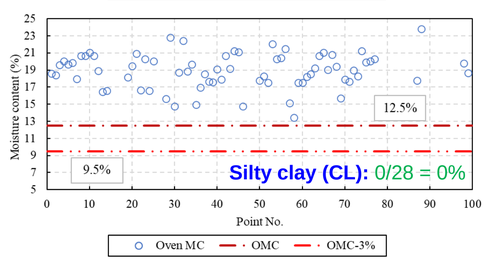
Zorn 2000 LWDs (3878, 3879, 4421)

[1] if OMC-3% ≤ MC_{field} ≤ OMC:

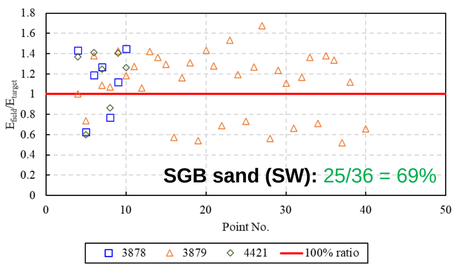


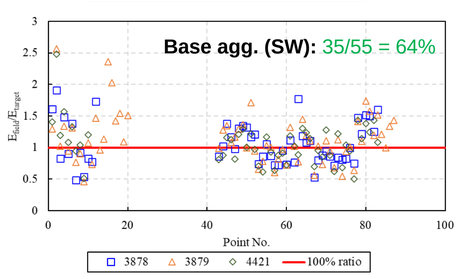






[2] if E_{field}/E_{target} ≥ 100%:





CONCLUSIONS

- The lab LWD modulus generally increased with the increase of applied stress and decreased with the increase of moisture content, moreover, it showed a constant value when the moisture content was higher than a cutoff.
- The deflection in LWD test on Proctor mold generally increased with the increase of moisture content and applied stress.
- With measured field moisture contents and LWD modulus ratios of measured to target field LWD moduli, the proposed QA criteria concluded that the lean clay (CL) and the silty clay (CL) were unacceptable because of overall high moisture contents while the SGB sand (SW) and the base aggregate (SW) were mostly acceptable.
- The modulus-based construction QA method for unbound materials using LWDs was promising.

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