Advances in Designing Field Compaction: M-D Relations

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ATTENTION: TP&D, DESIGN, CONSTRUCTION, MAINTENANCE AND TRAFFIC OPERATIONS ENGINEERS

MEMORANDUM

Texas Department of Transportation

SPECIAL PROVISION AND/OR SPECIFICATION CHANGE MEMORANDUM 15-12

TO: District Engineers **Date:** March 14, 2012

FROM: John F. Obr, P. E.
Construction Division Director

SUBJECT: Statewide Special Provision 132---007 (04), "Embankment"

The above-referenced special provision has been approved for statewide use and is optional for all projects using Item 132 beginning with the May 2012 letting.

This special provision revises Article 132.3., Section D., Compaction Methods, by adding language that affords the contractor the option to use a computer-generated density curve.

Please disseminate this information to your Transportation Planning & Development, Construction, Maintenance, and Traffic Operations Engineers.

cc: TxDOT Specification Committee
Federal Highway Administration
Associated General Contractors

2004 Specifications

APPROVED:
Date 02/24/12
Federal Highway Administration

Examined and Recommended for Approval
Date 2-23-12

SPECIAL PROVISION

132---XXX

Embankment

For this project, Item 132, "Embankment," of the Standard Specifications, is hereby amended with respect to the clauses cited below, and no other clauses or requirements of this Item are waived or changed hereby.

Article 132.3 Construction, Section D. Compaction Methods. The first paragraph, last sentence, is replaced by the following:

> Compact embankments in accordance with Section 132.3.D.1, "Ordinary Compaction," or Section 132.3.D.2, "Density Control," as shown on the plans. Section 132.3.D.3, "Density Control by Computer-Generated (CG) Curve," may be used by the contractor as an option for density control.

Article 132.3 Construction, Section D. Compaction Methods, is supplemented by the following:

3. **Density Control by Computer-Generated (CG) Curve.** At the Contractor's discretion, a CG curve may be used for density control. The option to use a CG curve for density control is not available for soils with a PI greater than 35; follow the requirements of Section 132.3.D.2, "Density Control."

Compaction Control Report

ABC Engineering

Report Produced By

User:	Les Davis
Company:	ABC Engineering
Date:	12/8/2009 12:25:54 PM CST
Report Number:	2009.0498

Project Number:	99012	Fill:	Expansion
Project Name:	I10 Expansion	Work Segment:	WS 23-9
Project Phase:	Construction Quality Assurance (CQA)	Lift:	Grade +2
Project Owner:	JPO	Soil Desc:	Dark yellowish sandy clay

Site Specifications

Min % Max Dry Density	95%
Resilient Modulus Factor	1500
Lab Reference Standard	ASTM D698 (SP)

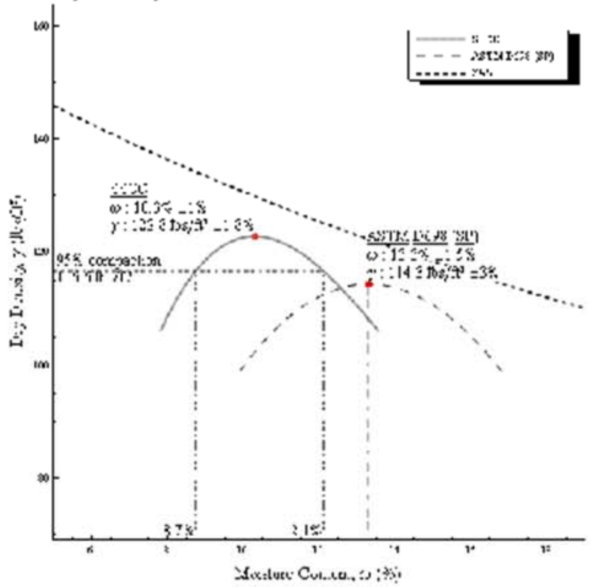
Site Conditions

Loose Lift Thickness (in)	8
Compactor	CAT 815
USC Classification	CL
Specific Gravity	2.65
Liquid Limit (%)	33
Plasticity Index (%)	15
Plastic Limit (%)	18
% Fines (%)	65
% Gravel (%)	0
% Sand (%)	35

SSCC Fill Properties at 95% Compaction

		Dry Side	Wet Side	Tolerance
ω (%)		8.7	12.1	±1%
γ (lbs/ft³)		116.6	116.6	±1.8%
S (%)		55.4	76.7	±2%
e		0.42	0.42	±2%
Na (%)		13.1	6.8	±2%
σ (lbs/ft²)	ASTM D2166	3,729	3,228	±10%
c' (lbs/ft²)	ASTM D2850	789	745	±10%
Ø' (°)	ASTM D2850	44	40	±5%
ω Potential (%)		+7.0	+3.6	±2%
Free Swell (%)	ASTM D2435	3.4	2.2	±1.5%
TrueCBR® (%)	Soaked	1.1	3.9	±2%
TrueCBR® (%)	Unsoaked	37.9	6.6	±2%
Res Mod (lbs/in²)	Soaked	1,769	5,926	±2%
Res Mod (lbs/in²)	Unsoaked	56,907	9,976	±2%

SSCC®: Site Specific Compaction Curve® location



Note: Curve shapes and sizes will vary with automated plot scaling.

Graphics powered by Mathematica

Construction Controls

Minimum % of Maximum Dry Density

SSCC	95%
SSCC®: Site Specific Compaction Curve® location	
ASTM D698 (SP)	102%

Construction Moisture Range @ 95%

8.7% - 12.1% (±1% MC)

Minimum # of Roller Passes

12* ** Full lift coverage required*

Curve Frequency:

Compaction curves should be obtained regularly with changes in material index properties and upon change in color or texture for effective construction control.

Authorization By:____________________

Print Name:____________________

Date:__________ Firm Reg.#:____________

What Have We Done Since 1930?

- Use Laboratory Compaction Results (2 Energy) for Field Compaction. (No Field Standard?)
- <u>Compactor Technology</u> Has Advanced (Multiple Energy). We have not changed?
- <u>Monitoring Technology</u> Has Advanced. We are only measuring the density and moisture content.
- <u>No Correlation</u> Between Field Compaction and Laboratory Compaction?

Field Vs. Lab Compaction

Lab Compaction (Sample Size, Energy, Mold)

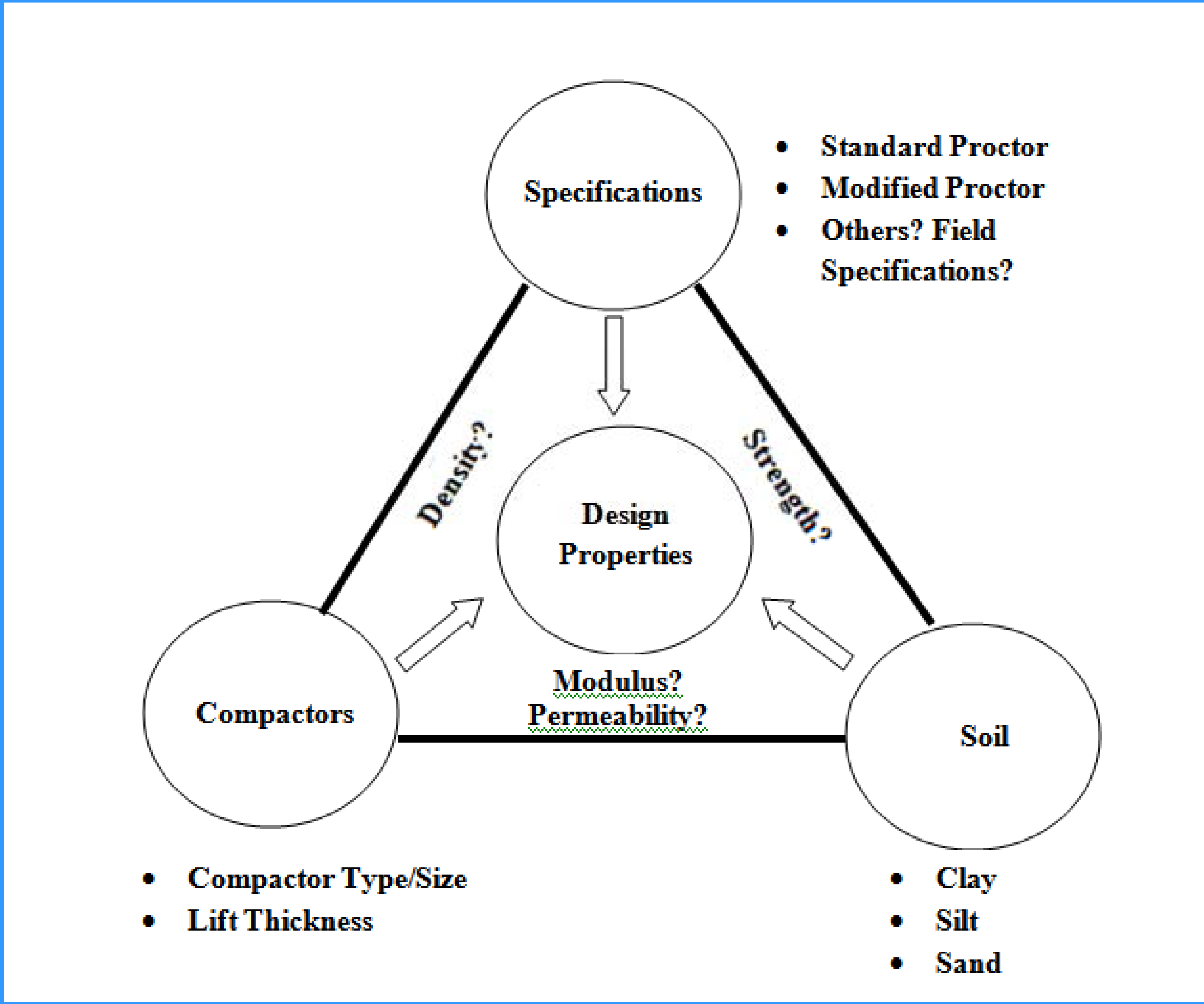
Field Compaction

WHAT IS COMPACTION OF SOILS ?

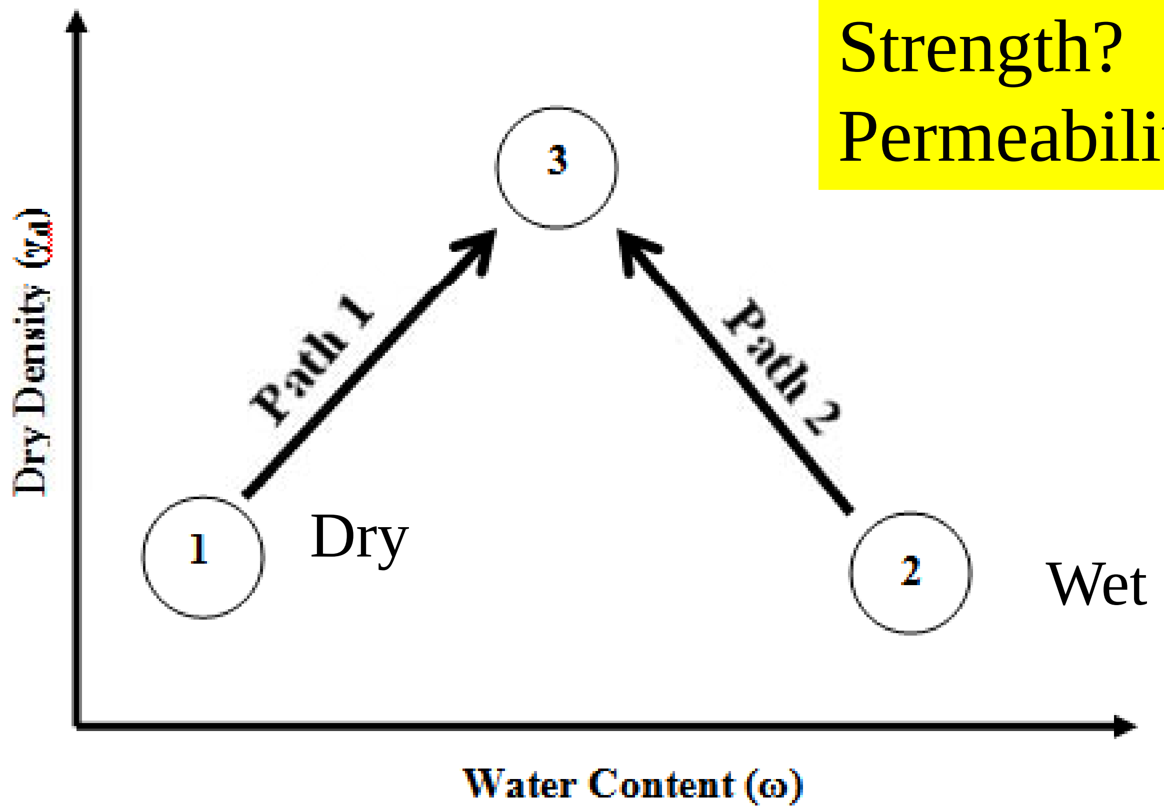
COMPACTOR + SOIL = COMPACTION

What Advancements?

Major Components in Field Compaction



Compacted Soil Properties Depend on the Energy/Stress Path of Compaction



Strength?
Permeability?

Same Soil (Dry & Wet) Compacted Differently

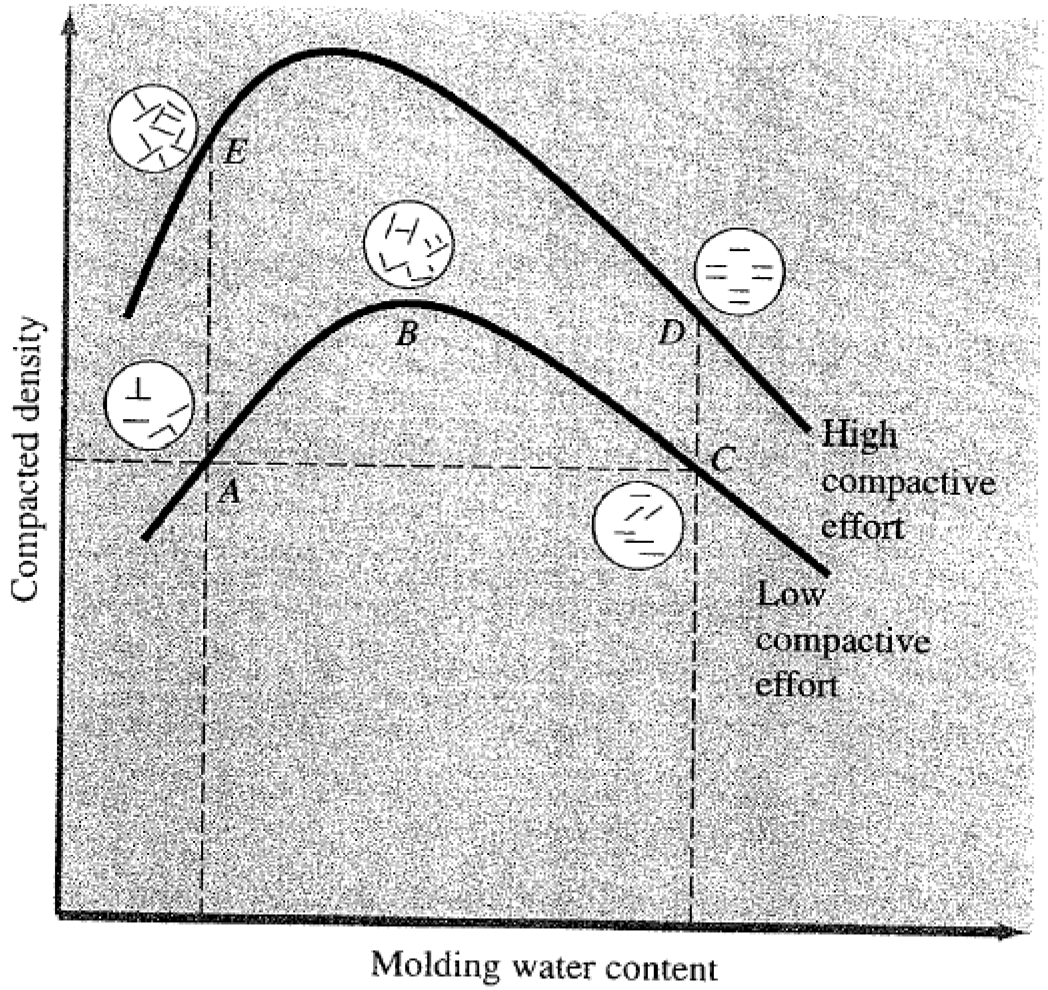
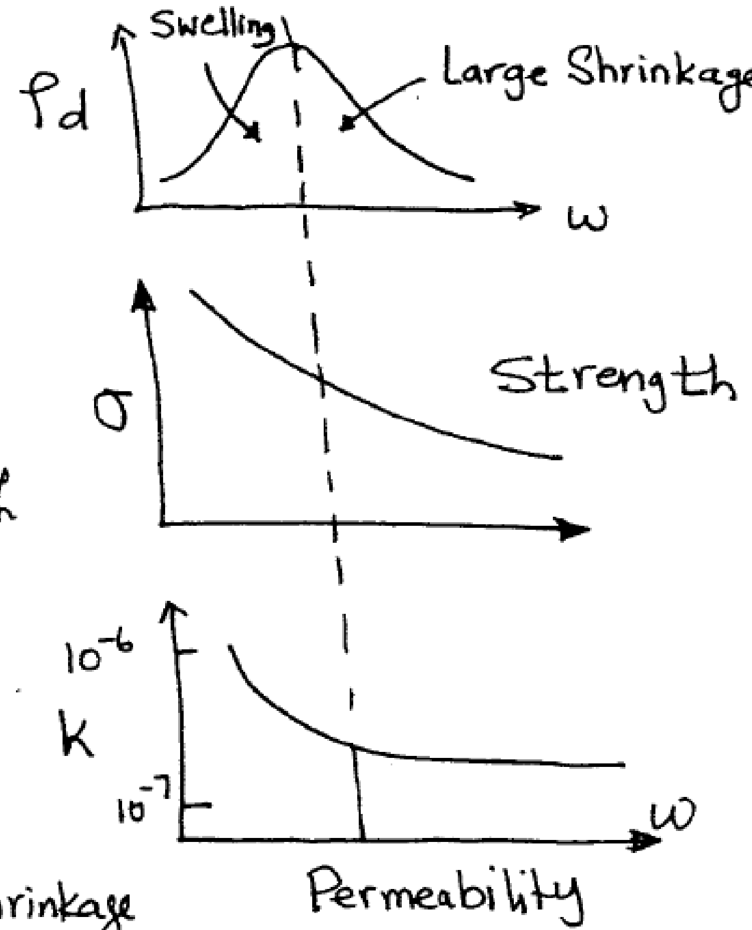
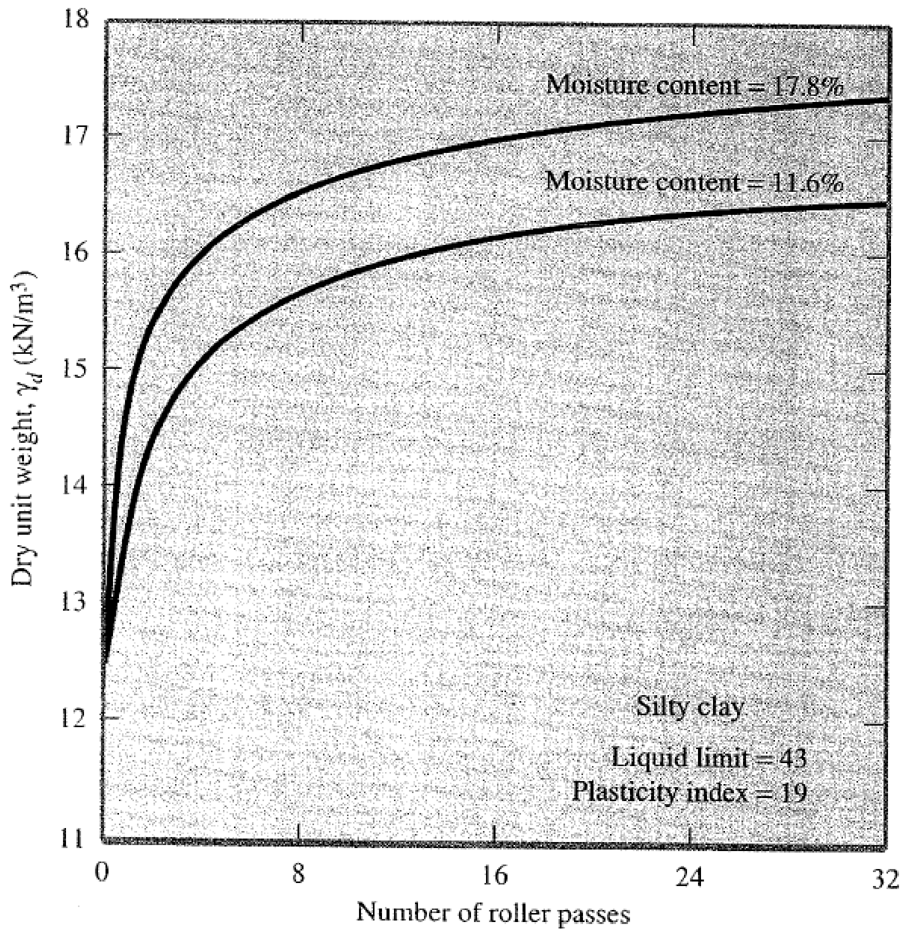


FIGURE 3.10 Effect of compaction on the structure of clay soils (Redrawn after Lambe, 1958)

Other Properties

- Strength decreases with increase in w/c
- Permeability decreases with increase in w/c. Reaches a minimum at about w_{opt}.
- Compact dry of optimum - Swell
- Compact very wet of Optimum - Shrinkage





(a)

FIGURE 3.15 (a) Growth curves for a silty clay—relationship between dry unit weight and number of passes of 84.5-kN three-wheel roller when compacted in 229-mm loose layers at different moisture contents (Redrawn after Johnson and Sallberg, 1960); (b) Vibratory compaction of a sand—variation of dry unit weight with number of roller passes; thickness of lift = 2.44 m (Redrawn after D'Appolonia, Whitman, and D'Appolonia, 1969)

What Have We Done ? Laboratory Correlations & Modeling..

Relations between compaction parameters and physical properties of fine soil (SI units) (Sivrikaya et al. 2008)

Properties	Testing Method	Relations	Equation Numbe
Optimum Moisture Content, Plastic Limit	Standard Proctor Compaction	$w_{opt} = 0.94 w_P$	(1)
Max Dry unit weight, Optimum Moisture Content		$\gamma_{dry/max} = 21.97 - 0.27 w_{opt}$	(2)
Max Dry unit weight, Optimum Moisture Content		$\gamma_{dry/max} = 23.45 e^{-0.018 w_{opt}}$	(3)
Optimum Moisture Content, Plastic Limit	Modified Proctor Compaction	$w_{opt} = 0.69 w_P$	(4)
Optimum Moisture Content, Liquid Limit		$w_{opt} = 0.35 w_L$	(5)
Max Dry unit weight, Optimum Moisture Content		$\gamma_{dry/max} = 22.33 - 0.285 w_{opt}$	(6)
Max Dry unit weight, Optimum Moisture Content		$\gamma_{dry/max} = 23.72 e^{-0.0184 w_{opt}}$	(7)

Will This Help in The Field?

How to Interpret the Compaction Curve?
Soil is a 3 Phase Material: Solid, Water and Air

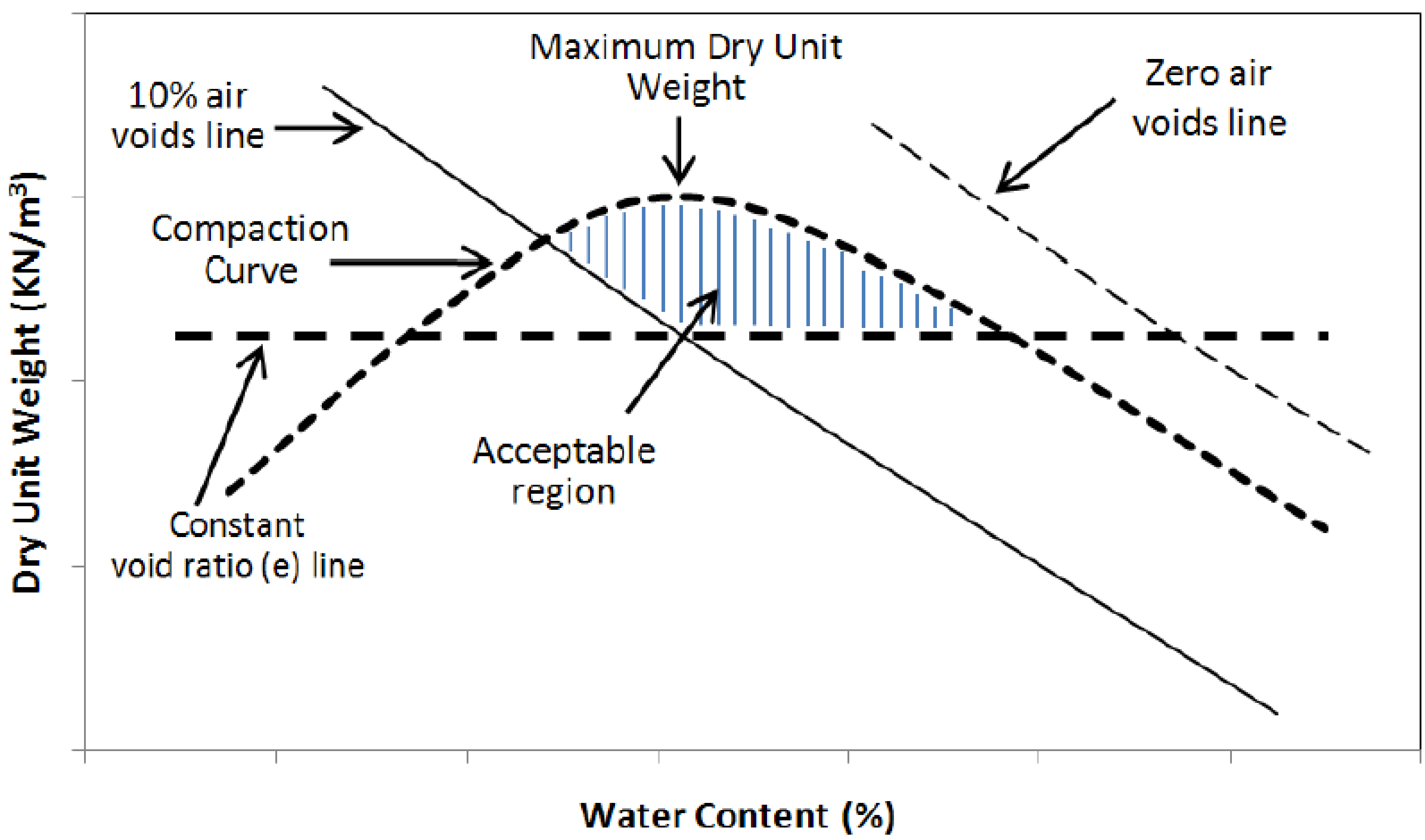


Figure 1. Typical acceptable zone for compacted soils

OBJECTIVES

- **Field** Versus **Laboratory** Compaction ?
- Computer Generated **(CG)** Curves
- Intelligent Compactor **(IC)**
- Design and Build **New Devices** (A Device for Compacted Soil Characterization (SP-CIGMAT)).
- Verify the Performance of **SP-CIGMAT** in the Field .

Texas Hurricane Center
for Innovative Technology

1994
CIGMAT

Field Test Site

Field Compaction

Before Compaction

After Compaction

Field Checks of Density

Nuclear density gauge

Quality Control Procedure
California Bearing Ratio (CBR) Test

Field Study: 10 Soils (CL, CH, SC)

SELECTED CL SOIL

Table 2. Summary of Physical Properties of Soils

Soil Type		LL	PL	PI	Specific Gravity	Remarks
CL	Mean	42	16	26	2.69	Lesser variation in the soil properties compared to other CL soils selected for the field study. Also had less LL and PI to other CL soils
	Standard deviation	2.2	2.2	2.2	0.016	
	COV (%)	5.3	13.8	11.6	0.60	

Field Vs. Lab (CL): Curve Location & Shape

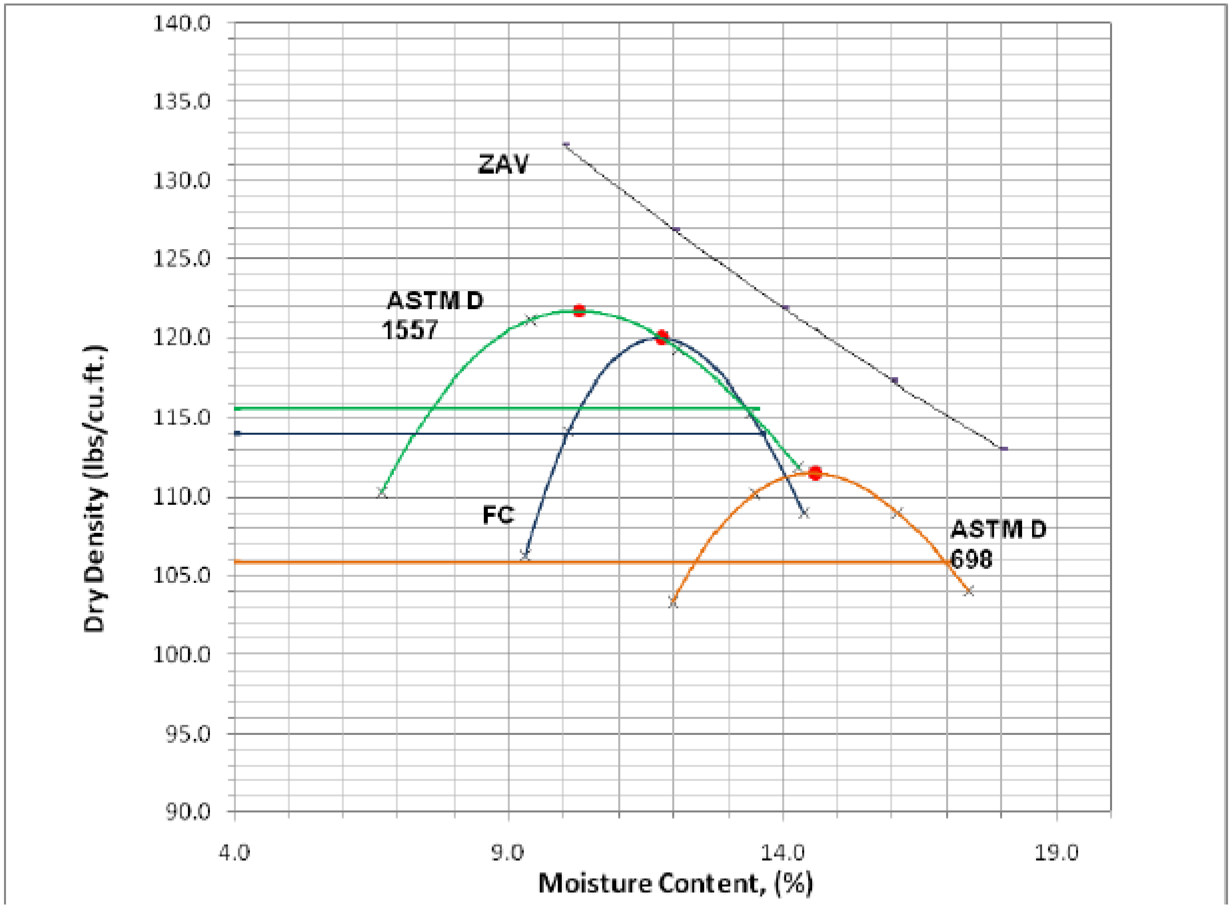


Figure 4. Laboratory and Field Compaction Results for a CL Soil

How to get the field curve (FC)?

Compacted Soil Properties (CL): Field vs. Lab (Moisture, γ_d, S_r, e, N_a)

Table 3. Summary of Compacted Properties of CL-A Soil

Compaction Method		Moisture Content(%)	Dry Unit Weight (lb/cu.ft)	Degree of Saturation (S) (%)	Void Ratio (e)	Air Voids (%)
Standard Proctor (SP)	Optimum	14.6	111.5	77.7	0.51	7.49
	95% Dry	12.5	105.9	57.5	0.59	15.70
	95% Wet	16.9	105.9	77.7	0.59	8.23
Site Specific Compaction Curve (SSCC)	Optimum	11.8	120.0	79.6	0.40	5.82
	95% Dry	10.1	114.0	57.5	0.47	13.63
	95% Wet	13.6	114.0	77.4	0.47	7.24
Modified Proctor (MP)	Optimum	10.3	121.7	73.1	0.38	7.41
	95% Dry	7.6	115.6	45.2	0.45	17.05
	95% Wet	13.3	115.6	79.2	0.45	6.49

SPECIAL PROVISION

132---007

Embankment

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Computer Generated (CG) Curves

Table 3
Computer Generated Lab and Field Compaction Curve Input Criteria

Input Variables	Test Method
Liquid Limit, %	Tex-104-E
Plasticity index (PI), %	Tex-106-E
Soil gradation	Tex-110-E, Tex-111-E
Soil classification	Tex-142-E
Compaction roller brand, type, and model	N/A
Loose lift thickness, in.	N/A
Soil specific gravity	Use 2.65 for soil type SC. Use 2.68 for soil type CL. Use 2.69 for soil type CH.

Provide a compaction control report showing all input and output parameters and CG compaction curves, including:

- CG Tex-114-E laboratory maximum dry density (D_{acg})
- CG Tex-114-E laboratory optimum moisture content (W_{optcg})
- CG field maximum dry density (D_{fcg}) ←
- CG field optimum moisture content (Wf_{optcg})
- Graph of CG laboratory and field compaction curves and the "Zero Air Voids Line"
- Minimum number of roller passes to achieve the required density and moisture content.

Meet the requirements for field maximum dry density (D_{fcg}) and field optimum moisture content (Wf_{optcg}) specified in Table 4, unless otherwise shown on the plans. Use only the roller specified as an input parameter for the CG curve to meet density requirements.

Table 4
Field Density Control Requirements

Description	Density	Moisture Content
	Tex-115-E	
PI ≤ 15	≥ 98% D_{fcg}	≥ Wf_{optcg}
15 < PI ≤ 35	≥ 98% D_{fcg} and ≤ 102% D_{fcg}	≥ Wf_{optcg}

Each layer is subject to testing by the Engineer for density and moisture content. During compaction, the moisture content of the soil should be above CG optimum moisture content but should not exceed the value shown on the moisture-density curve, above optimum, required to achieve 98% dry density.

Major Issues With Compaction….

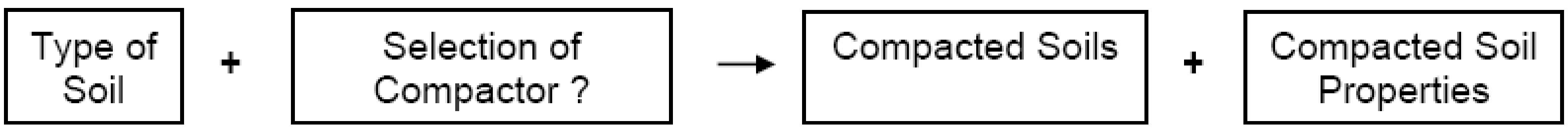

Figure 1 - Major issues in Achieving the Goals of Compacted Soils

Frequently Asked Questions (FAQ)

(1) Is the M-D relationship same for the field and laboratory?
(2) Is a test pad needed for field verification?
(3) Any method available to select the compactor based on available soil on site?
(4) Any method available to select the soil type based on available compactor on site?
(5) Can trial & error practice be avoided in fill construction?
(6) Can contractors construct fills at crew capacities?
(7) What properties of field compacted soil (strength, modulus of resilient) can be determined?
(8) Is the available information on the web?

INTELLIGENT COMPACTION

(IC)

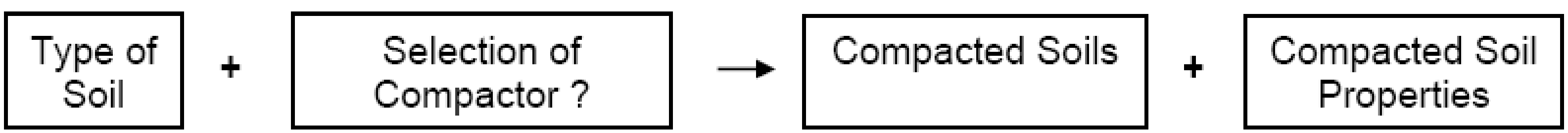

Figure 1 - Major issues in Achieving the Goals of Compacted Soils

IS IT COMPACTOR OR COMPACTION?

Intelligent Compaction Technology

An Innovation in Compaction Control and Testing

FHWA

Asphalt Pavement Engr.

Office of Pavement Technology

Federal Highway Administration

www.fhwa.dot.gov/pavement/

Compaction Monitoring Using Intelligent Soil Compactors (1)

R. Anderegg[1], Dominik A. von Felten[2], and Kuno Kaufmann[3]

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[2]Ammann Compaction Ltd., Eisenbahnstrasse 44, Langenthal (Switzerland), CH-4900; PH (++41) 62 916 63 74; FAX (++41) 62 916 64 60; email: d.vonfelten@ammann-group.ch
[3]Ammann Compaction Ltd., Eisenbahnstrasse 44, Langenthal (Switzerland), CH-4900; PH (++41) 62 916 63 73; FAX (++41) 62 916 64 60; email: k.kaufmann@ammann-group.ch

(2)

Abstract

The nonlinear vibrations of dynamic soil compactors are taken as the basis for feedback control systems for intelligent compaction. According to the achieved compaction, the parameters of the soil compactor are continuously changed.

The vibratory roller measures permanently the stiffness of the subgrade. In conjunction with GPS-data, this measurement can be used as a QA/QC tool. The stiffness data are directly correlated to plate bearing test.

In practice, the intelligent compaction ensures that the compaction job is completed in a minimum number of passes, the result is monitored and the compaction energy is automatically adjusted while measuring the soil stiffness.

1. Measures the Stiffness of subgrade.

3. QA/QC tool

2. Stiffness Related to Plate Bearing test (Strength?)

NCHRP
REPORT 676

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Intelligent Soil Compaction Systems

Year 2010

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

SDOT Studies

Table 1.1. Summary of field research sites.

State	Project	Dates	Rollers[a]	Soils[b]
MN	Mn/ROAD research site	July 2006	Ammann SD Bomag SD, PD Caterpillar SD, PD	Subgrade: A-6(5), A-4(3), A-2-6 Base: A-1-b, A-1-a
CO	I-25 reconstruction	Aug.–Oct. 2007	Bomag SD Caterpillar SD Dynapac SD	Subgrade: A-6(7), A-4, A-4(3) Subbase: A-1-a Base: A-1-a
MD	I-70 interchange	Nov. 2007	Bomag SD Dynapac SD, PD Sakai SD	Subgrade: A-2-4, A-4 Base: A-1-a, A-1-b
FL	Branan Field Chaffe/ I-10 interchange	April 2008	Case/Ammann SD Dynapac SD Sakai SD	Subgrade: A-3, A-2-4 Base: A-1-b
NC	NC311/I-85 divided highway	May–June 2008	Bomag SD Case/Ammann SD Sakai SD	Subgrade: A-2-4, A-4, A-1-b Base: A-1-a

[a]SD = smooth drum, PD = pad foot drum.

[b]American Association of State Highway and Transportation Officials classification provided; see Appendix A for more detail.

Include Texas……

COMPACTORS – Measurement Values (MV)

(Automatic Feedback Control)

Table 1.2. Summary of rollers used during the study.

Roller	MV	Drum Length, m (ft)	Drum Radius, m (ft)	Static Mass, kg (lb)	Static Linear Load, kN/m (kip/ft)	Excitation Frequency, Hz	Excitation Force, kN (kip)
Ammann/Case AC110/SV212	k_s	2.20 (7.22)	0.75 (2.46)	11,500 (25,350)	31.5 (2.2)	20–34	0–277 (0–62)
Bomag BW113-BVC	E_{vib}	2.13 (7.00)	0.75 (2.46)	14,900 (32,850)	42.4 (2.9)	28	0–365 (0–82)
Caterpillar CS563	CMV_C MDP	2.13 (7.00)	0.76 (2.49)	11,100 (24,500)	26.9 (1.8)	32	133, 266 (30, 60)
Dynapac CA362	CMV_D	2.13 (7.00)	0.77 (2.53)	13,200 (29,100)	37.3 (2.6)	32	0–260 (0–58)
Sakai SV510	CCV	2.13 (7.00)	0.75 (2.46)	12,500 (27,600)	32.2 (2.2)	37, 28	186, 245 (42, 55)

K_s & E – Stiffness of Soil

CMV – Compaction Meter Value

CCV – Continuous Compaction Value

What is the Soil Property?
Dry Density, M/C, Modulus?

What is Need for Field Compaction?

1. What is the M/C for Compaction? (Lab or Field)

2. Will the IC give you the M/C? No

3. How Many Roller Passes?

(Intelligent Compaction?)

Soil Stiffness (K_s)

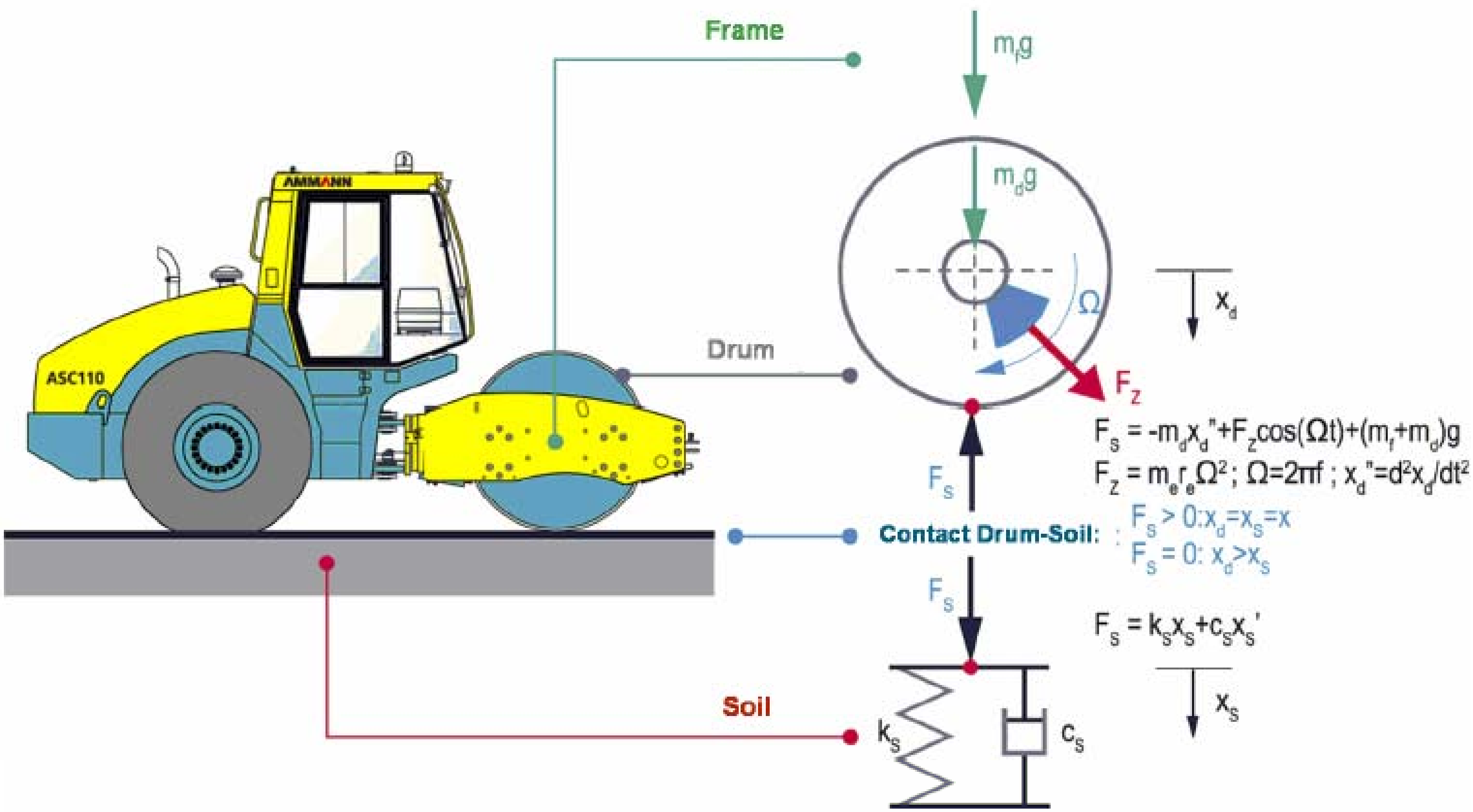


Figure 1. Analytical model of vertical vibration of a single drum roller (circular excitation). This model is also valid for vertical deflection of vibratory plates (directed excitation)

In analytical terms, the steady-state dynamic behavior of the soil-machine system from figure 1 can be described with the help of the equation of motion according to:

$$F_S = (m_f + m_d)g + m_e r_e \Omega^2 \cos(\Omega t) - m_d \ddot{x} \qquad x_d := x \qquad (1)$$

where F_S = soil-drum-interaction force (kN), m_d = drum mass (kg), m_f = frame mass (kg), x_d = vertical displacement of the drum (m), $m_e r_e$ = eccentric moment of unbalanced mass (kgm), Ω = circular excitation frequency (Hz). The dot notation signifies the differentiation with respect to time.
The soil-drum interaction force can alternatively be written

$$F_S = k_S x_d + c_S \dot{x}_d \quad \text{if} \quad F_S \geq 0\,,\; F_S \equiv 0 \;\text{ else} \qquad (2)$$

where k_S = soil stiffness (N/m), c_S = soil damping (Ns/m).

$$x_d = \sum_i A_i \cos(i\Omega \cdot t - \varphi_i) \qquad x_d := x \qquad (3)$$

where φ_i = phase lag between the generated dynamic force and the part of drum displacement with frequency if (°).

Depending on the operational status, the vibration displacement has one or more frequencies:

permanent drum-ground contact, linear: i=1

periodic loss of contact, nonlinear: i=1, 2, 3 (“Overtones”)

bouncing/rocking, subharmonic: i=1/2, 1, 3/2, 2, 5/2, 3

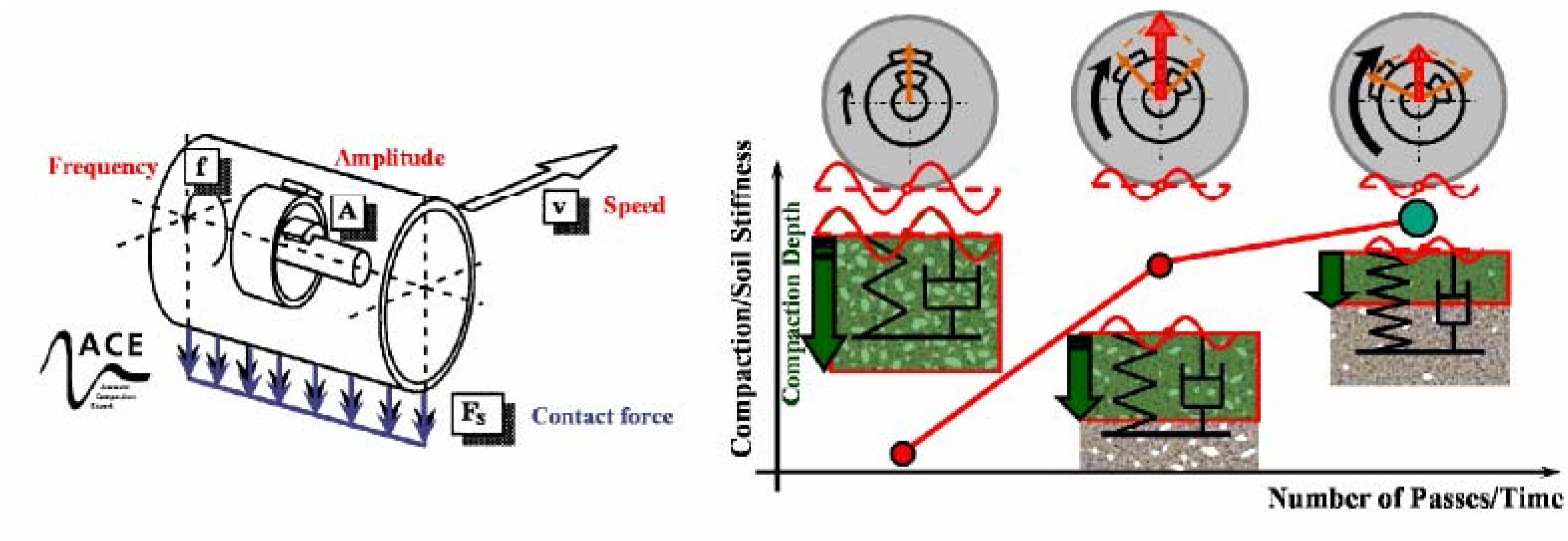
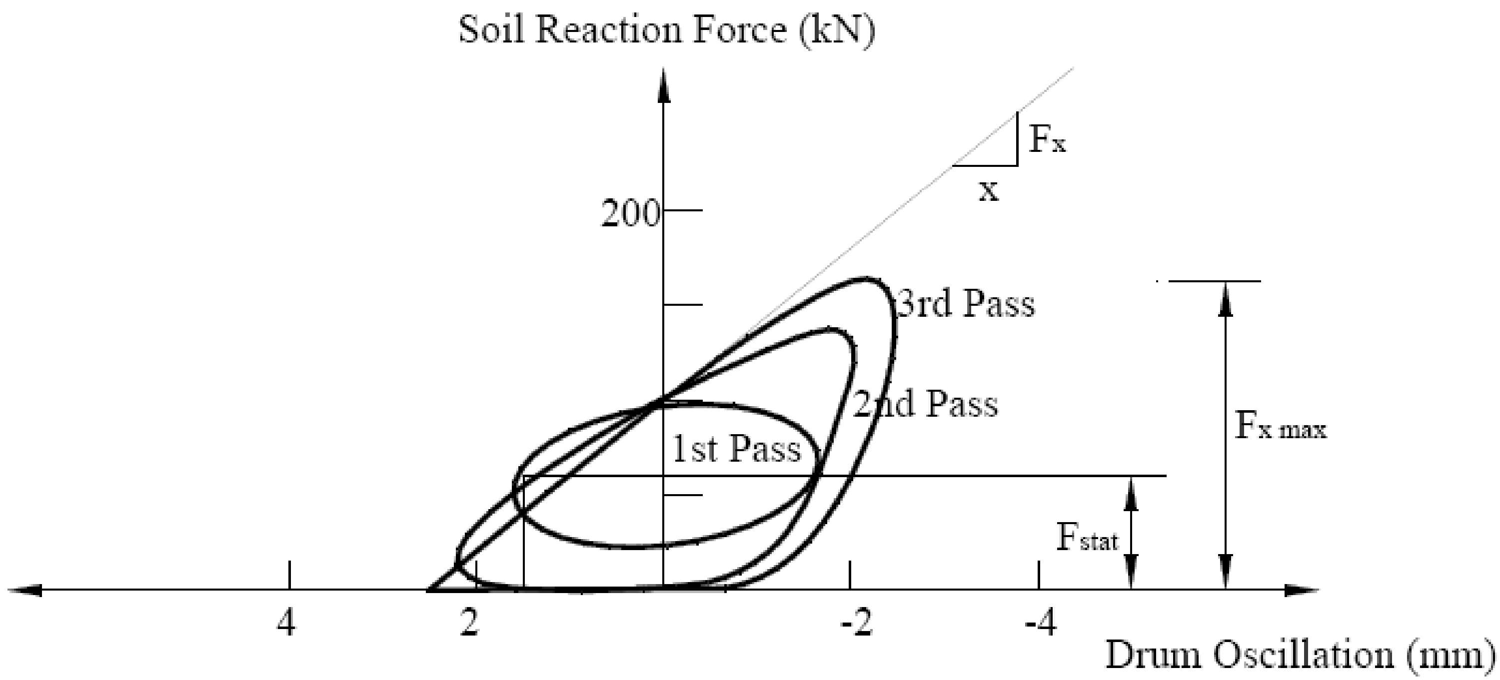


Figure 4. Ammann Compaction Expert ACE: automatic control of amplitude and frequency

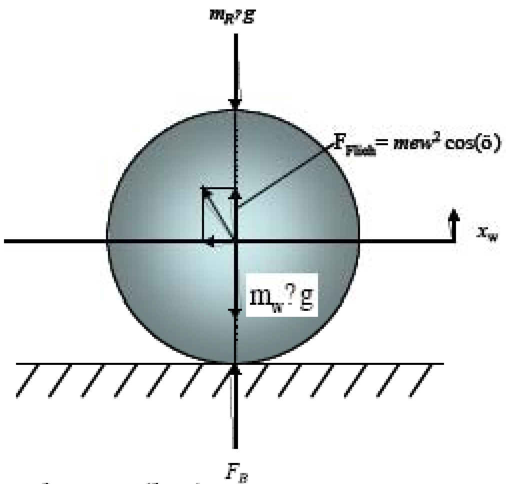
What Should be the Moisture Content?


Soil Reaction Force (kN)
200
Fx
x
3rd Pass
2nd Pass
1st Pass
Fx max
Fstat
4
2
-2
-4
Drum Oscillation (mm)

From Acceleration to Stiffness

$$F_B \cong -m_d \ddot{x}_d + m_u r_u \Omega^2 \cos(\Omega t) + (m_f + m_d) g$$

$$F_B \cong k_B x_d + d_B \dot{x}_d$$



F_B: soil-drum-interaction-force

x_d: vert. disp. of drum (m)

m_f: mass of the frame (kg)

r_u: radial distance for m_u

g: acc. due to gravity (m/sec²)

$\dot{x}_d$: velocity of drum

d_B: damping coefficient (d_B ~ 0.2)

m_d: mass of the drum (kg)

$\ddot{x}_d$: acceleration of drum

m_u: unbalanced mass (kg)

$\Omega = 2\pi\ f$

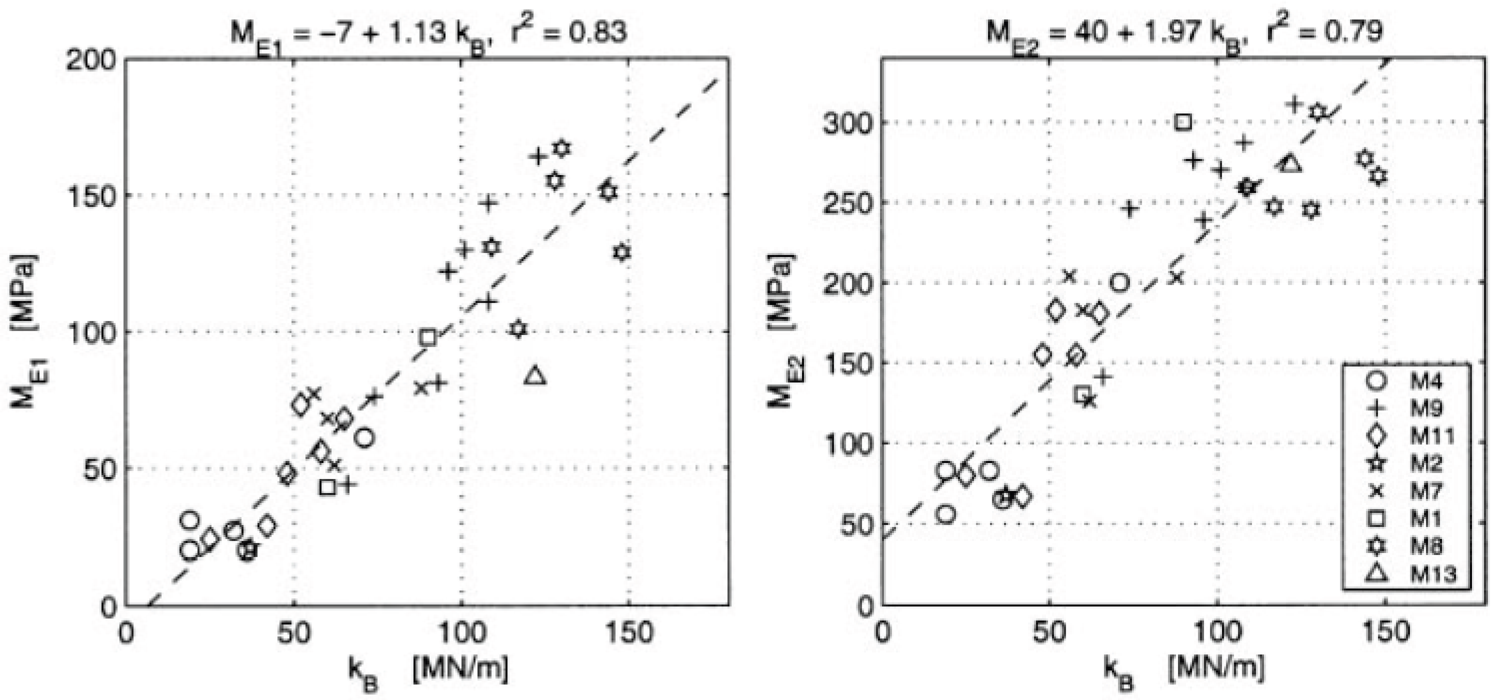
f: frequency of rotating shaft (Hz)

k_B: stiffness of soil

From Stiffness to Modulus (theoretical)

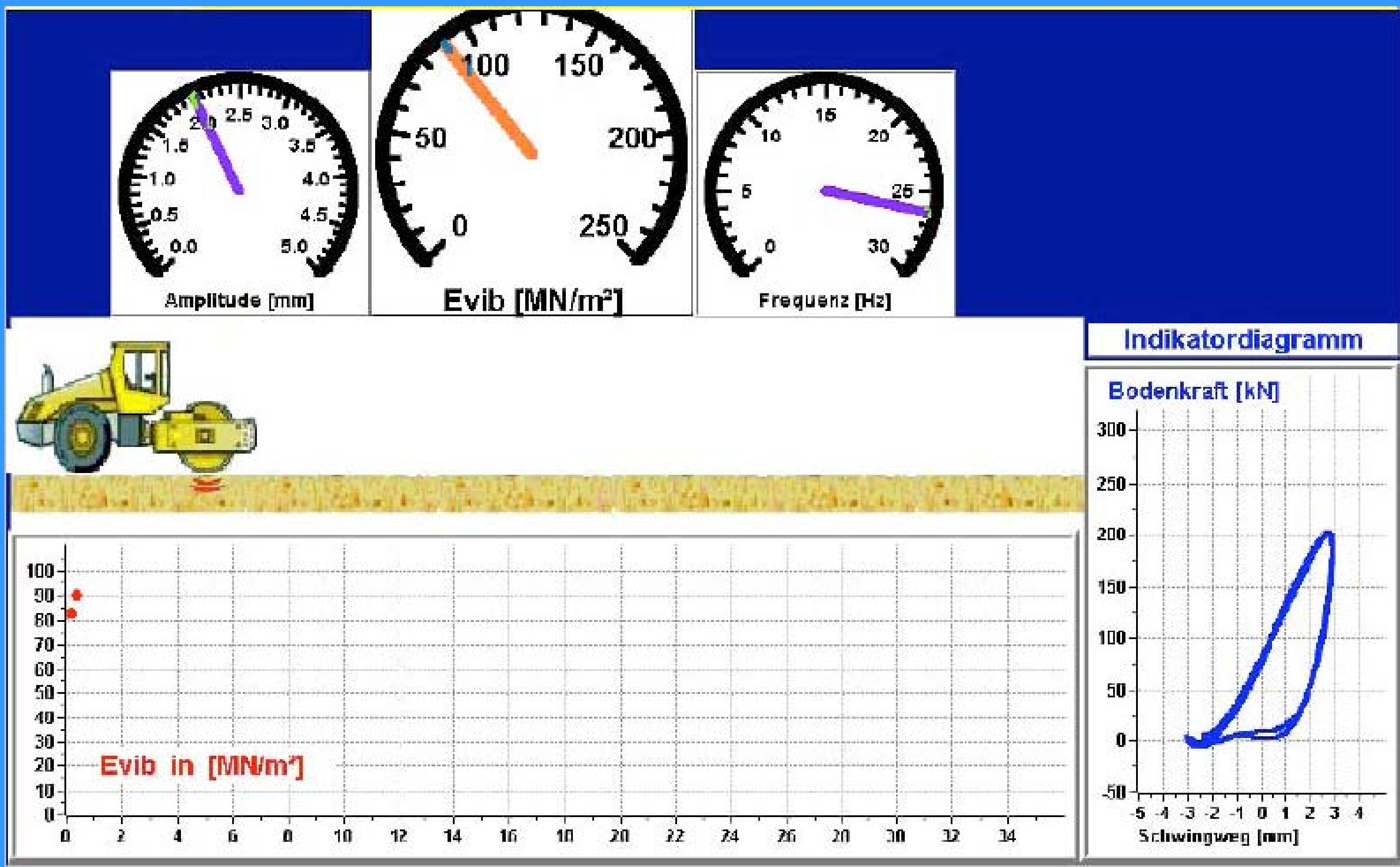
$$k_B = \frac{E \cdot L \cdot \pi}{2 \cdot \left(1 - \nu^2\right) \cdot \left(2.14 + \frac{1}{2} \cdot \ln\left[\frac{\pi \cdot L^3 \cdot E}{\left(1 - \nu^2\right) \cdot 16 \cdot \left(m_f + m_d\right) \cdot R \cdot g}\right]\right)} \quad [\mathrm{MN/m}]$$

From Stiffness to Modulus (experimental)



From AMMANN

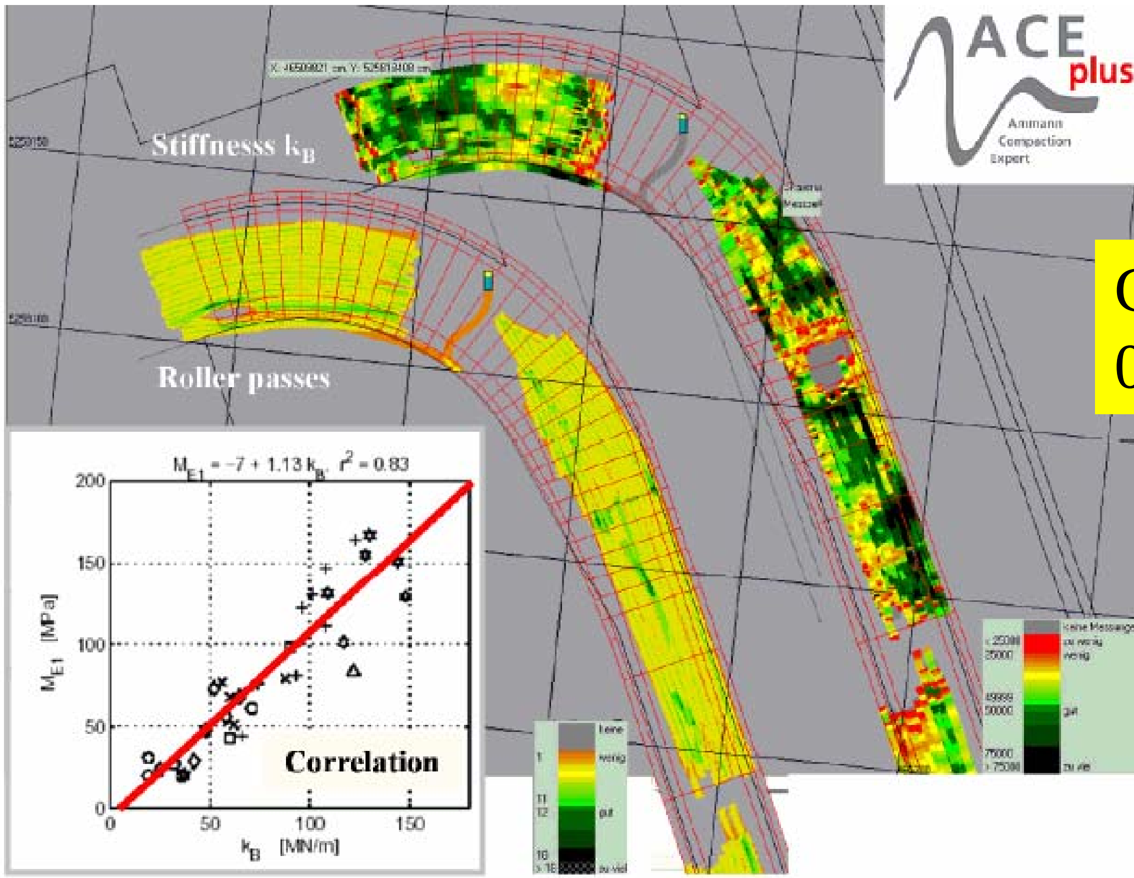
Controls in a Compactor



CCC

GPS-based Continuous Compaction Control displays the Compaction process

If we link the work-integrated bearing capacity measurement of "intelligent rollers" with the information on position and time supplied by the GPS system, the compaction process can be recorded and presented in graphic form. The machine operator is able to use the graphic visualization of the compaction process to assess the compaction achieved, the number of roller passes, the increase in compaction and other information, so as to optimize his work accordingly. Moreover, digital construction plans can be read in, and the working procedure and the compaction result can be recorded and evaluated on them. Figure 5 shows a compaction result comprising the soil stiffness attained and the number of roller passes. The original construction plan was available in digital form and was read in prior to starting work.



GPS Accuracy
0.4 to 0.8 inch

Figure 5. ACE_{plus}:Continuous Compaction Control using differential GPS technology. The soil stiffness measurement is directly correlated to the data of plate bearing test

NEW MONITORING DEVICES

1. Modulus

2. Strength

Modulus ?

1. Initial, Tangent, Secant, Resilient, Cyclic?

2. What Test? Lab vs. Field

3. Replace Dry Density?

FUTURE PRACTICE

Based on Modulus

- LAB: Modulus test to get modulus vs. water content curve
- SPEC: x% of E_{max} within range of w_{opt}
- FIELD: Intelligent compaction and check that E_{max} and w meet the specs

J-L Briaud, Texas A&M University

Which Modulus?

PLATE MODULUS in FIELD


BPT: Briaud Plate Test

J-L Briaud, Texas A&M University

NEW PENETROMETER

SP- CIGMAT

Pavement Design

Modulus of Resilient (Mr) = k $(CBR)^n$

Liner

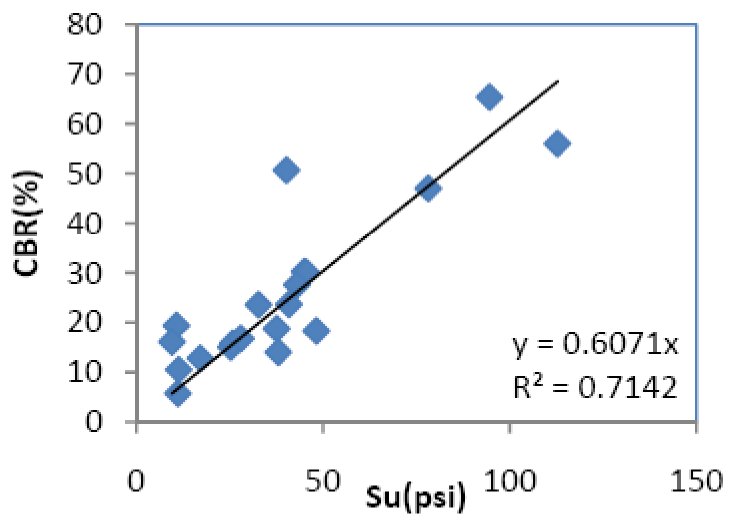
$$CBR = K + aLL + bPL + cG_s + d\gamma_d + e\omega + fS_u + gE \text{ -------------- } (4)$$

Nonlinear

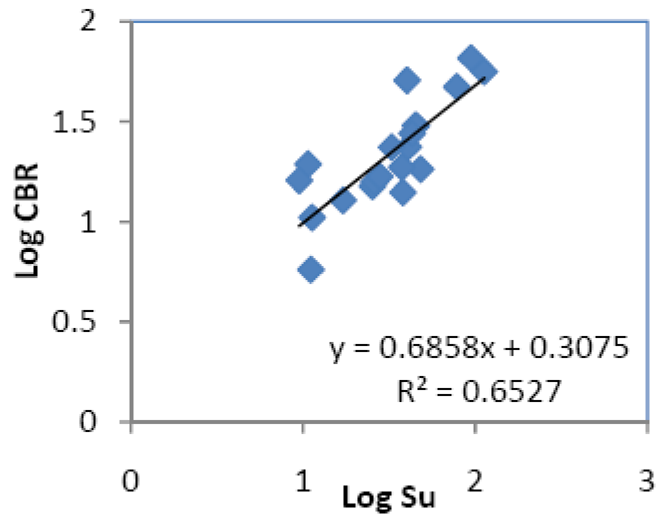
$$CBR = k \times LL^a \times PL^b \times Gs^c \times {\gamma_d}^d \times \omega^e \times {S_u}^f \times E^g$$

also represented as

$$Log\ CBR = LogK + aLogLL + bLogPL + cLogG_s + dLog\gamma_d + eLog\omega + fLogS_u + gLogE \text{ ---------------- } (5)$$



Overall – Linear



Overall - Nonlinear

$$CBR = m\,(Su)^f$$

$$\text{Resilient Modulus } M_r = f(Su)$$

Field Penetrometer: SP-CIGMAT

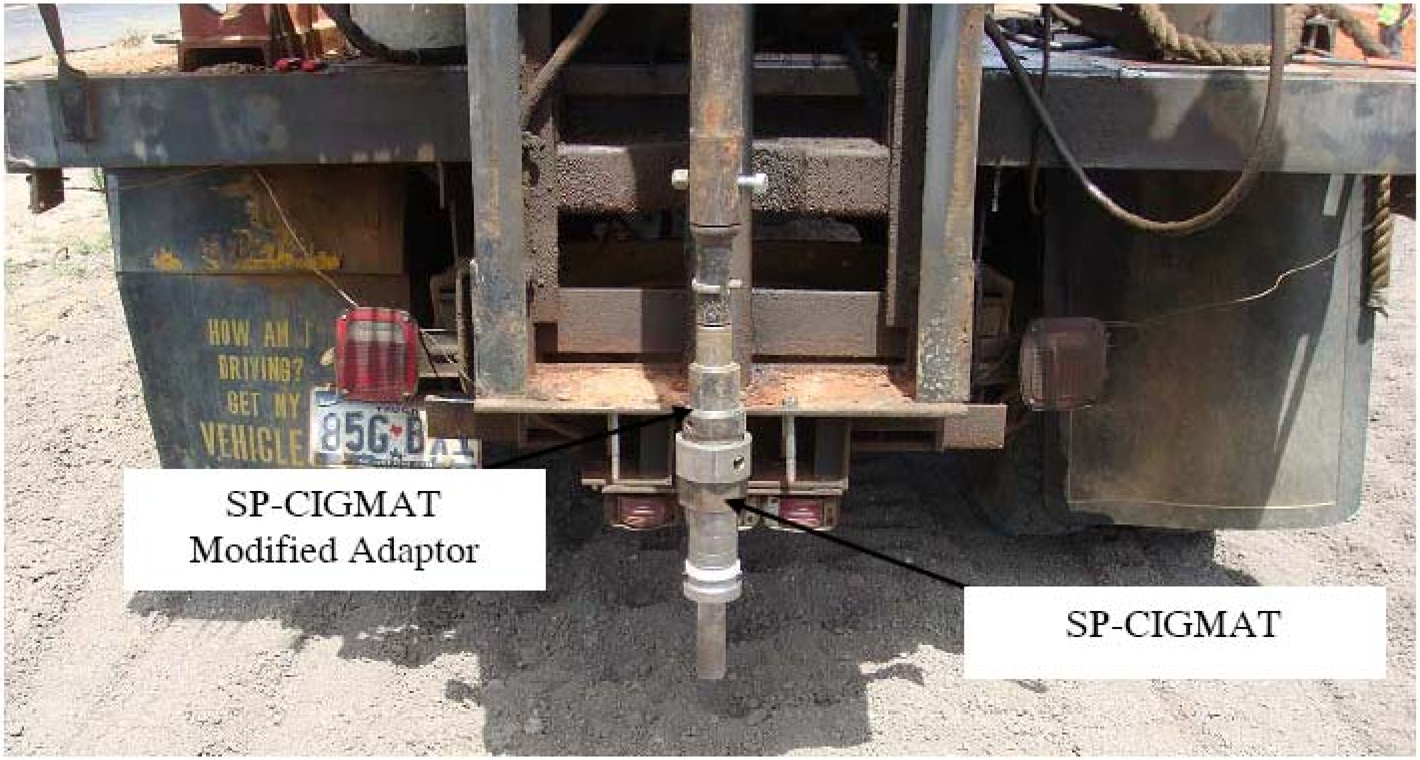


Figure 5. SP-CIGMAT Mounted on a Soil Sampling Rig

Quality Control Procedure

SP-CIGMAT Penetrometer

Hole created after shelby tube sample

CIGMAT Penetrometer performing the test

Deflected Spring After Test

Shear Strength

The bearing capacity theory with non-linear relationship, where relationship between soft rock/stiff clay unconfined compressive strength (σ_u, psi) and ultimate strength (q_{ult}, psi) was suggested by Zhang and Einstein (1998) and Vipulanandan et al. (2007) was used and is as follows:

$$q_{ult} = \alpha_q (\sigma_u)^m \quad , \qquad (1)$$

where, magnitudes of parameters m and α_q depend on the type of soft rock/stiff clay and unconfined compressive strength (σ_u, psi = $2S_u$)). This relationship can be used to relate the undrained shear strength of soil (S_u) to the penetrometer deflection (δ_{max}). The relationship for penetrometer deflections (δ_{max}) and the shear strength (S_u) is as follows:

$$S_u = 56.4 * \delta_{max}^{1.78} \quad N= 19 , R^2=0.72. \qquad (2)$$

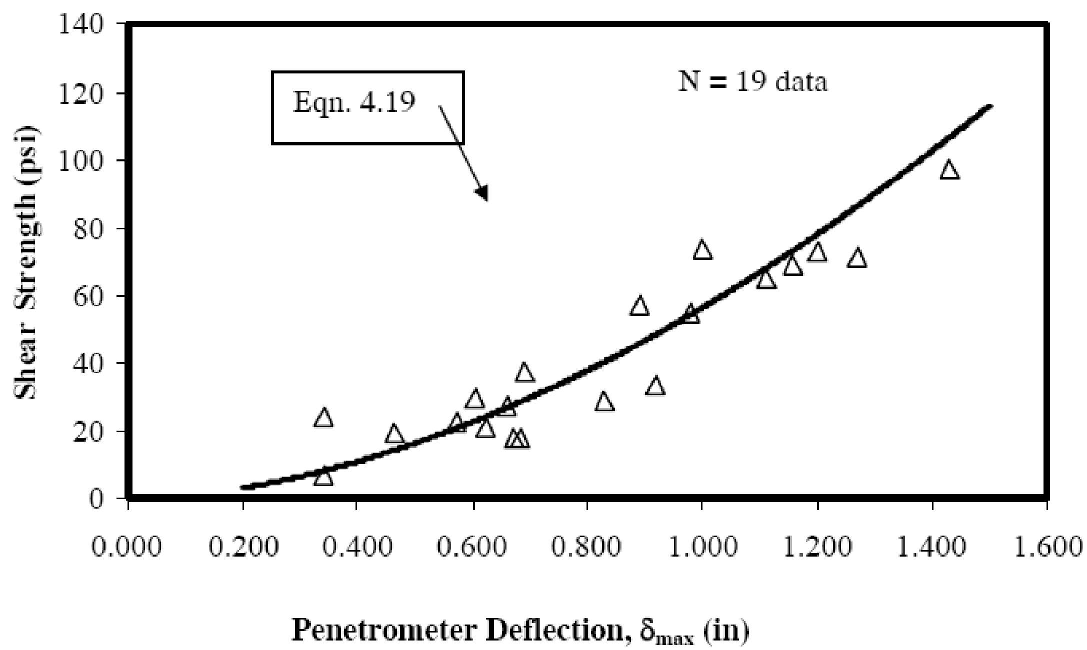
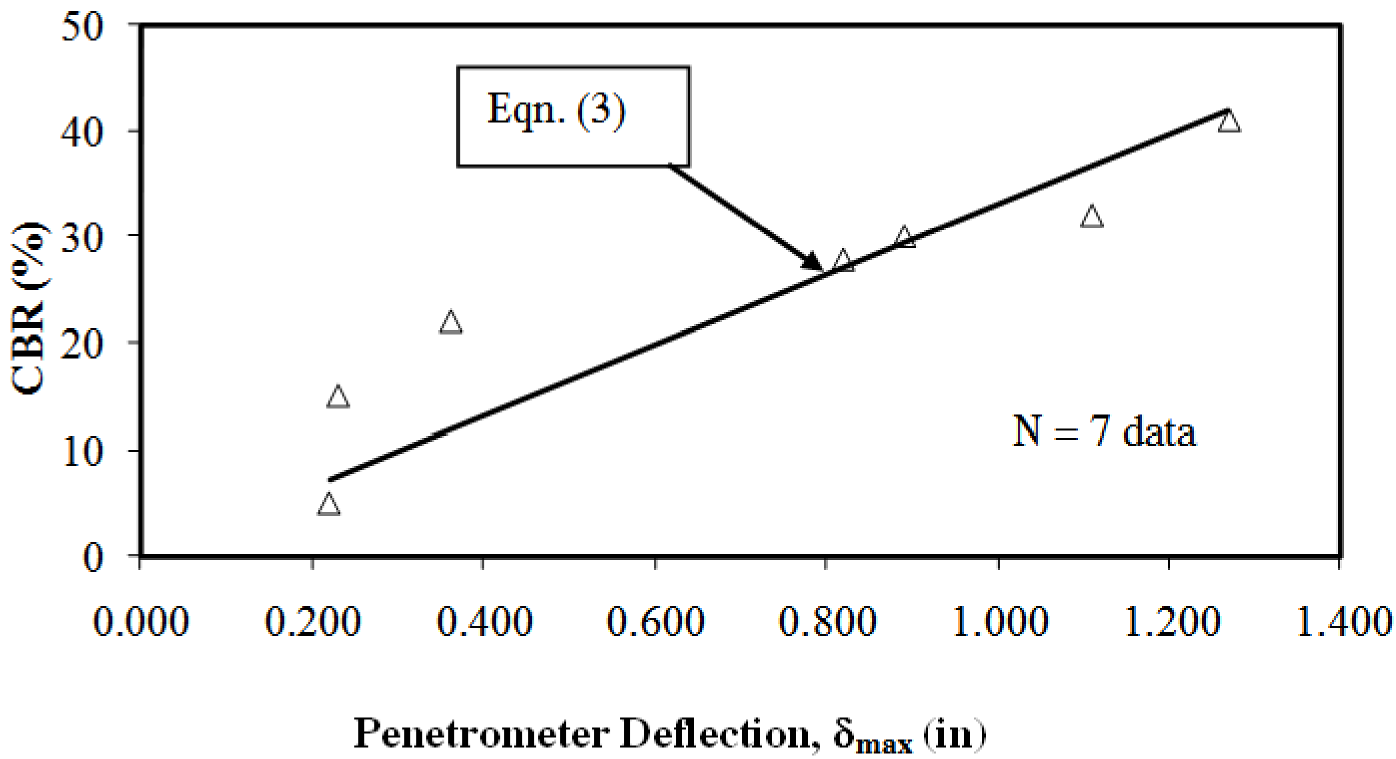


Figure 6. Relationship between SP-CIGMAT deflections (δ_{max}) and Shear Strength (S_u)

California Bearing Capacity Ratio (CBR)

Present design approaches of subgrades for pavement design use CBR values to determine the resilient modulus. Hence it was of interest to determine the correlation between CBR and SP-CIGMAT penetrometer deflection. Compacted field samples were collected in CBR molds and test were performed in the laboratory. Total of 7 CBR tests were performed and the relationship for penetrometer deflections (δ_{max}) and the CBR was as follows:

$$CBR = 33\,\delta_{max}, \qquad N = 7, \qquad R^2 \text{ of } 0.78. \tag{3}$$



Conclusions

(1) Field Compaction is not Laboratory Compaction.

(2) Intelligent Compactor is being Used as QA/QC for Compaction (Soil Modulus?)

(3) New Advances in Compaction Technology (Computer Generated Curves) Can be Used for Design and Monitoring

(4) Others/SP-CIGMAT Can be Used During Construction for Compacted Soil Characterization (Strength, CBR).

CIGMAT
1994

Thank You & Questions?

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