CONSTRUCTION AND QUALITY CONTROL OF FLEXIBLE PAVEMENT AND RIGID PAVEMENTS
MARCH 03-05,2022

Non-Destructive Testing of Pavement Evaluation in Low Volume Roads

National Rural Infrastructure Development Agency

Ministry of Rural Development

National Institute of Technology

Warangal, Hyderabad

LECTURE-10

Non-Destructive Testing of Pavement Evaluation in Low Volume Roads

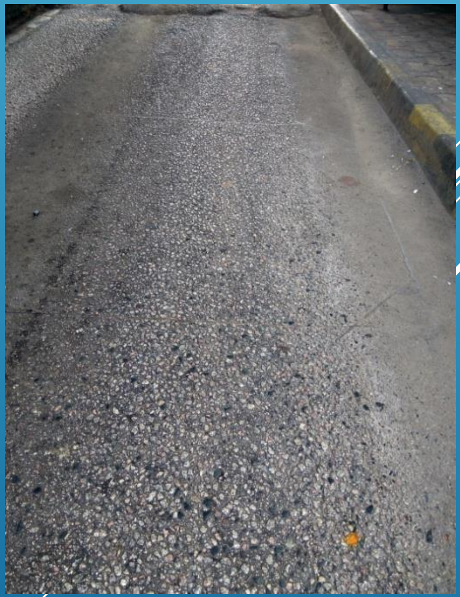
PRESENTATION OUTLINE

- Pavement Evaluation and Purpose
- Techniques for Pavement Evaluation
- Non-Destructive Tests and Principles
- Data Collection Dos and Don'ts!
- Summary and Discussions

- Contractor done adequate Job?
- Does this road need maintenance??
- Should this pavement be rebuilt??
- Should we overlay this Job?
- PCI- either current or future……

PAVEMENT EVALUATION-PURPOSE!

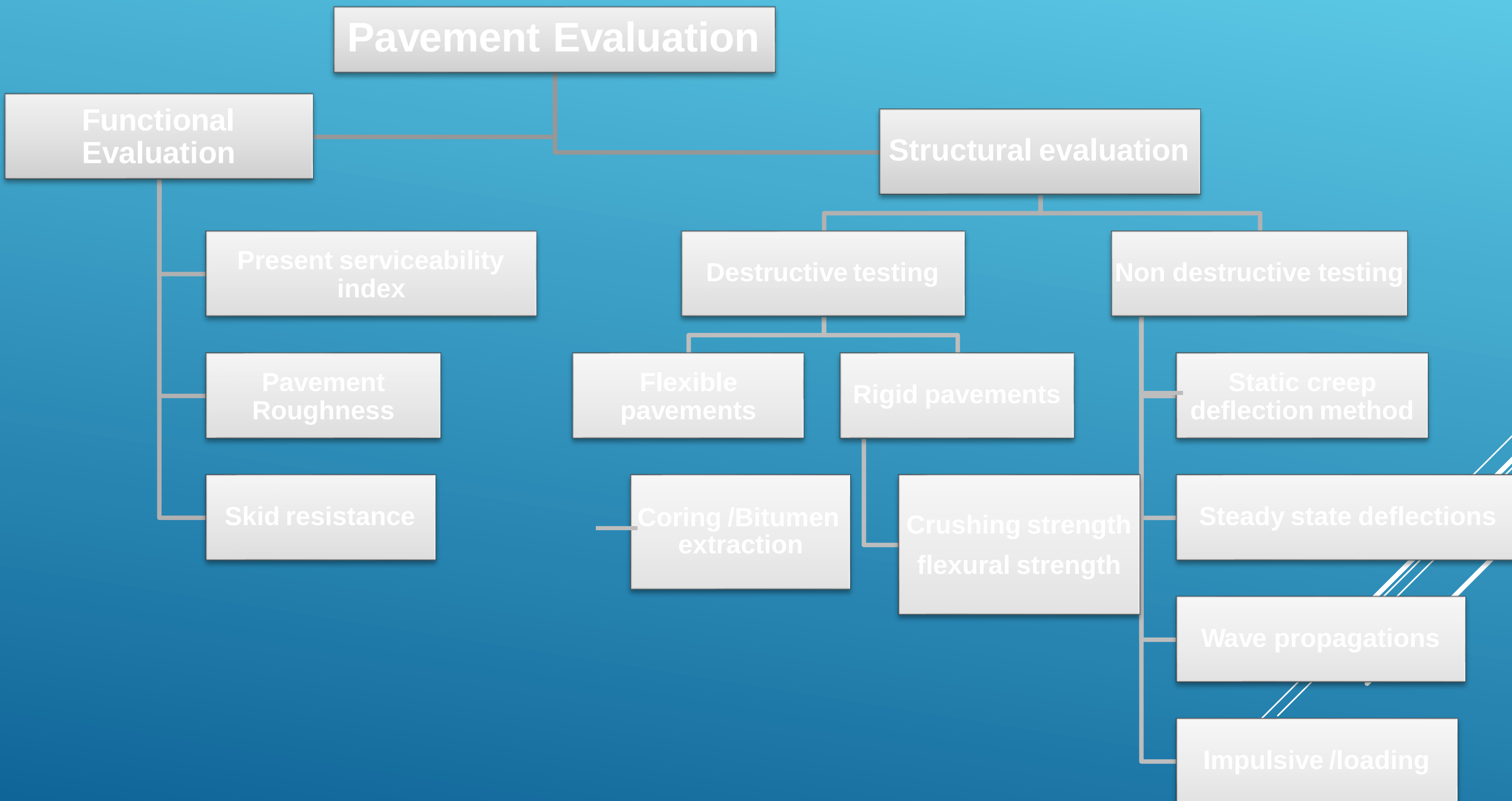
Process to determine the state of the art of the health condition of the pavement for the purpose of maintenance and extend the life of the pavement



CONTD....

- How and against what criteria?
    - How is the pavement performing?
    - Materials and their condition?
- Are there surprises?
    - The cores say one thing but…
    - What lurks below?
- Are we trying to address real problem?
    - Best M&R actions for true conditions?
    - Can we afford the best fix now and how ?

PAVEMENT EVALUATION METHODS



FUNCTIONAL AND STRUCTURAL EVALUATION

- **Functional Evalaution**
    - Surface characteristics of a pavement
    - Longitudinal evenness (smoothness)
    - Skid Resistance, Rutting and Cracking
    - Intervention and its type is decided
- **Structural Evalaution**
    - Layer thickness and material properties
    - Strength and is load related
    - Remaining Service Life is determined
    - Rehabilitation or Strengthening f pavement

FUNCTIONAL EVALAUTION: VISUAL CONDITION SURVEY

- **Visual Condition or Distress Survey**
- **Some time stand alone procedure for decision making**
- **Visual Condition Survey consists of**
    - **(a) Recording of Pavement Distresses**
    - **(b) Pavement Rating and**
    - **(c) Detailed Presentation of PC**
- **Visual Condition Survey Procedure:**
    - **At east 02 trained people for recording of pavement distresses**
    - **Pavement distress information may be carried out by viewing the pavement surface from a slow-moving vehicle or by walking on the pavement**

CONTD
..

- Portable data recording devices (data capture devices [DCDs]) may also be used during surveying, enabling faster data processing by the use of specially developed software.
- Pavement rating may be descriptive or quantitative

Code	Distress type	Code	Distress type
1	Ravelling	12	Reflection cracking
2	'Pocket' holes	13	Shrinkage cracking
3	Potholes	14	Edge cracking
4	Severe surface disintegration	15	Slippage cracking
5	Linear joint cracking	16	Shoving
6	Linear joint cracking with branching off cracks	17	Corrugation
7	Linear joint cracking with disintegration	18	Rutting
8	Wheel path linear cracking	19	Bleeding
9	Wheel path cracking with branching off cracks	20	Depression
10	Alligator cracking	21	Depression at utility cuts
11	Transverse cracking	22	Other surface distresses

DESCRIPTIVE RATING OF PAVEMENT CONDITION

- **In case of descriptive rating of the pavement condition, the terms *Good, Fair and Bad* are usually used.**

- **Good : Pavement section requires no intervention**

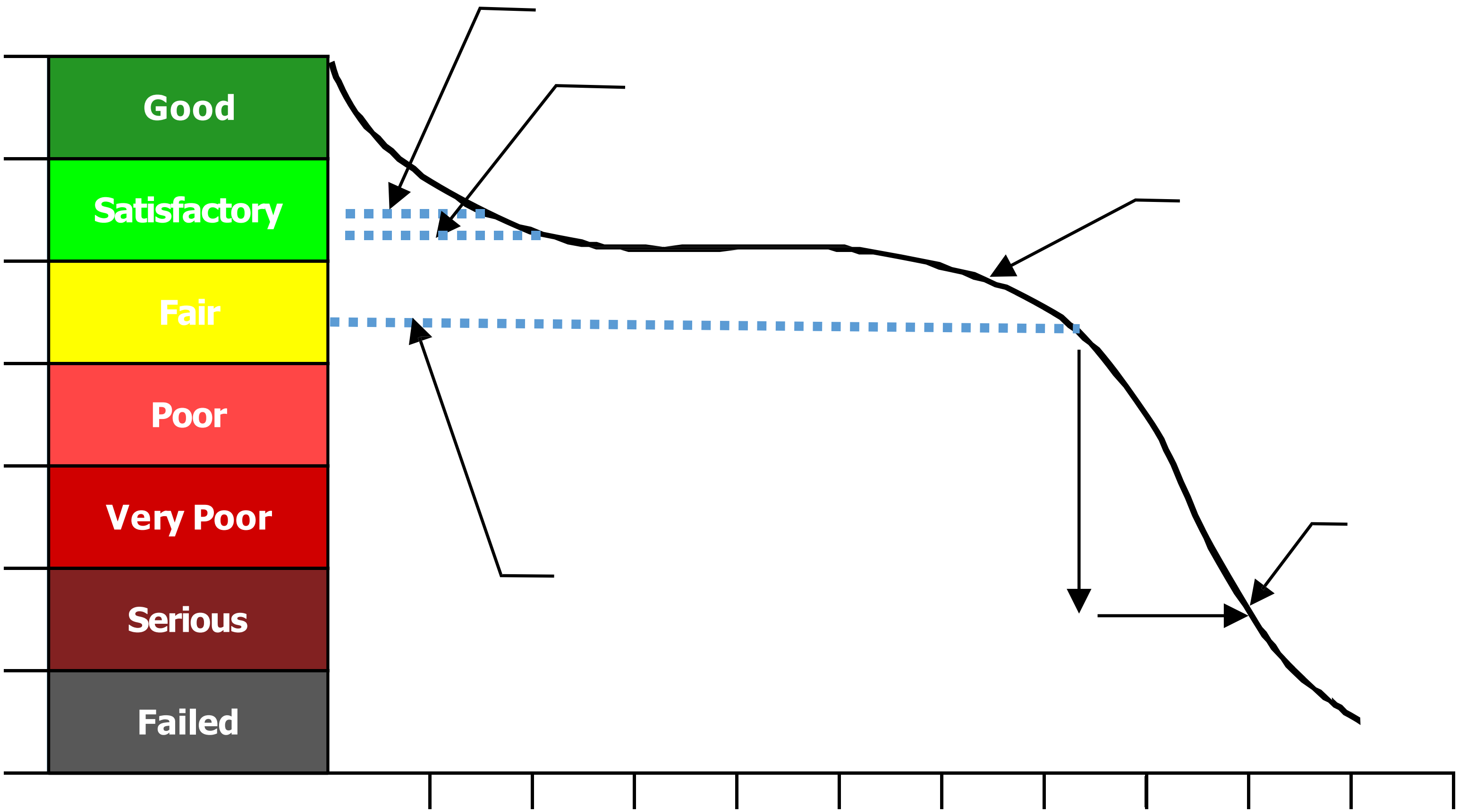
- **Fair : Requires some kind of M& R Surface layer**

- **Bad :Structurally failed& requires rehabilitation of all bituminous layers/even reconstruction of the pavement structure**

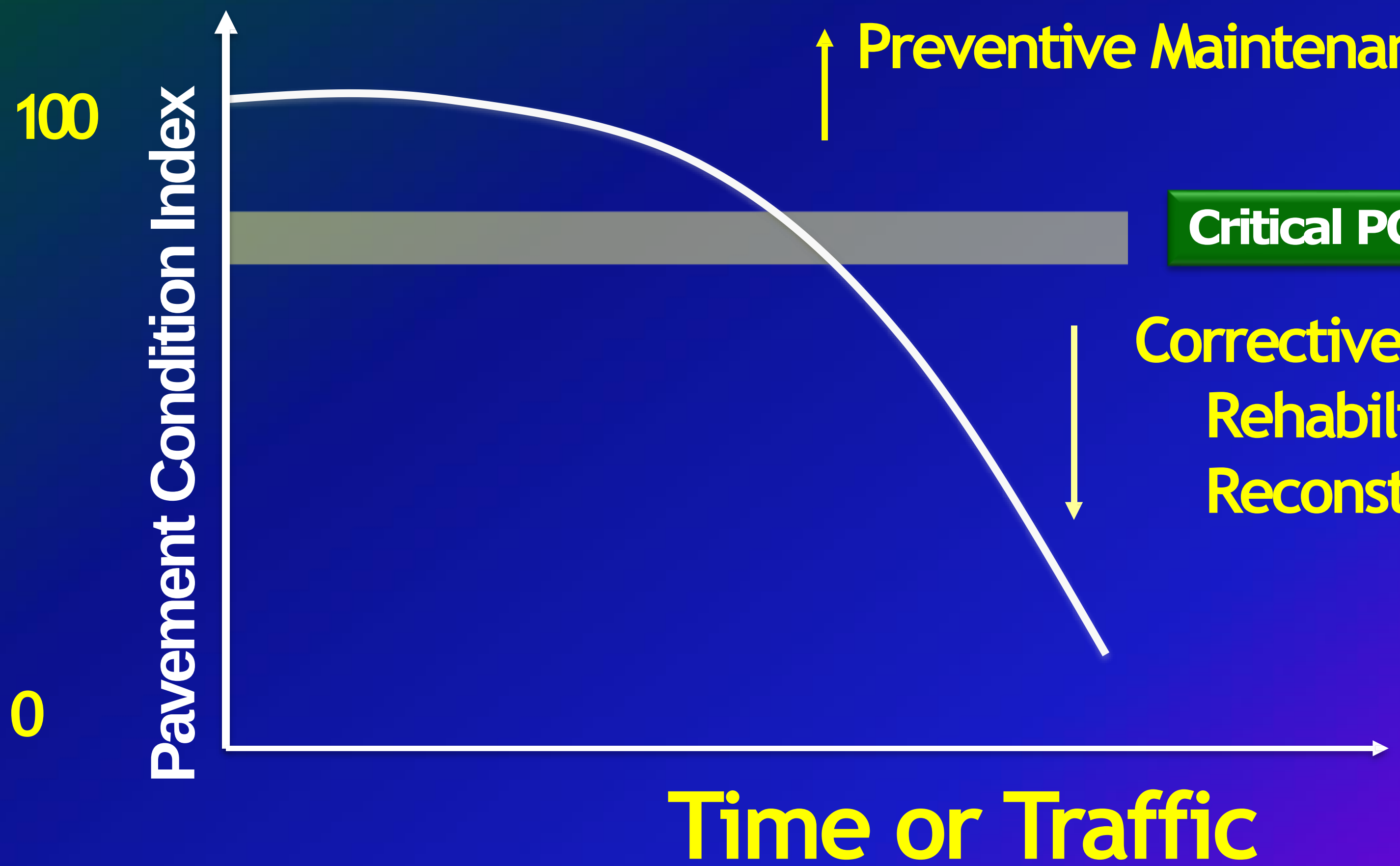
QUANTITATIVE RATING CONDITION

- PCI or distress level is determined-ASTM D 6433
  - PCI >85 : Good
  - PCI 70 to 85 : Satisfactory
  - PCI 55 to 69 : Fair
  - PCI 40 to 54 : poor
  - PCI 25 to 39 :Very poor
  - PCI 10 to 24 : Serious
  - PCI 0 to 9 : failed.

- Results are usually presented graphically on a linear scale representing the length of the road section surveyed, using different colours for each descriptive or quantitative rate and determine the order of priority of the pavement sections for maintenance or rehabilitation


Good
Satisfactory
Fair
Poor
Very Poor
Serious
Failed

CRITICAL PCI !!



DYNAMIC CONE PENETROMETER-INTRODUCTION

- The DCP is light, portable and tests are quick and simple.
- Information can be gathered with min disturbance to the in-situ material.
- Scala (Scala,1956) in South Africa as In-situ evaluation
- Strength pavement layers and subgrade conditions
- Klein (1982) Comparasion Studies between
  - Sound pavement sections with failed pavement sections
  - Suggested minimum strength for the base course
- DCP Used as QC and QA in arth wok by measuring penetration
- The quality assessment of compacted subgrade layers using DCPdevices is widely reported in the literature (Kleyn 1975; Harison1987; Burnham 1997; Gabr et al. 2000; Alshibli et al. 2005;Rahman et al. 2008; Yoon et al. 2009; Kim et al. 2010; Meehanet al. 2012; Yang et al. 2016; Ganju et al. 2016)
- Developed correlations between DPI and like CBR, $M_{R,}$ and E etc.

CONTD…

- What is DCPT-Purpose and Parts!!
- How Does it works- Operation/technique/data recording and analysis
- What are the benefits for us!!
  - Layer stiffness and Layer thickness, Acceptance and verification and Correlations!!

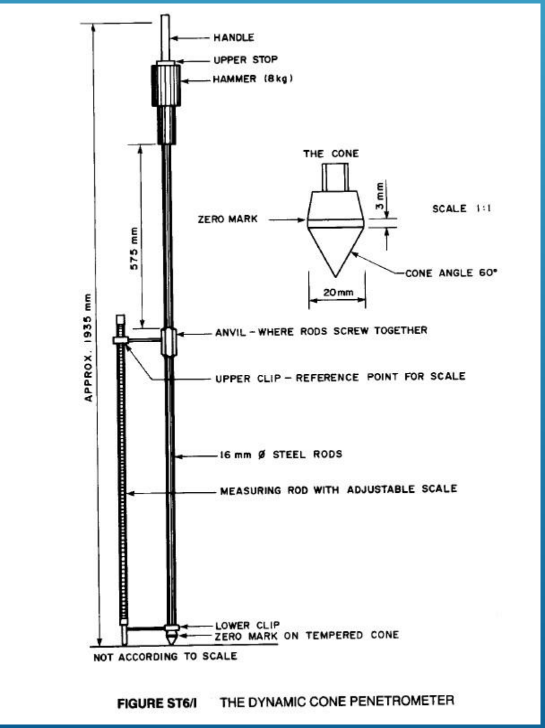
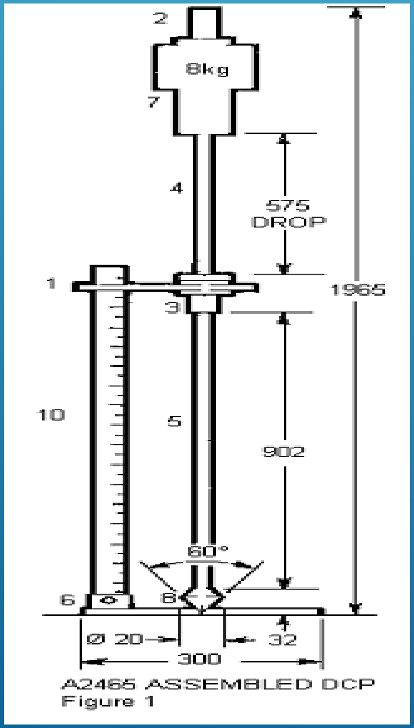
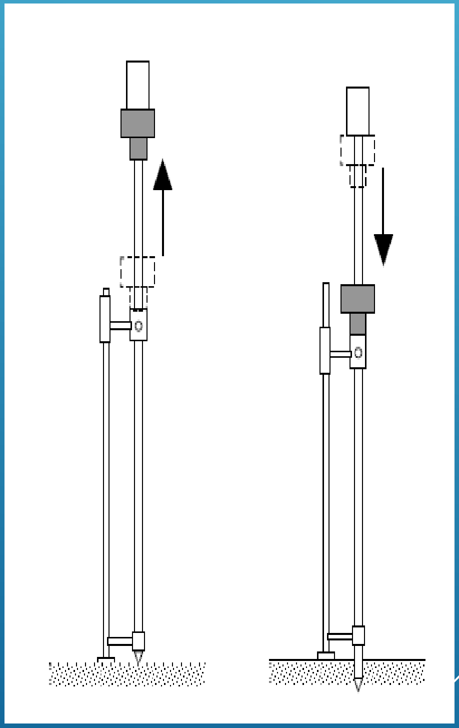


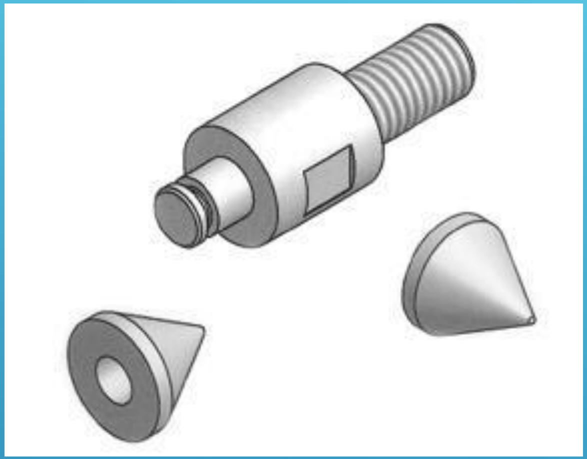
FIGURE ST6/I THE DYNAMIC CONE PENETROMETER



A2465 ASSEMBLED DCP
Figure 1



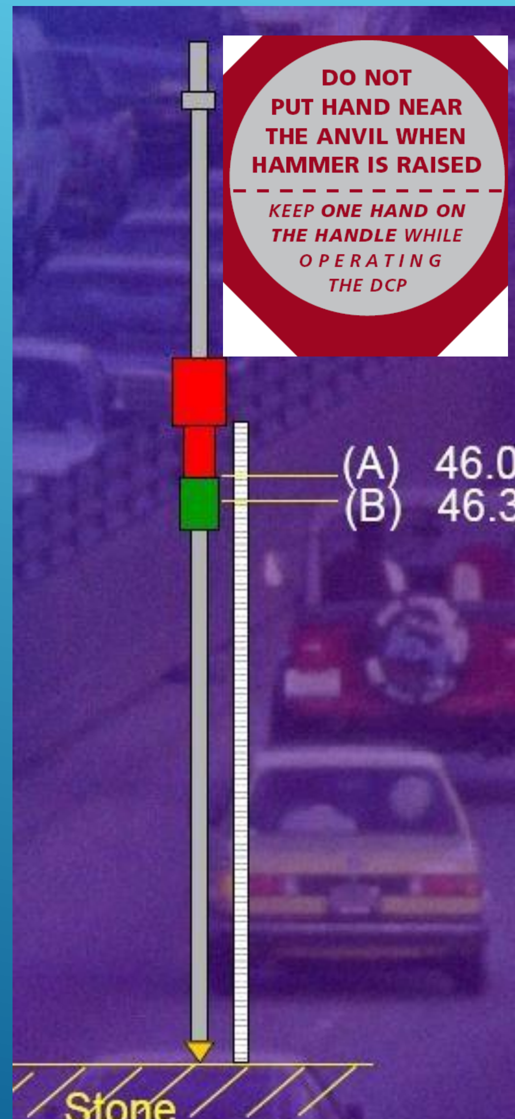
CONT D..



HOW THE DATA IS RECORDED!!

Anytown, LA – Hwy 1, Sta. 19+00 RL	Blow #	Rod Reading, cm
Top of Asphalt/Concrete	0	NA
Top of Testing Surface (bottom of drilled hole, if applicable)	0	46.0 (A)
Reading after First Blow	1	46.3 (B)
Reading after Second Blow	2	46.6
Reading after Third Blow	3	46.9
Reading after Fourth Blow	4	47.2
Reading after Fifth Blow	5	47.5
Reading after Last Blow	?	???

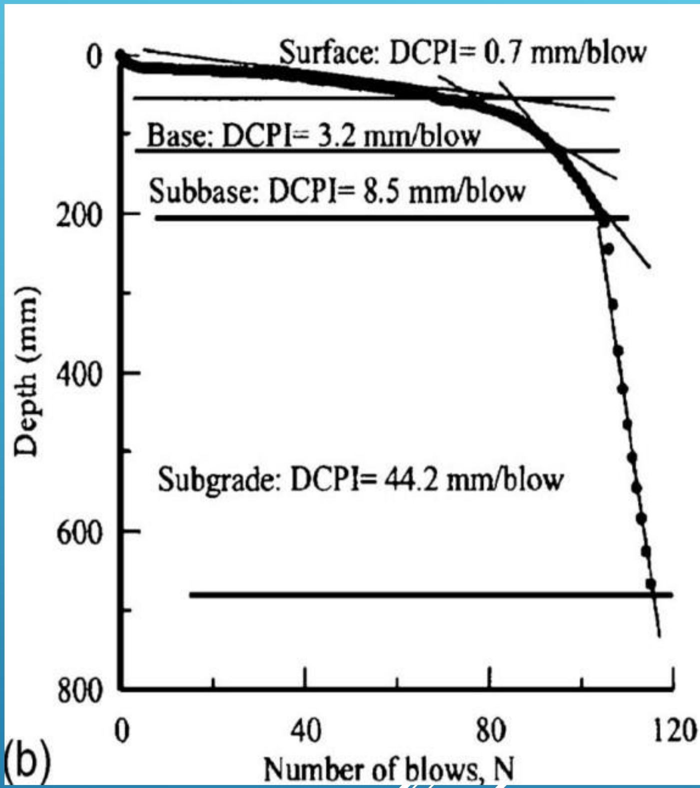
Blow #	Rod Reading, cm	Distance per Blow	Cumulative Penetration	Distance below Surface
0	NA	cm this times ten = DCPI	cm Running Total	cm can plot as inches or elev.
0	46.0	0.0	0.0	equal to tip location below surface
1	46.3	0.3	0.3	0.3
2	46.6	0.3	0.6	0.6
3	46.9	0.3	0.9	0.9
4	47.2	0.3	1.2	1.2
5	47.5	0.3	1.5	1.5
6	47.8	0.3	1.8	1.8



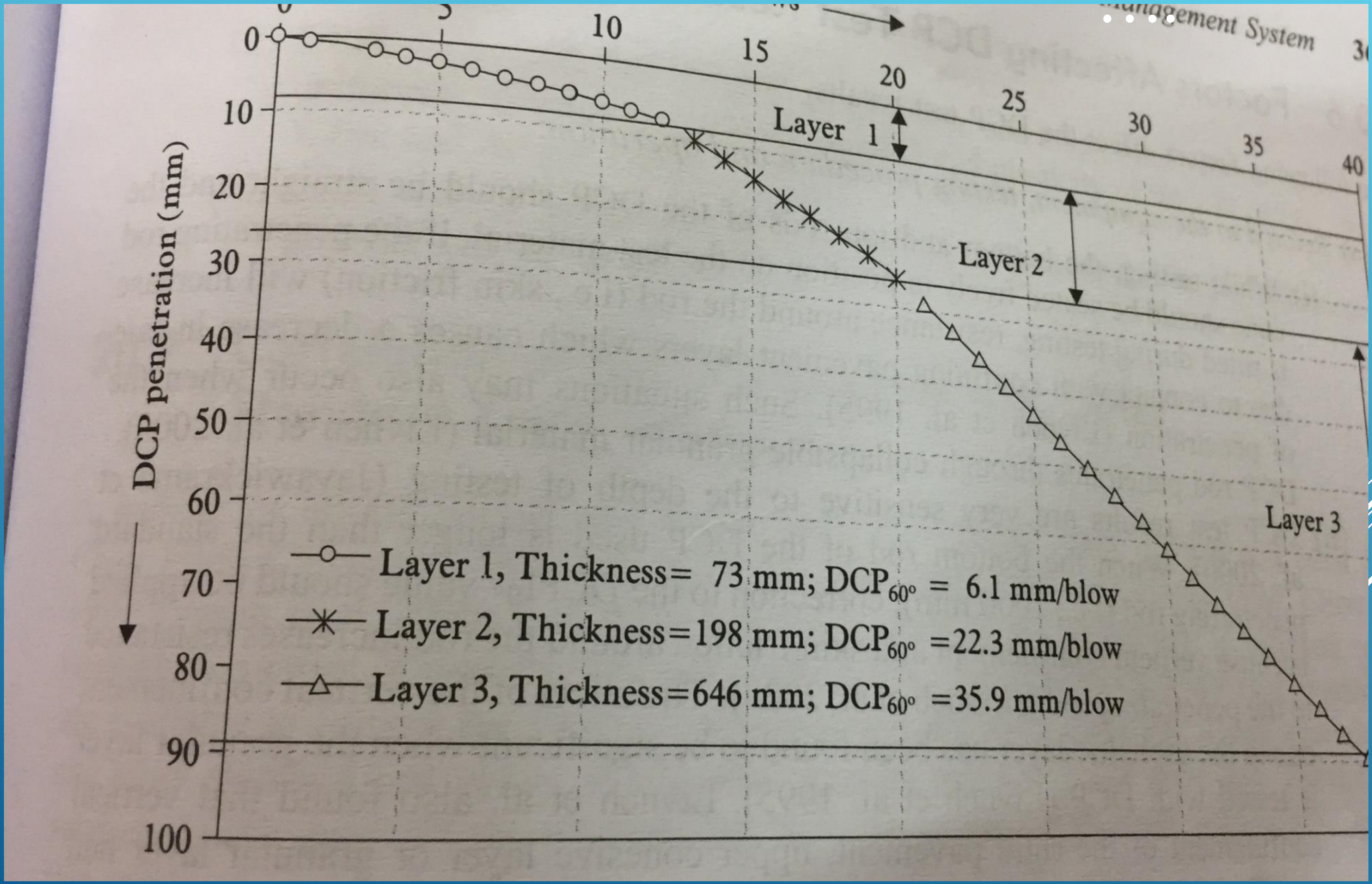
	(1) Number of Blows	(2) Cumulative Penetration (mm)	(3) Penetration Between Reading (mm)	(4) Penetration per Blow (mm)	(5) Hammer Blow Factor	(6) DCP Index mm/blow	(7) CBR %	(8) Moisture %
1	0	0	--	--	--	--	--	
2	5	25	25	5.0	1	5.0	50	
3	5	55	30	6.0	1	6.0	40	
4	15	125	70	4.7	1	4.7	50	
5	10	175	50	5.0	1	5.0	50	
6	5	205	30	6.0	1	6.0	40	
7	5	230	25	5.0	1	5.0	50	
8	10	280	50	5.0	1	5.0	50	
9	5	310	30	6.0	1	6.0	40	
10	5	340	30	6.0	1	6.0	40	
11	5	375	35	7.0	1	7.0	35	
12	5	435	60	12.0	1	12.0	18	

WHAT KIND OF INFROMATION IS OBTAINED!

- Determines the stiffness mm/blow
  - Flatter slopes indicates stiff layers
  - Steeper slopes indicate weak layers
- Layer Change is Identified by the slope change
  - Thickness can be verified
  - Weak layers can be identified
  - Minimal Disturbance
  - Lower layer thickness without and destruction
  - Can compare different sites



CONTD



10
15
20
25
30
35
40
Layer 1
Layer 2
Layer 3
DCP penetration (mm)
0
10
20
30
40
50
60
70
80
90
100
Layer 1, Thickness= 73 mm; DCP60° = 6.1 mm/blow
Layer 2, Thickness=198 mm; DCP60° =22.3 mm/blow
Layer 3, Thickness=646 mm; DCP60° =35.9 mm/blow

RELATIONSHIPS BETWEEN DCPI AND SOIL PARAMETERS

Reference	Correlation	Description	Soil type
Harison (1987)	$\log(\text{CBR}) = 2.81 - 1.32 \times \log(\text{DPI})$	Laboratory tests	Granular and cohesive materials
Livneh (1989)	$\log(\text{CBR}) = 2.20 - 0.71 \times (\log \text{DPI})^{1.5}$	Field and laboratory tests	Granular and cohesive materials
Livneh (1991)	$\log(\text{CBR}) = 2.14 - 0.69 \times (\log \text{DPI})^{1.5}$	Field and laboratory tests	Granular and cohesive materials
Livneh et al. (1994)	$\log(\text{CBR}) = 2.46 - 1.12 \times (\log \text{DPI})$	Field and laboratory tests	Granular and cohesive materials
Ese et al. (1994)	$\log(\text{CBR}) = 2.44 - 1.07 \times \log(\text{DPI})$	Field and laboratory tests	Aggregate base course
Coonse (1999)	$\log(\text{CBR}) = 2.53 - 1.14 \times \log(\text{DPI})$	Laboratory tests	Residual soil
Gabr et al. (2000)	$\log(\text{CBR}) = 1.40 - 0.55 \times \log(\text{DPI})$	Field and laboratory tests	Aggregate base course
Salgado and Yoon (2003)	$\gamma_d = \left(10^{1.5} \cdot \text{DPI}^{-0.14} \cdot \sqrt{\frac{\sigma_v'}{P_A}}\right)^{0.5} \cdot \gamma_w$	Field tests	Clayey sand
Mohammadi et al. (2008)	$\text{Dr} = 189.93/(\text{DPI})^{0.53}$ $E_{\text{PLT}} = 53.73/(\text{DPI})^{0.74}$ $G_{\text{PLT}} = 75.74/(\text{DPI})^{0.9}$ $K_s = 898.36/(\text{DPI})^{0.9}$ $\Phi = 52.16/(\text{DPI})^{0.13}$	Laboratory tests	Sandy soils
Mohammad et al. (2009)	$M_r = \frac{1{,}045.9}{(\text{DPI})^{1.096}}$	Field and laboratory tests	Cohesive subgrade soils
Ganju et al. (2016)	$\text{Blow count} = -0.22\,\text{OMC}^2 - 1.16\,\text{OMC} + 27.94$ $\text{Blow count} = 0.17\,\text{OMC}^2 - 5.94\,\text{OMC} + 59.54$ $\text{Blow count} = 13.03e^{(-0.2219\text{PI})} + 8.052e^{(-0.00483\text{PI})}$ $\text{Blow count} = 4.029\ \ln(C_u) + 2.640$	Field tests	Clean sands Coarse grained soils Fine grained soils Clean sand with low fines content

Note: CBR = California bearing ratio (%); DPI = dynamic penetration index (mm/blow); γ_d = unit weight of clay soil (kN/m^3); γ_w = unit weight of water (kN/m^3); P_A = reference stress (kPa); σ_v' = vertical effective stress (kPa); E = Young's modulus (MPa); D_r = relative density (%); E_{PLT} = deformation modulus of soil from plate load test (kPa); G_{PLT} = shear modulus of soil from plate load test (kPa); k_s = modulus of subgrade reaction (MN/m^3); ϕ = friction angle of soil (degrees); S_r = degree of saturation of the soil (%); N = measured blow count; E_{LWD} = dynamic modulus from LWD (MPa); M_r = resilient modulus (MPa); OMC = optimum moisture content; C_u = coefficient of uniformity; and PI = plasticity index.

J. Constr. Eng. Manage., 2018, 144(9): 04018086

CORRELATION OF CBR VERSUS DCP INDEX-ASMD6951

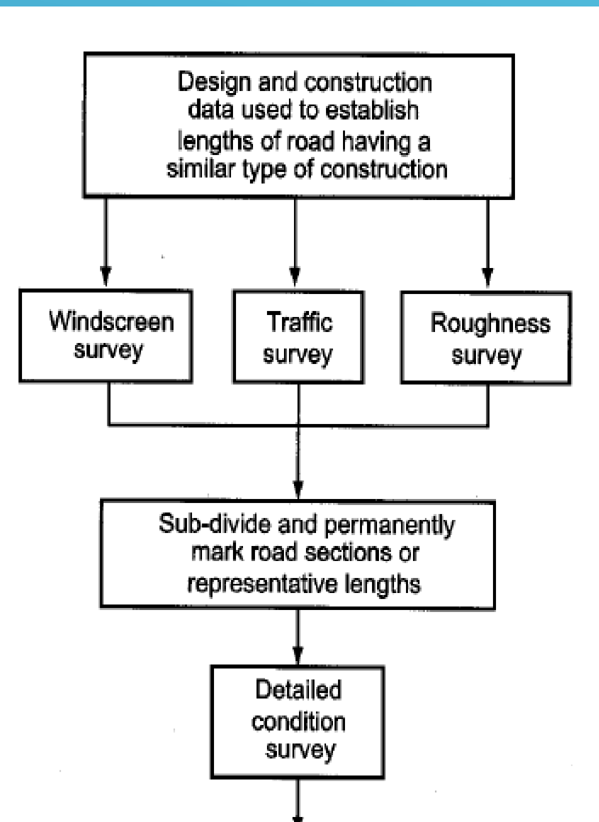
DCP Index mm/blow[A]	CBR %	DCP Index mm/blow[A]	CBR %	DCP Index mm/blow[A]	CBR %
<3	100	39	4.8	69–71	2.5
3	80	40	4.7	72–74	2.4
4	60	41	4.6	75–77	2.3
5	50	42	4.4	78–80	2.2
6	40	43	4.3	81–83	2.1
7	35	44	4.2	84–87	2.0
8	30	45	4.1	88–91	1.9
9	25	46	4.0	92–96	1.8
10–11	20	47	3.9	97–101	1.7
12	18	48	3.8	102–107	1.6
13	16	49–50	3.7	108–114	1.5
14	15	51	3.6	115–121	1.4
15	14	52	3.5	122–130	1.3
16	13	53–54	3.4	131–140	1.2
17	12	55	3.3	141–152	1.1
18–19	11	56–57	3.2	153–166	1.0
20–21	10	58	3.1	166–183	0.9
22–23	9	59–60	3.0	184–205	0.8
24–26	8	61–62	2.9	206–233	0.7
27–29	7	63–64	2.8	234–271	0.6
30–34	6	65–66	2.7	272–324	0.5
35–38	5	67–68	2.6	>324	<0.5

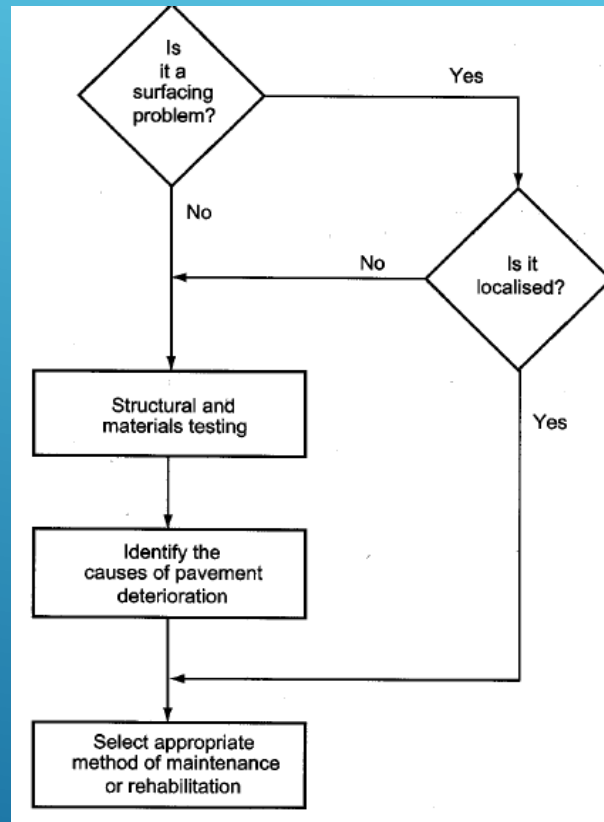
RRPPS-LVR-DCPTI

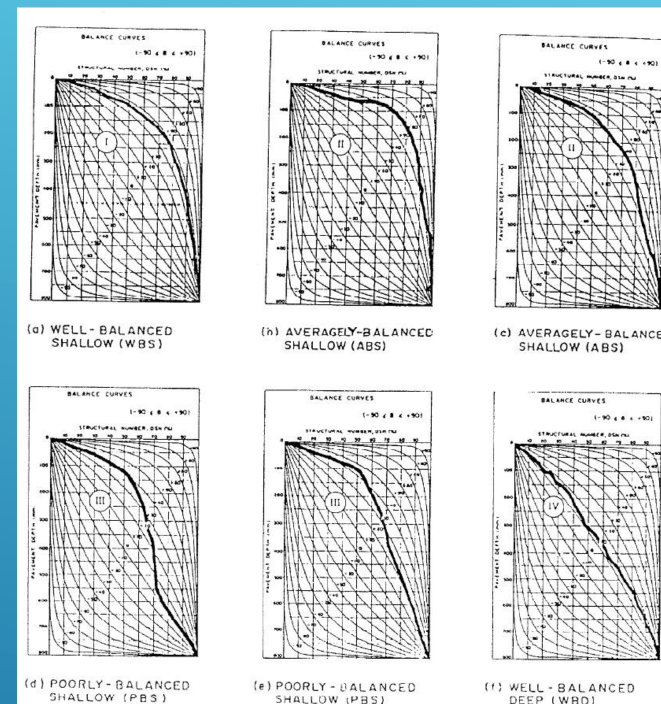
Road ID	Apr-08			Sept-2008			Feb-09			May-09			Jan-10			Jun-10			Dec-10		
	BC[1]	SB[2]	SG[3]	BC	SB	SG	BC	SB	SG	BC	SB	SG	BC	SB	SG	BC	SB	SG	BC	SB	SG
G1	2.17	3.00	3.00	2.41	3.22	3.42	2.67	3.52	4.26	3.39	3.86	5.84	3.49	4.44	7.96	4.19	5.52	10.50	7.31	8.19	11.00
G2	1.63	2.00	2.27	2.43	2.45	2.45	2.68	3.17	4.36	4.30	5.18	5.92	5.15	5.63	6.04	6.58	7.92	8.67	6.86	13.15	22.67
G3	1.51	2.55	3.04	1.53	2.60	3.21	2.73	3.00	3.26	3.30	3.37	3.43	3.33	3.48	3.69	3.47	3.91	3.91	3.66	4.68	4.87
G4	1.75	2.08	2.66	2.05	3.00	3.04	2.16	3.13	3.31	3.23	3.70	5.50	3.71	3.92	5.50	4.41	5.02	7.00	5.09	6.91	9.19
K1	1.00	1.60	2.98	1.94	2.08	3.45	2.03	2.41	3.72	2.14	2.51	4.07	2.79	3.00	4.72	4.62	5.40	5.40	4.80	5.85	6.00
K2	2.85	2.90	5.00	3.13	4.13	5.00	3.44	4.14	6.36	4.46	4.57	6.80	4.52	5.79	9.25	4.86	5.97	10.40	7.64	8.35	12.00
K3	1.94	3.18	3.46	3.00	3.37	5.15	3.05	5.23	6.60	-	5.55	7.20	4.46	6.14	8.00	5.37	7.64	9.00	6.75	9.26	12.46
K4	2.62	3.00	3.48	3.05	3.21	3.66	3.29	3.42	4.94	3.68	3.80	5.10	4.68	5.45	5.88	5.49	6.07	6.60	6.44	6.56	11.47
W1	1.34	1.80	2.75	2.04	2.29	3.67	2.86	4.31	4.50	3.55	5.02	5.33	5.63	5.78	8.26	7.16	7.92	9.65	9.32	10.00	10.14
W2	2.40	3.35	3.97	3.24	4.13	4.57	3.50	4.22	5.14	4.55	4.93	6.68	5.20	6.84	6.92	6.91	7.26	10.77	8.30	8.90	12.00
W3	2.39	2.65	4.78	2.70	3.45	4.90	3.10	4.76	5.00	3.34	4.89	5.08	4.16	5.73	6.71	4.27	6.62	7.70	5.64	10.15	14.14
W4	2.00	2.82	3.22	3.43	3.66	3.67	3.77	3.80	4.00	4.00	4.00	4.06	4.23	4.26	4.93	4.50	5.23	5.32	5.77	6.23	6.32
W5	2.68	2.70	3.25	3.18	3.65	4.89	3.85	3.89	5.34	4.29	4.43	5.69	4.63	5.77	6.25	5.50	5.77	6.63	5.78	6.05	6.73
W6	2.65	4.32	5.00	3.46	5.01	8.00	3.52	5.71	8.87	3.82	9.77	10.28	4.01	10.43	11.44	4.82	12.31	12.39	5.53	13.85	16.02
W7	2.00	2.82	3.21	3.53	3.66	3.81	3.77	3.80	3.92	4.06	4.17	4.36	4.26	4.47	5.86	5.47	6.05	6.47	7.07	8.54	9.42

Note: [1]*BC- Base course, SB- Subbase course*[2], *SG- Subgrade*[3]

ROAD PAVEMENT EVALUATION AND REHABILITATION PROCEDURE

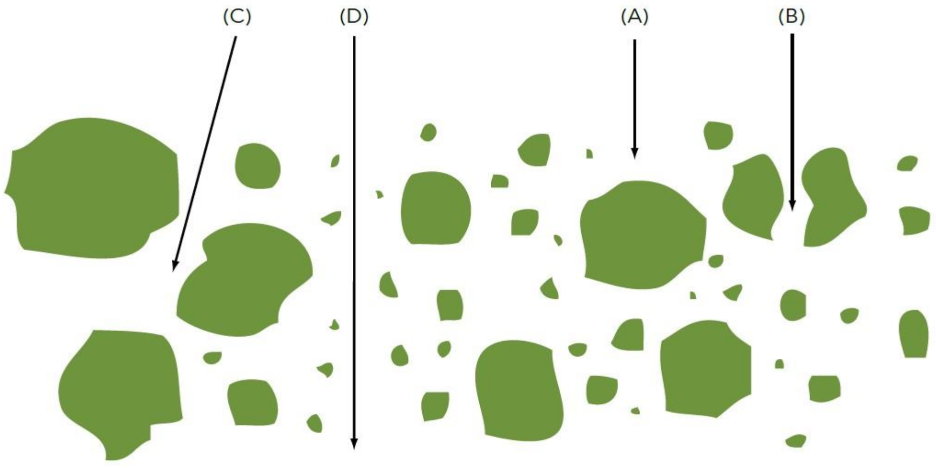






EXISTING ROADS

- **On existing roads and tracks!**
- **DCP carried out full length to a depth of at least 800 mm.**
- **DCP tests should be carried in staggered manner.**
- **At least 10 DCP tests for Statistical reliability!**
- **No. of blows and the corresponding depth of penetration.**



(a) Cone cannot penetrate.	(b) Cone breaks stone. DCP profile shows a plateau and subsequent readings may be low.	(c) Rod pushed aside and tilts at an angle. Excessive friction on rod gives low reading.	(d) Normal result.

Objective	Minimum test spacing
Routine testing for the rehabilitation of paved roads	500m or less
Areas of distress in paved roads	100m or less
Upgrading of gravel roads to sealed roads	500m or less
Design of spot improvements	50m or less

Road condition	Frequency of testing (number/km)
Uniform, fairly flat, reasonable drainage - low risk	5
Non-uniform, rolling uneven terrain, variable drainage - medium risk	10
Distressed, uneven terrain, poor drainage - high risk	20

NEW ROAD

- The construction of new roads can result in two processes
- Test pits and Sampling
    - Existing roads
    - New roads
    - at least 0.5 m below the expected natural subgrade level.
    - In cut sections, the depth can be reduced to 0.3 m but in potentially problematic materials
- Assessment of moisture conditions along alignment
    - at least 2 samples should be collected per kilometre of the proposed subgrade materials for moisture content and Optimum Moisture Content (OMC) determination from the outer wheel tracks of the road at depths of 0-150, 150-300 and 300-450 mm.

CLEGG IMPACT HAMMER

- CIT , Australia-1970s and used for density control during compaction
- Quick , simple to operate, portable, and inexpensive
- Current methods for measuring strength are too tedious and costly!!
- The CIT has three primary components:
- A guide tube, a compaction hammer, and a meter

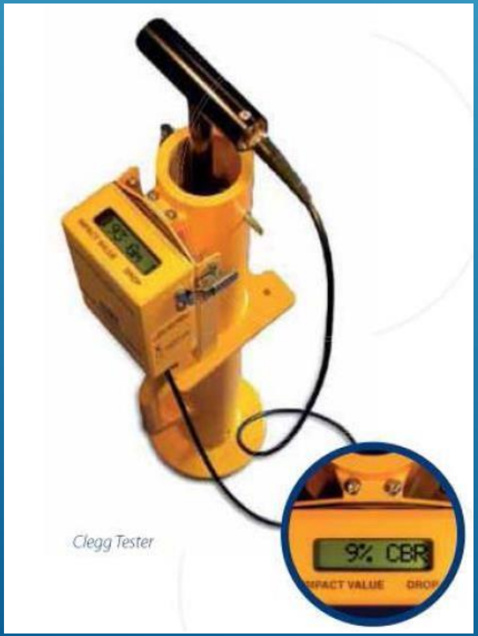



Table 3. Applications of various Clegg Impact Hammers.

Application	Hammer type	Description	Results	Reference
Measuring compaction for a large uniform area	4.5 kg	Determining moisture content of clay soils	Clegg hammer can be used in clayey soils up to 13% moisture content. Neglected above 20% moisture.	Zgútová, Decký, Šrámek, and Drevený (2015)
Evaluating moisture content, surface density, and drainage system for sports surfaces	2.25 kg	Identifying risk factors for synthetic equestrian surfaces	Decrease in risk of injuries requires higher moisture content of 19.08% and medium surface density.	Holt et al. (2014)
Measuring Vehicle impacts on snow roads	2.25 kg	Measures the surface strength to monitor the changes in snow strength	Can provide suitable uses for future development	Shoop, Knuth, and Wieder (2013)
Determining the relation between ground hardness and related injuries	2.25 kg	Measuring ground hardness across 20 grounds over 2007 and 2008 AF seasons.	Displayed low number of injuries. Further investigation required.	Twomey, Finch, Lloyd, Elliott, and Doyle (2012) and Twomey, White, and Finch (2012)
Determining the target value of compacted gravel for pipelines	N/A	Measuring in-place properties of soils to evaluate compaction suited for pipelines	Can measure the in-place properties of soils which is used to measure compaction.	Howard (2011)
Testing Ballast and subgrade materials for In situ strength.	4.5 kg	Rail revitalisation project. Case study to compare in situ and laboratory test.	CIH on subgrade materials showed similar results to laboratory CBR values.	Drechsler and Parken (2010)
Quality control for roadway compaction and construction	10 kg	Evaluation of Clegg Impact hammer for compaction of soils	CIV value increases with increase in compaction. Hammer size is important in quality control.	Kim, Prezzi, and Salgao (2010)
Assessing strength of Saudi calcareous marl soil with and without chemical treatment (cement and lime)	N/A	Using marl soil to enhance indigenous soils in eastern Saudi Arabia for the use as a road base material.	Cement has a higher strength and durability than lime. CIV increases with the increase in cement content.	Al-Amoudi, Khan, and Al-Kahtani (2010)

Table 4. Clegg Impact Value for base course strength and stiffness.

Clegg Impact Value (CIV)	Base course strength/stiffness
> 75	Very High
60–75	High
45–59	Medium – High
30–44	Low – Medium
< 30	Low

CONTD

…

Road Name	Chainage	DCPI	Lab CBR	CBR by Clegg	CBR by Livnah
TG-AN	SB 3/250	4.6	21.16	33.88	48.00
TG-AN	B 3/250	4.9	30.65	30.87	44.60
TG-AN	SB 3/100	5.1	33.57	30.87	42.58
TG-AN	B 3/100	5.8	37.95	28	36.68
SG-SP	B 3/900	4.7	25.54	30.87	46.81
SG-SP	SB 3/900	4.9	30.65	33.88	44.60
SG-SP	SB 3/500	5.4	33.94	28	39.85
SG-SP	B 3/500	5.9	35.03	37.03	35.96
SM-SUB	SB 0/400	2.5	22.62	22.68	97.36
SM-SUB	B 0/50	2.7	23.35	37.03	89.05
SM-SUB	SB 0/50	3.1	27.37	25.27	75.86
SM-SUB	B 0/400	3.3	31.75	40.32	70.55
ED-KM	SB 3/900	2.7	21.16	20.23	89.05
ED-KM	B 3/500	3.1	27	40.32	75.86
ED-KM	SB 3/500	3.4	27	37.03	68.15
ED-KM	B 3/900	3.9	29.19	25.27	58.13
PWD-SIN	B 2/250	4.3	21.16	25.27	51.90
PWD-SIN	B 1/850	4.8	23	30.87	45.68
PWD-SIN	SB 2/250	5.2	25.18	15.75	41.63
PWD-SIN	SB 1/850	5.9	33.94	37.03	35.96
HASANPARTHY	SB 1/050	4.6	20.8	28	48.00
HASANPARTHY	B 1/050	5.1	25.18	37.03	42.58
HASANPARTHY	B 1/250	5.3	25.18	25.27	40.72
HASANPARTHY	SB 1/250	5.7	25.54	22.68	37.43

Correlation with CBR Values

The fourth reading of Impact Value can be converted to 'Equivalent % CBR' using the relationship below.

Equivalent % CBR = (0.24(IV) + 1)2

Example: 25 IV = ((0.24 x 25) + 1)2 % CBR

25 IV = 49% CBR approximately.

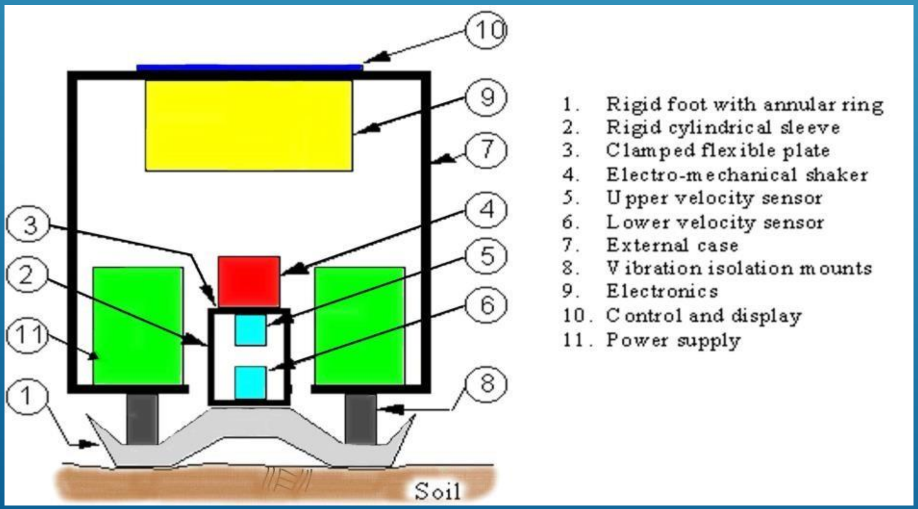
Table 5. Summary of the Correlations for the Field and Laboratory[a] CBR-CIV Relationships

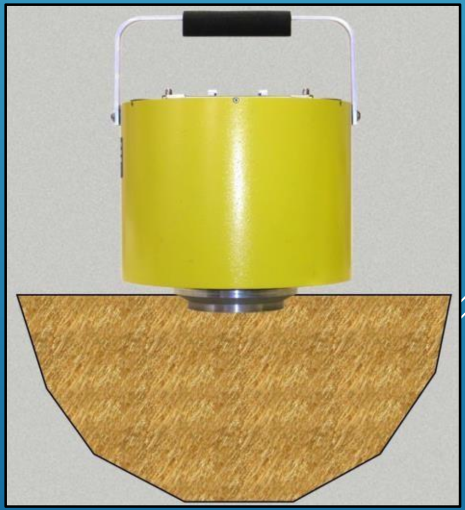
Type of test	Correlation equation	R^2	SEE
Laboratory[a]	$CBR = 0.1977\ (CIV)^{1.535}$	0.810	0.4790
In situ			
GM Soil	$CBR = 0.8610\ (CIV)^{1.1360}$	0.757	0.0936
Sm Soil	$CBR = 1.3577\ (CIV)^{1.0105}$	0.845	0.1545
GM & SM Soils (combined)	$CBR = 1.3489\ (CIV)^{1.0115}$	0.846	0.1420
Literature			
Clegg (1980)	$CBR = 0.07\ (CIV)^{2.0}$	0.788	b
Mathur and Coghlans (1987)	$CBR = 0.1085\ (CIV)^{1.863}$	0.787	b
General Model[a]	$CBR = 0.1691\ (CIV)^{1.695}$	0.850	0.1719

[a]Based on laboratory in situ and literature data.
[b]Not reported.

GEO-GAUGE APPLICATIONS(ASTM D6758)

- Developed by the defence industry for detecting land mines.
- Gauge measures Soil Stiffness in-place of compacted soil.
- Geogauge is to measure the impedance at the surface of the soil by measuring the stress imparted to the surface and the resulting surface velocity as a function of time.
- Depth of measurement 220 to 310 mm





SIMPLE, QUICK &SAFE !

Seating on Hard or Rough

Use Wet Sand To Ensure Maximum Contact

GEOGAUGE APPLICATIONS

- Compaction QC/QA
  Unbound & Bound Materials, Soil, Soil-Aggregates & Aggregates
- Cement Treated Materials
  Minimize Asphalt Surface Reflective Cracks
- Subgrade & Base Stabilization
  Ensure Required Strength & Minimize Construction Down Time
- Trench / Utility Cut Backfill
  Ensure Duplication Of Original Properties
- Hot & Cold Mix Asphalt QC/QA
  Compaction & Strength Evaluation
- Forensic Investigations

GROUND PENETRATING RADAR –WHAT IT DOES?

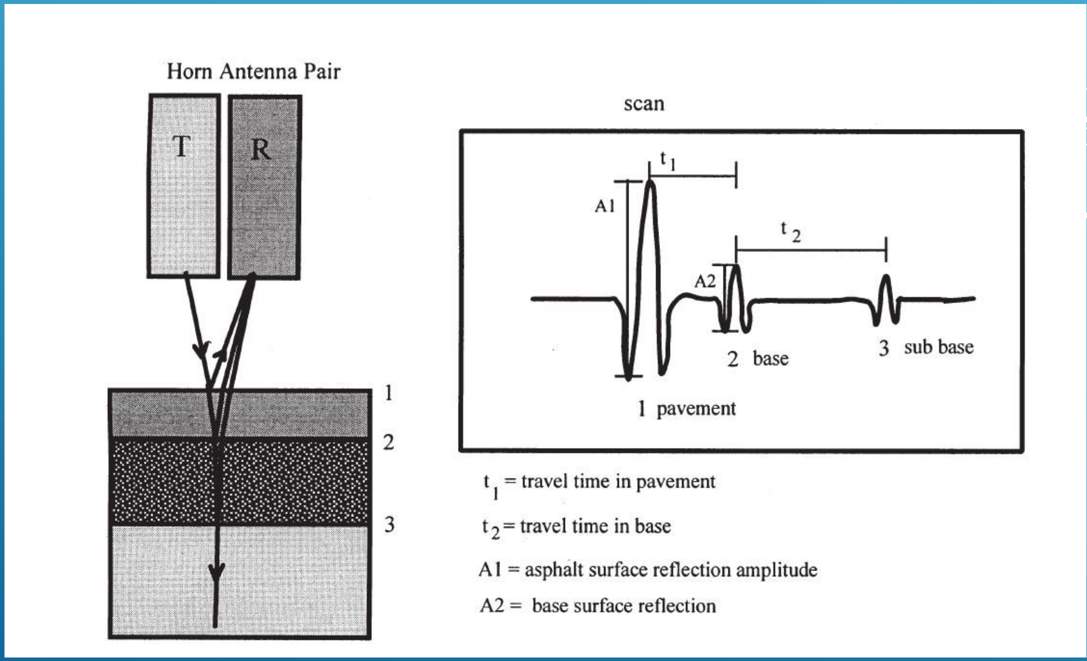
- 1960s-7,70'S - early development
  - Military applications
  - Tunnel and mine detection
- 1980's initial application in highways
- 1990's practical development in Pavements
- 2000+ -adoption by highway agencies
- It Does ....
  - Thickness of pavement layers
  - Reinforcing steel
  - Density variations
  - Subsurface moisture and voids

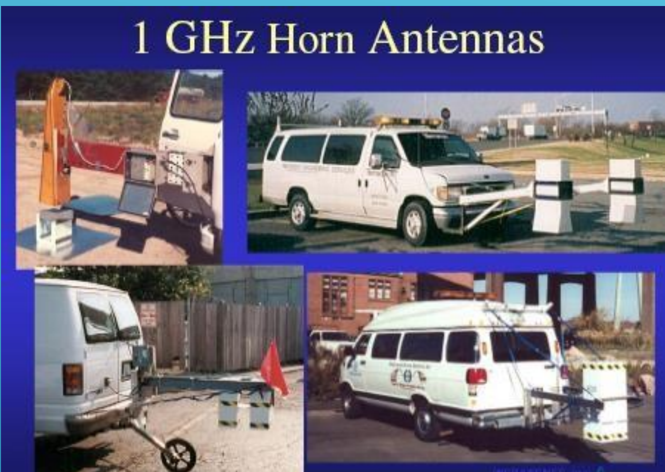
JUST THINK OF……

- Why is pavement thickness information useful?
- What are the current methods for obtaining thickness information?
- What are the advantages of using GPR for thickness evaluation?

GROUND PENETRATING RADAR

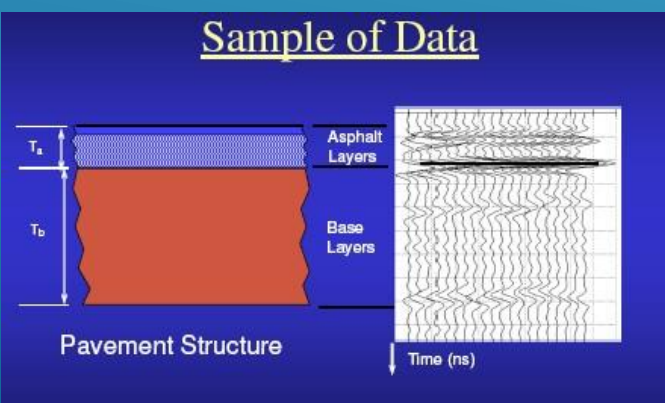
- **Ground Penetrating Radar (GPR) is a non-destructive and rapid geophysical method that operates by transmitting electro magnetic waves from an antenna and reflects off layers and objects hidden in the ground.**
- **GPR system configuration consists of one or more antenna elements, a control unit, and a monitor or external Tablet/PC, for storage and display of data.**

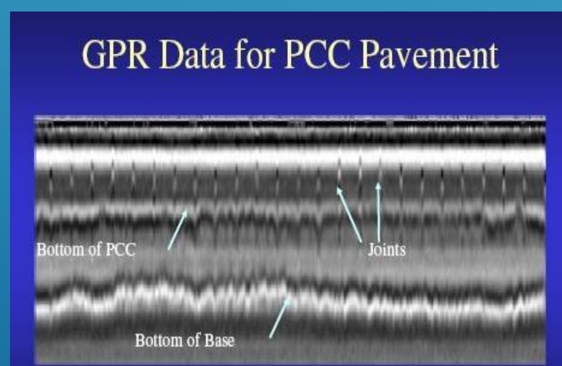


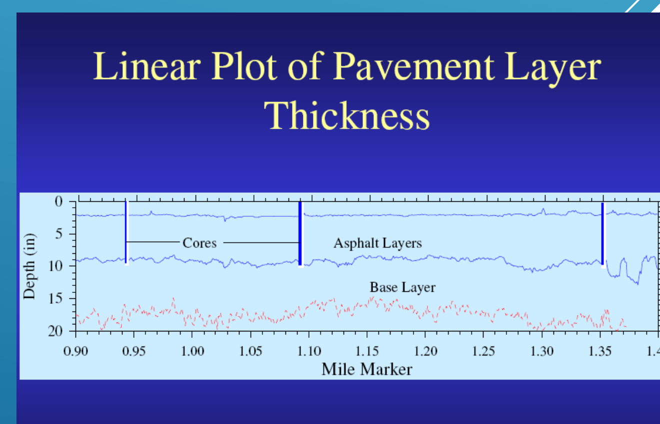

1 GHz Horn Antennas


Current Horn Antennas
1 GHz Horns
2 GHz Horns

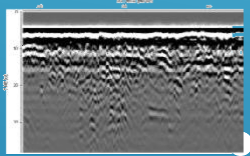

Ground-Coupled Antennas
1.5 GHz
500 MHz


Sample of Data
T_a
T_b
Asphalt Layers
Base Layers
Pavement Structure
Time (ns)

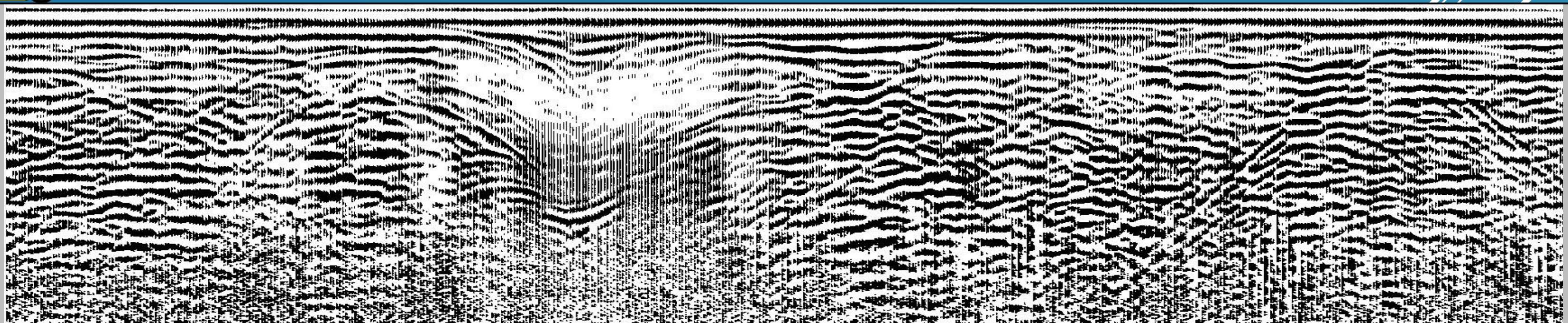

GPR Data for PCC Pavement
Bottom of PCC
Joints
Bottom of Base


Linear Plot of Pavement Layer Thickness
Depth (in)
0
5
10
15
20
Cores
Asphalt Layers
Base Layer
0.90
0.95
1.00
1.05
1.10
1.15
1.20
1.25
1.30
1.35
1.40
Mile Marker

Three areas have to be addressed in order to promote the GPR use in CE



- Advancement of GPR system, increase of sensitivity to enable usability in a wider range of conditions.
- Improvement of data processing/EM algorithms to ease the interpretation of results by un-experienced operators.
- Development of standards/guidelines and training of end users, to increase the awareness of operators.




LWD