สวทช NSTDA

NAC2023
18th NSTDA Annual Conference
การประชุมวิชาการประจำปี สวทช. ครั้งที่ ๑๘

การก่อสร้างถนนยั่งยืน จากเศษวัสดุก่อสร้าง

ศ.ดร.สุขสันต์ หอพิบูลสุข

28-31
มีนาคม 2566

Research Team

Prof. Suksun Horpibulsuk
Project Director

EXTERNAL TEAM

Prof. Panich Voottipruex*

Dr. Runglawan Rachan*

Dr. Patimapon Sukmak*

Dr. Gampranart Sukmak*

SUT TEAM

Dr. Apichat Suddeepong*

Dr. Menglim Hoy*

Dr. Teerasak Yaowarat*

DOH & DOR

Dr. Taworn Takaikaew*

Dr. Ittikorn Phummiphan*

CONSULTANT

Prof. Arul Arulrajah*

* Suranaree University of Technology, Thailand
* King Mongkut's University of Technology North Bangkok, Thailand
* Mahanakorn University of Technology, Thailand
* Walailak University, Thailand
* DOH: Department of Highway, Thailand
* DOR: Department of Rural Road, Thailand
* Swinburne University of Technology, Australia

Contents

1. Introduction
2. Advance Testing & Mechanistic-Empirical Design Method
3. Results & Discussion
4. Applications

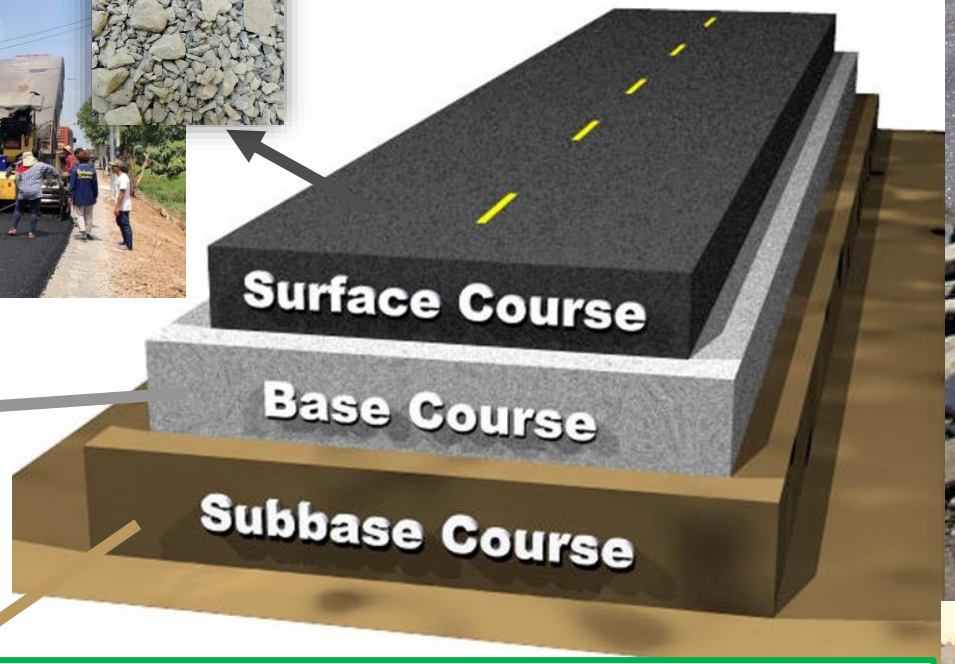
Introduction

Linear Economy Model

Natural Aggregate

Crushed Rock

Lateritic Soil



Asphalt concrete waste
10,000,000 ton/year

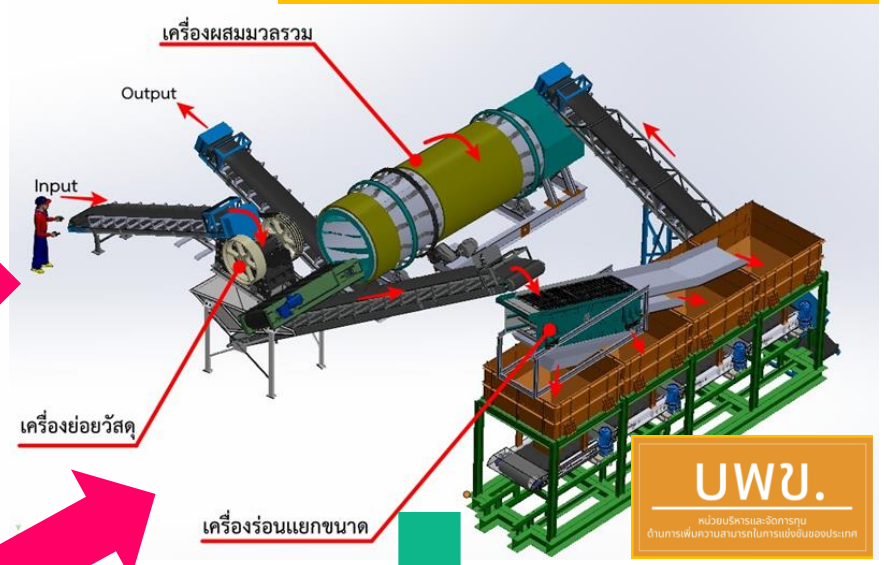
Concrete waste
300,000 ton/year

Linear Economy

Take → Make → Waste

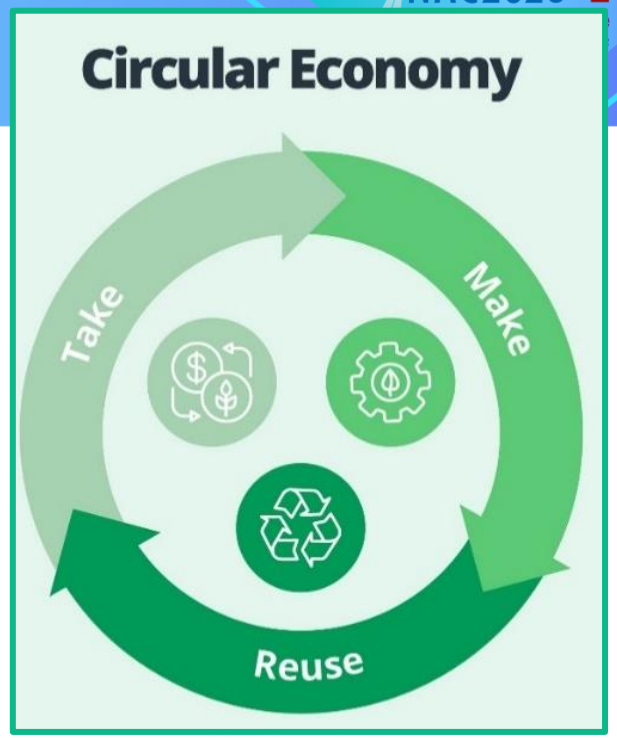
Circular Economy Model

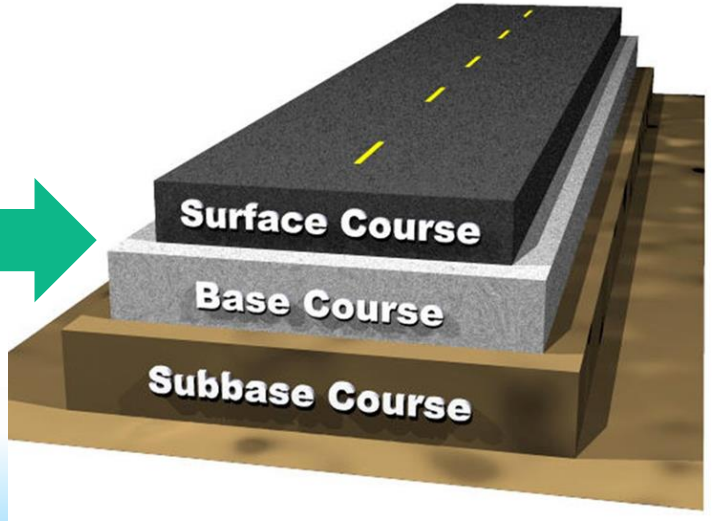
C&D Waste Recycling Plant



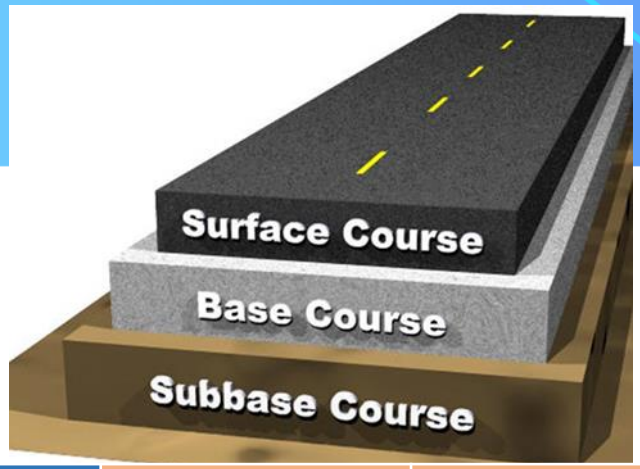
Recycled Asphalt Pavement (RAP)

Recycled Concrete Aggregate (RCA)





Geotechnical Properties



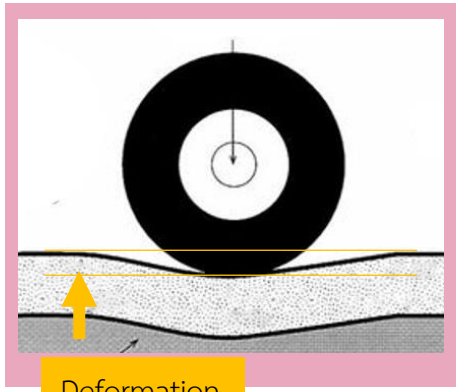
Geotechnical parameters	RCA (Arulrajah et al., 2013)	RAP (Arulrajah et al., 2013)	Typical quarry material	Crushed rock base type A (DOH, 2001)	Subbase material type A (DOH, 1989)
Fines content (%)	3.6	6.0	<10	≤ 8	≤ 8
Particle density—coarse fraction (kN/m^3)	27.1	23.5	>19.62	-	-
Particle density—fine fraction (kN/m^3)	26.0	23.4	>19.62	-	-
Water absorption--coarse fraction (%)	4.7	2.2	<10	-	-
Water absorption--fine fraction (%)	9.8	2.4	<10	-	-
MDD (kN/m^3)—modified compaction	19.13	19.98	>17.5	-	-
OMC (kN/m^3)—modified compaction	11.0	8.0	5-15	-	-
Flakiness index	11	23	<35	-	-
LA abrasion loss (%)	28	42	<40	≤40	≤60
CBR (%)	118-160	30-35	>80	≥80	≥25

Advance Testing & Mechanistic-Empirical Design Method

Sustainable Pavement Engineering

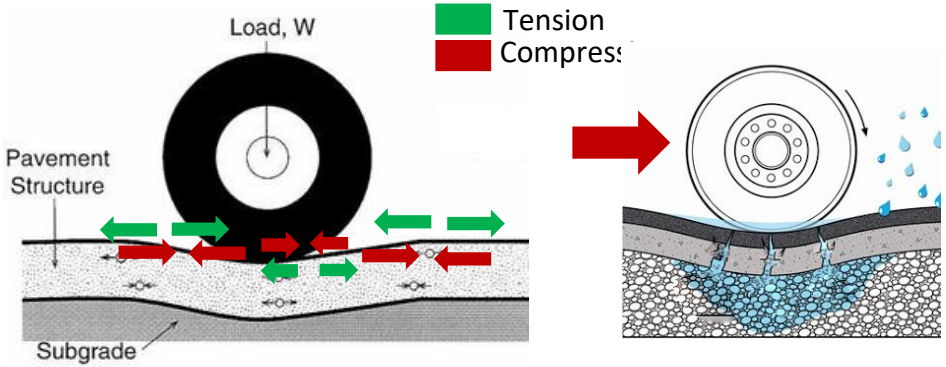
Use Appropriate Tests and Design Method

Rutting Failure



Deformation

Fatigue Cracking Failure



Advance Testing

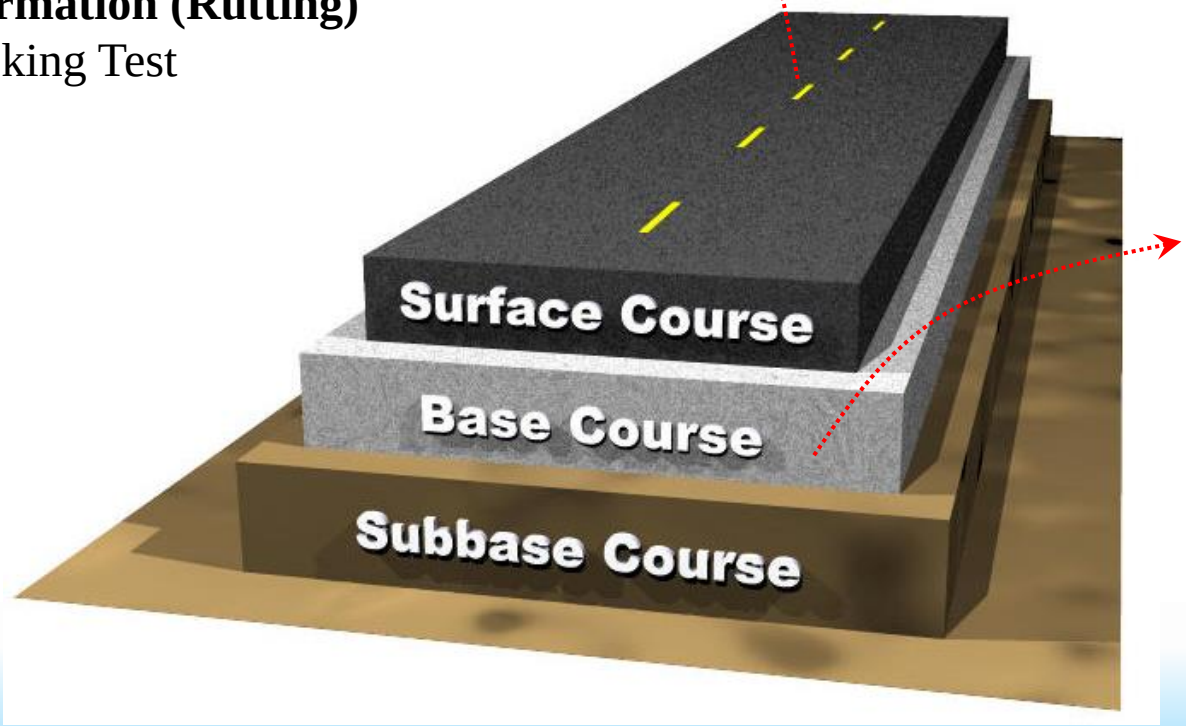
Asphalt Concrete Surface

Fatigue Cracking

- Indirect Tensile Strength (ITS)
- Indirect Tensile Resilient Modulus (ITM_R)
- Indirect Tensile Fatigue

Permanent Deformation (Rutting)

- Wheel Tracking Test



Base/Subbase

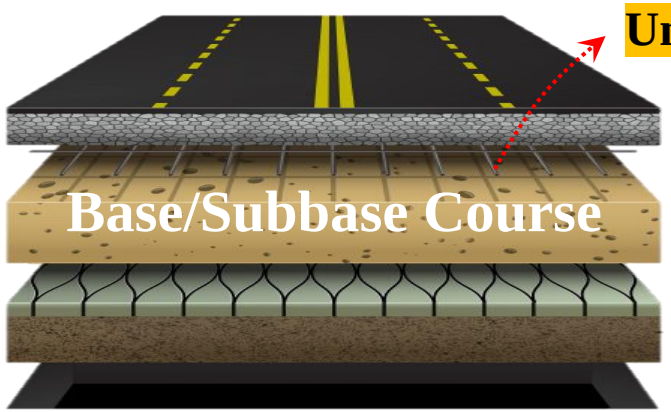
Unbonded Materials

- Resilient Modulus (M_R)
- Permanent Deformation

Stabilized Materials

- Indirect Tensile Resilient Modulus (ITM_R)
- Indirect Tensile Fatigue

Unbound Materials



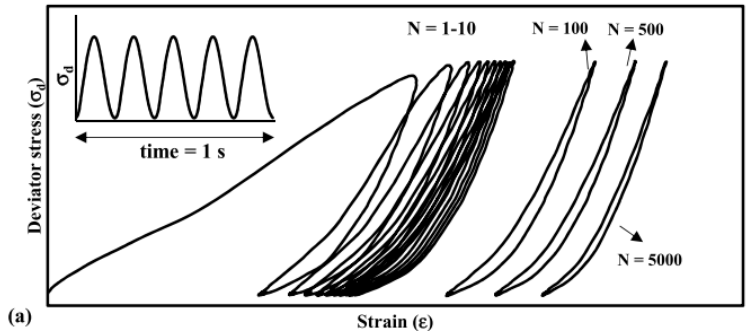
Unbound Materials

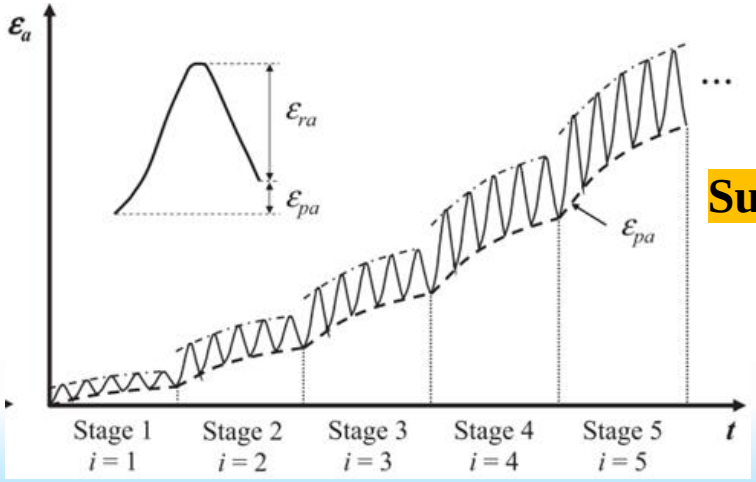
Permanent deformation test:

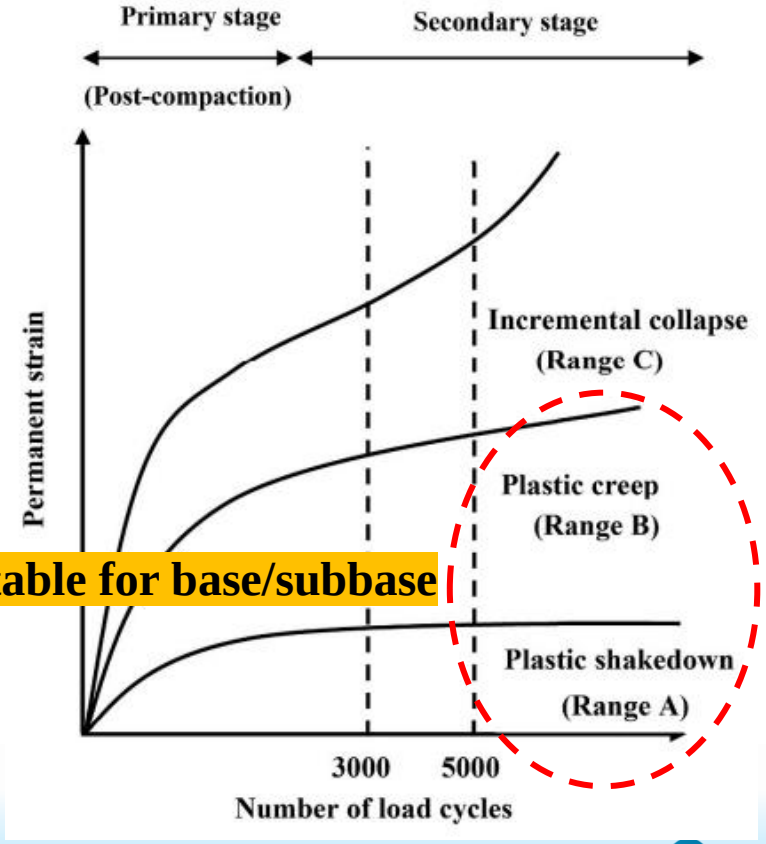
4-5 different stages, 10,000 repetitions

Static confining stress (σ_c): 20, 40, 60 kPa

Dynamic deviator stress (σ_d): 40-480 kPa (Haversine shape with a frequency of 5 Hz)



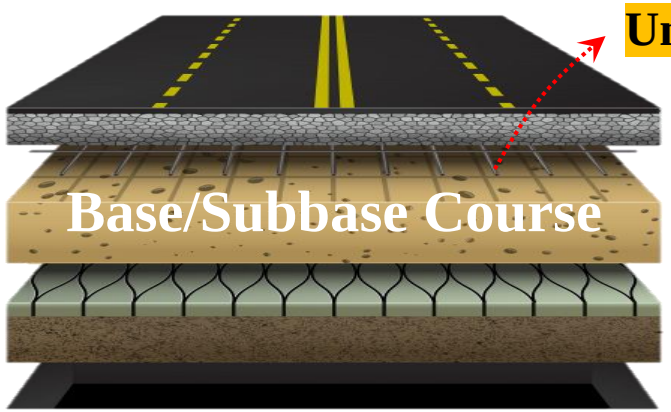


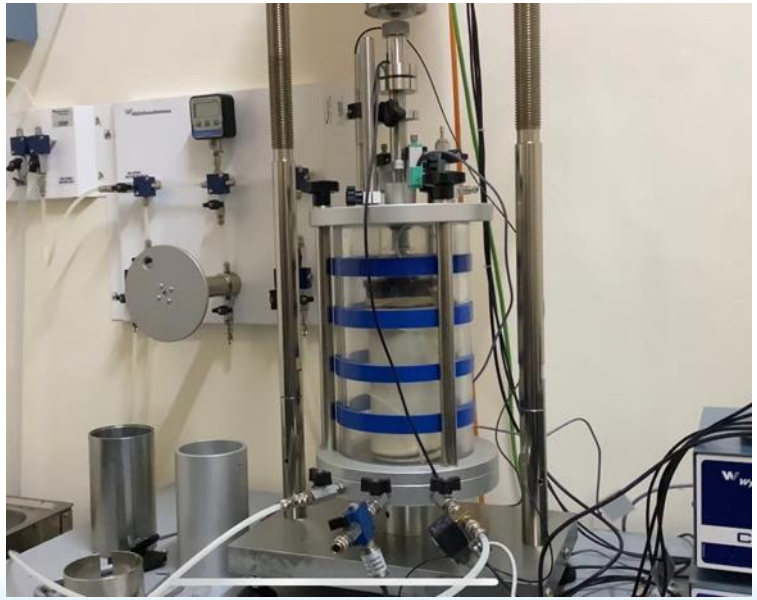


Suitable for base/subbase

(Werkmeister, 2004)

Unbound Materials



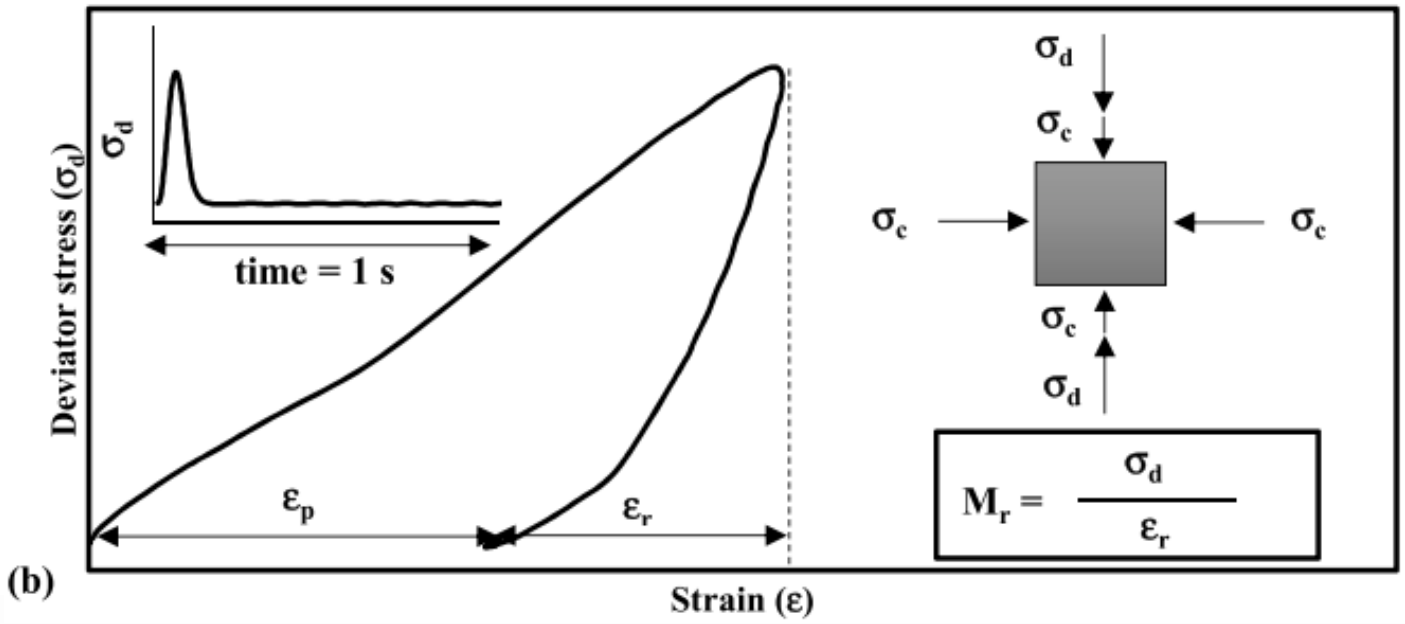


Resilient modulus test :

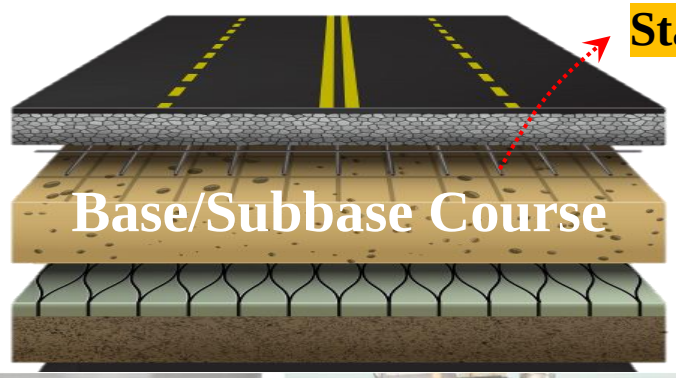
25 different stress stages

Confining stress (σ_c): 20-100 kPa

Deviator stress (σ_d): 10-600 kPa (Haversine shaped with loading time = 0.1 s and rest time = 0.9 s)



Stabilized Materials



Indirect Tensile Resilient Modulus (ITM_R)

Load pattern = 0.1 sec on 0.9 sec off

Temp. = 35 °C

Load = 15% of ITS

Test after 200 cycles of repeat load

ASTM D4123

Indirect Tensile Fatigue

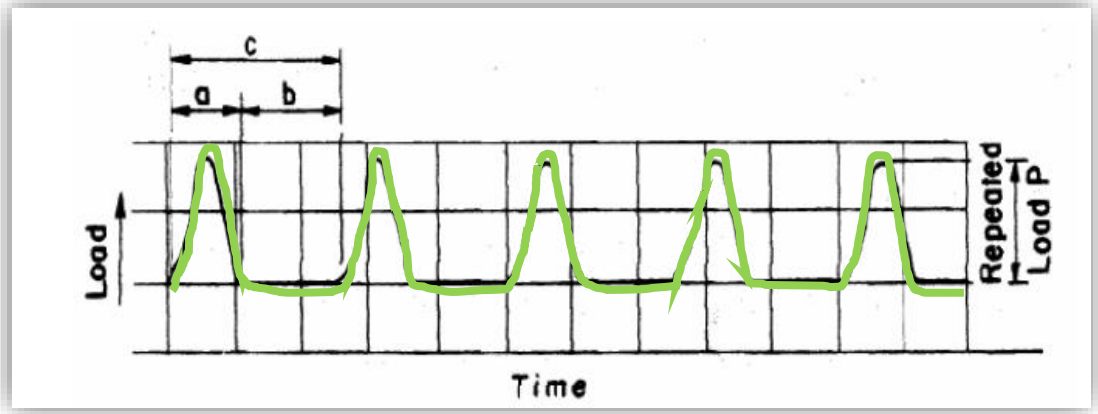
Load pattern = 0.1 sec on 0.9 sec off

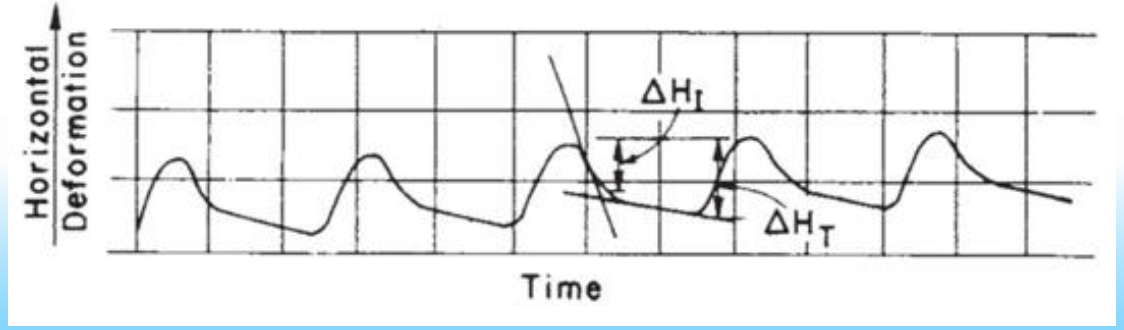
Temp. = 25 °C

Applied stress = 60%, 70%, 80% of ITS

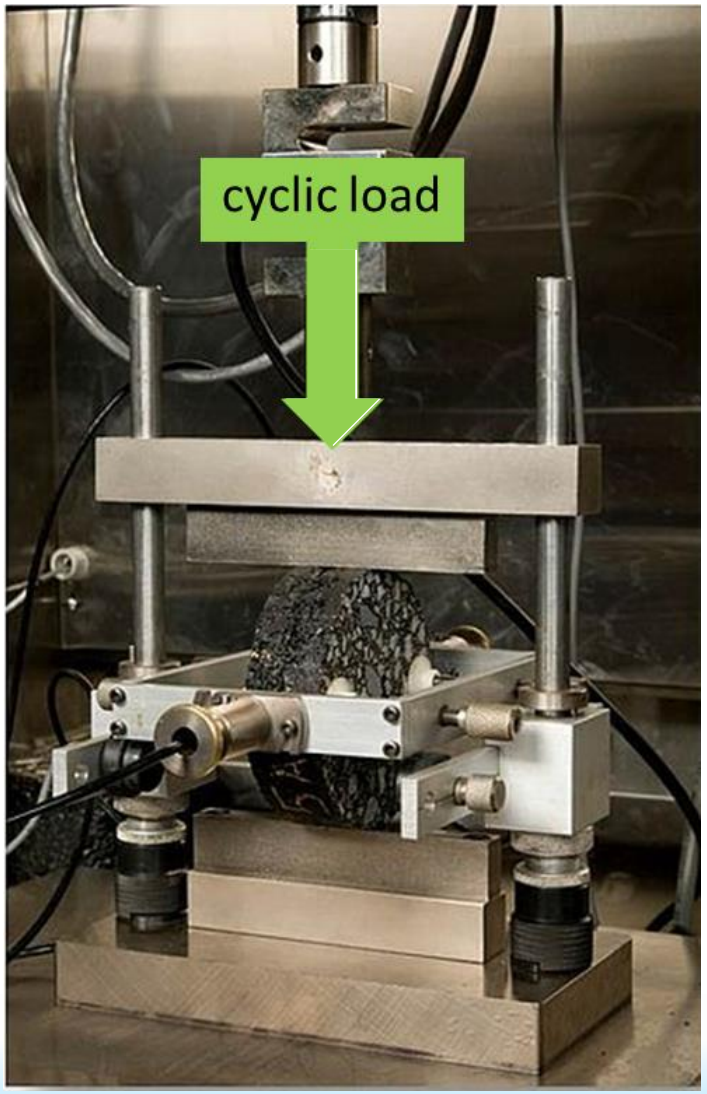
Number of repeat load at failure (NF)

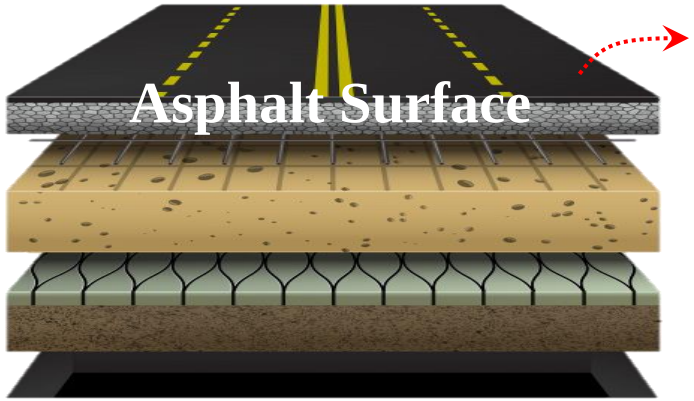
BS EN12697-24





Asphalt Concrete





Fatigue Cracking Criteria

Indirect Resilient Modulus (M_R)

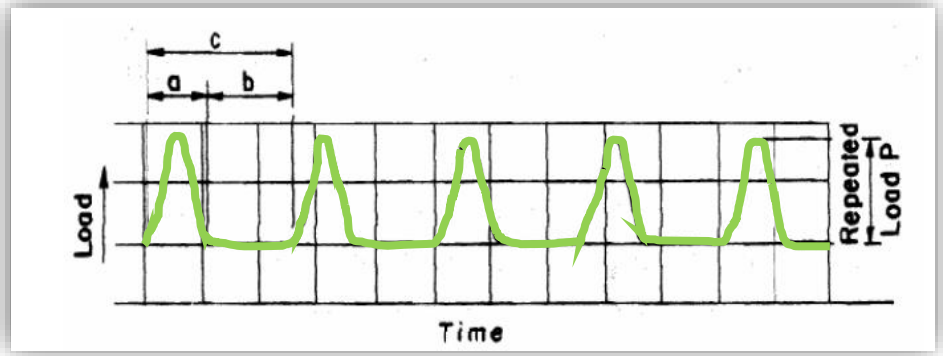
Load pattern = 0.1 sec on 0.9 sec off

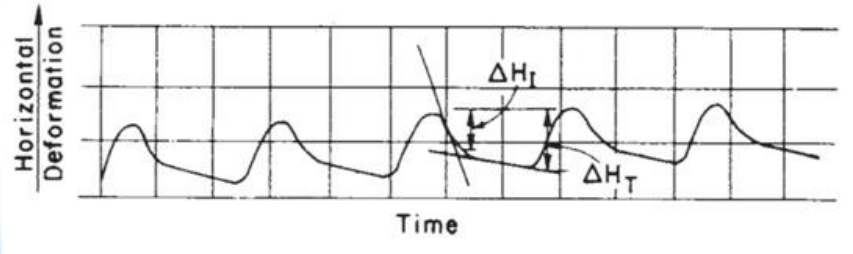
Temp. = 35 °C

Load = 15% of ITS

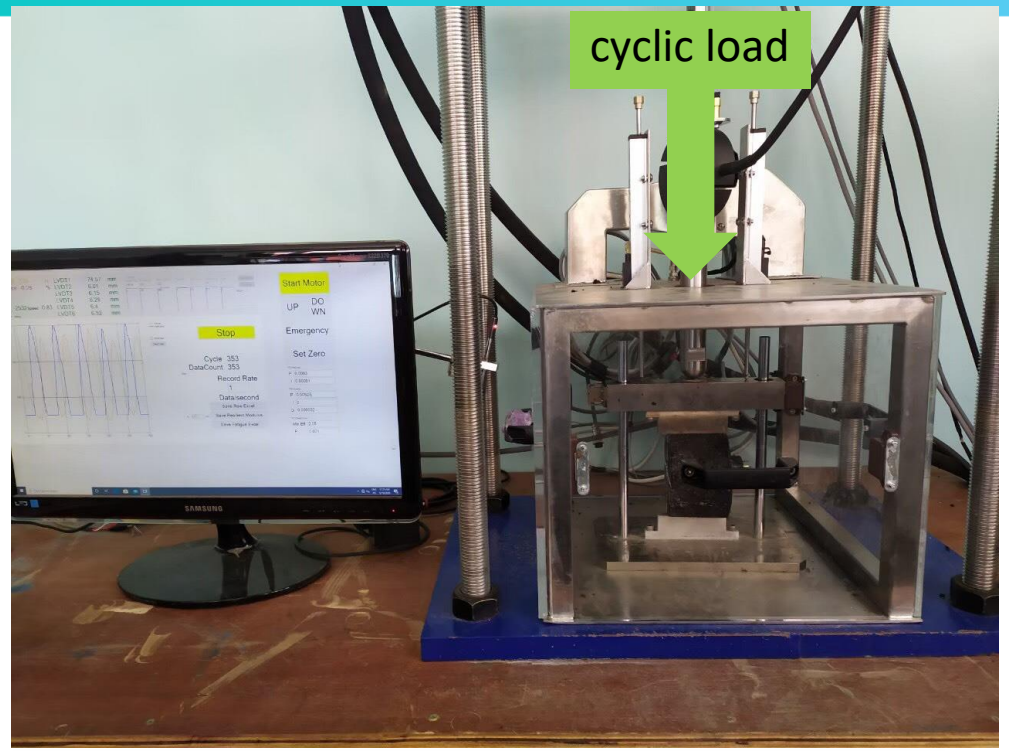
Test after 200 cycles of repeat load

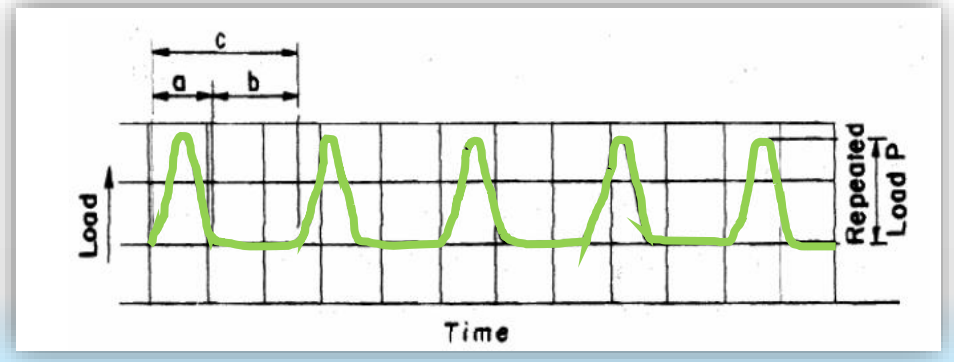
ASTM D4123

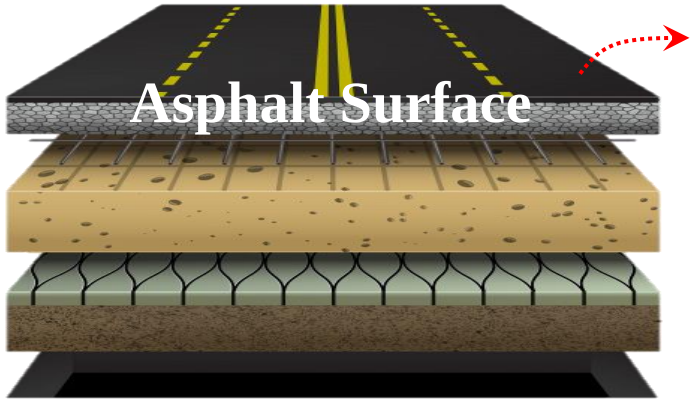




Asphalt Concrete Surface







Fatigue Cracking Criteria

Indirect Tensile Fatigue

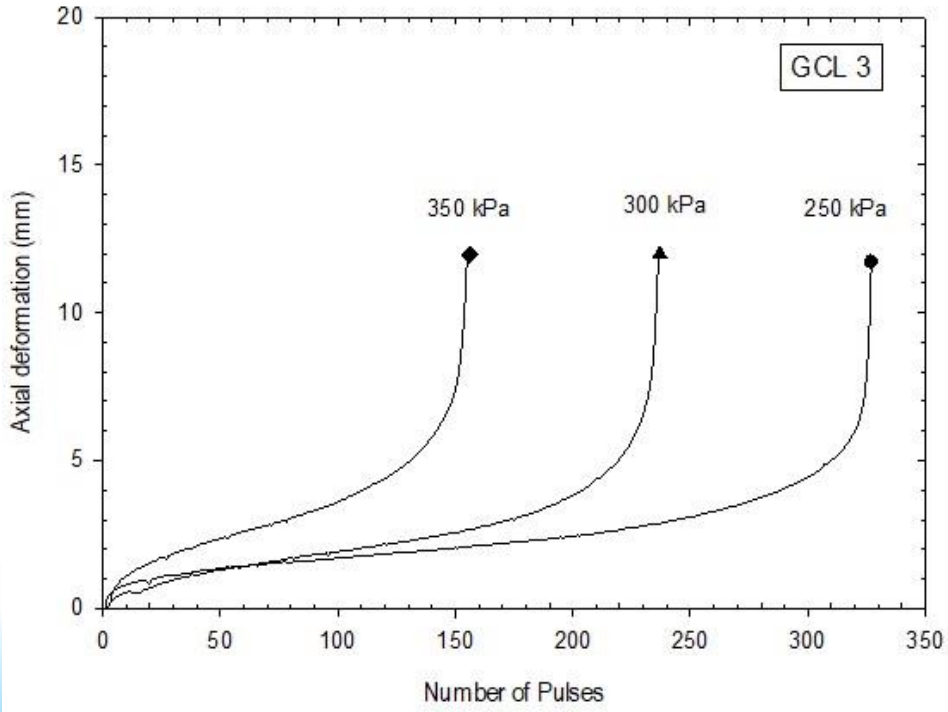
Load pattern = 0.1 sec on 0.9 sec off

Temp. = 25 °C

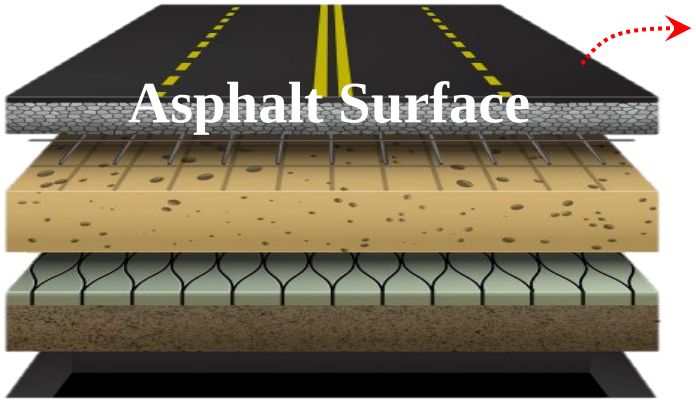
Applied stress = 250 kPa, 300 kPa, 350 kPa

Number of repeat load at failure (NF)

BS EN12697-24



Asphalt Concrete



Rutting Criteria

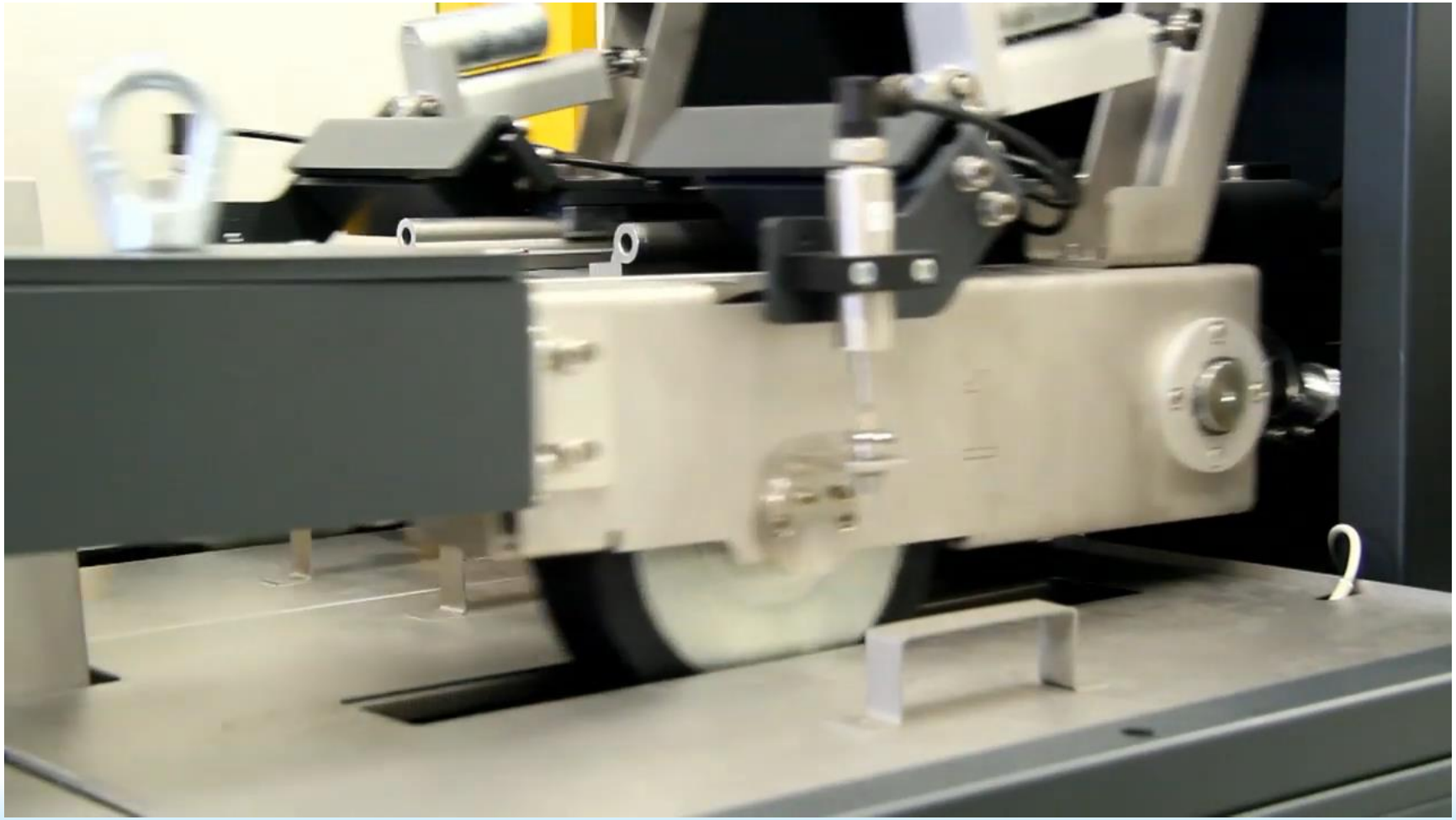
Wheel Tracking Test

"Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures"

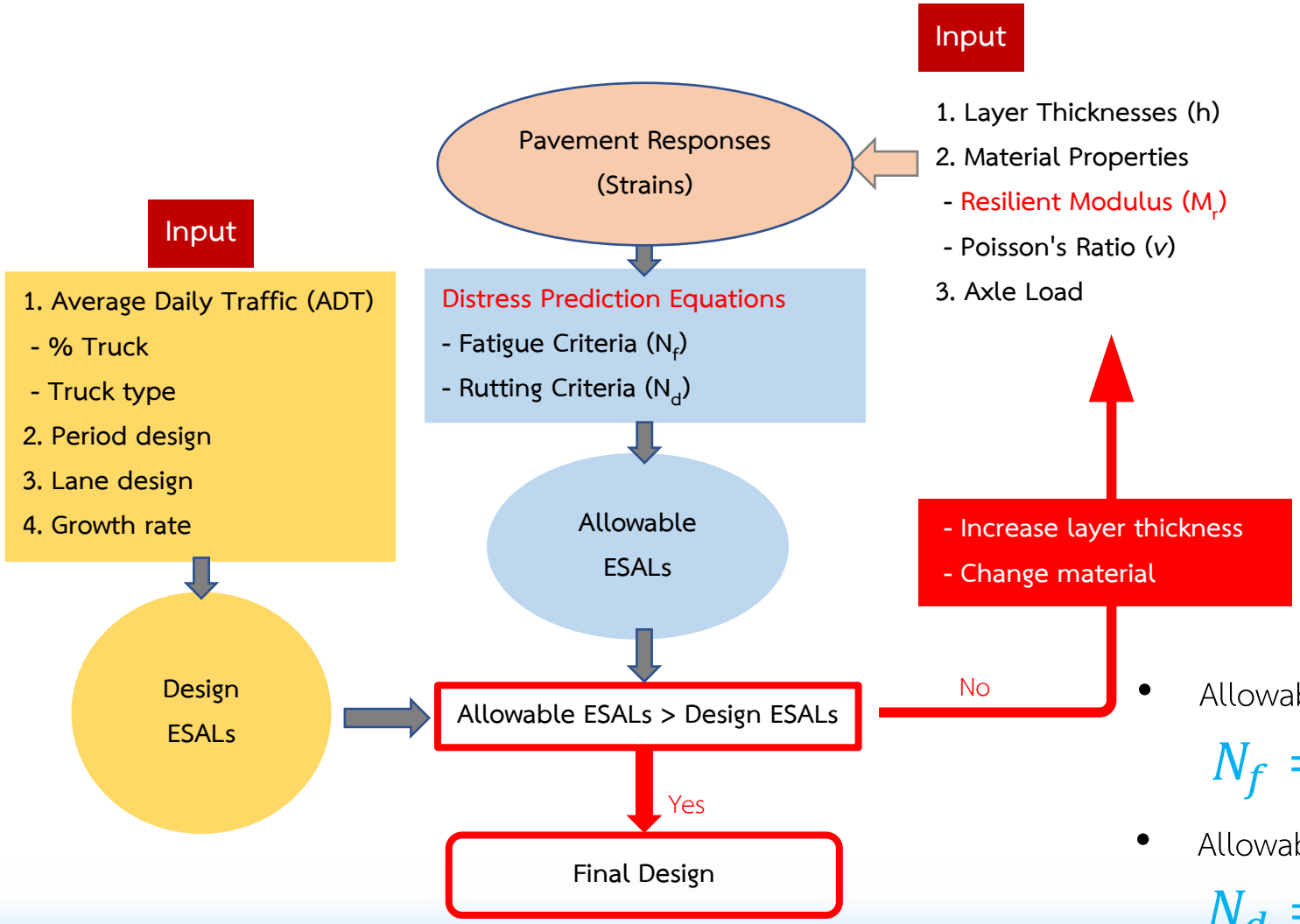
Based on AASHTO T324

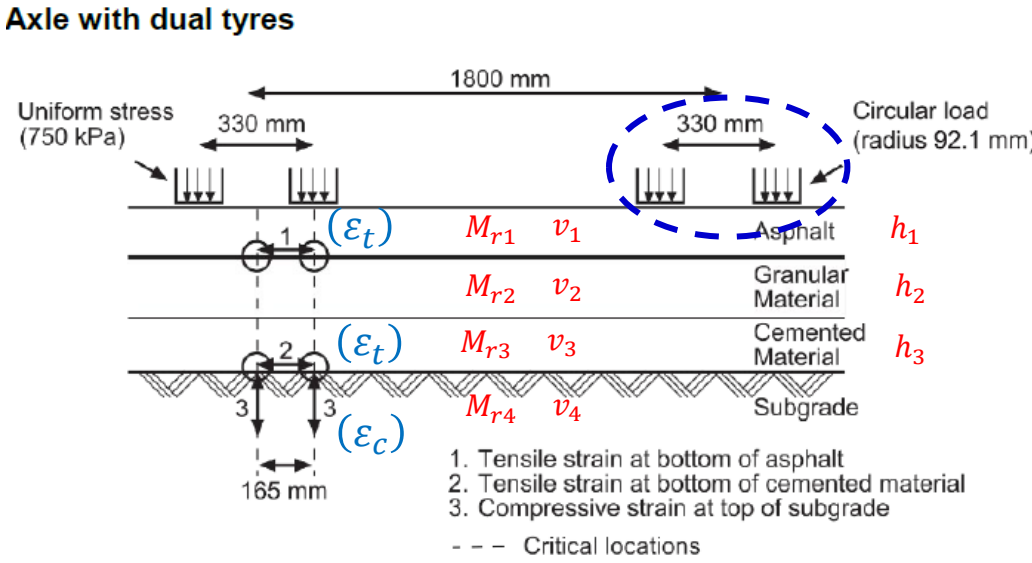
Asphalt Concrete

Wheel Tracking Test (Rutting Resistance)



Mechanistic-Empirical Design Method





- Allowable number of load repetitions to pavement fatigue cracking

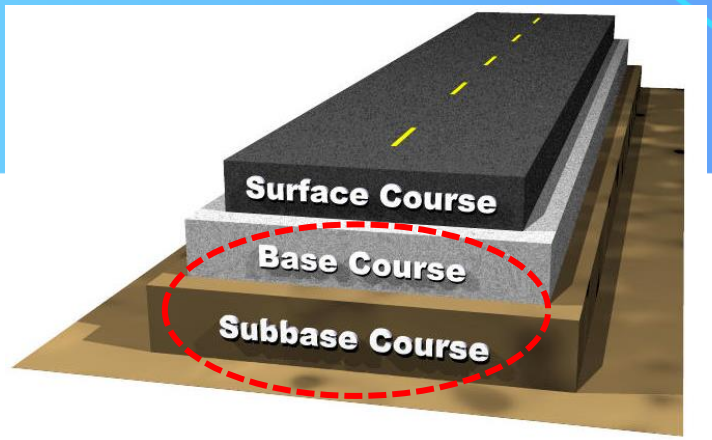
$$N_f = f_1(\varepsilon_t)^{-f_2}$$

- Allowable number of load repetitions to limit permanent deformation

$$N_d = f_3(\varepsilon_c)^{-f_4}$$

Results and Discussion

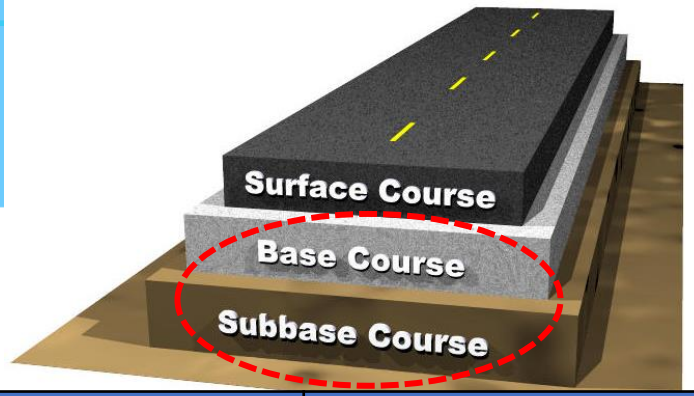
Unbound Materials



	RCA (Ghorbani et al. 2021)	RAP (Ghorbani et al. 2021)	Crushed rock base CBR = 80%	Subbase material CBR = 25%
Resilient Modulus (MPa)	453	258	193 (AASHTO, 1993)	96.5 (AASHTO, 1993)
Shakedown range ($\sigma_c = 40$ kPa)	A ($\boldsymbol{\sigma_d = 80 - 200}$ **kPa**) B ($\boldsymbol{\sigma_d = 320}$ **kPa**)	A ($\boldsymbol{\sigma_d = 80}$ **kPa**) B ($\boldsymbol{\sigma_d = 160 - 320}$ **kPa**)	A and B (Werkmeister, 2004)	A and B (Werkmeister, 2004)

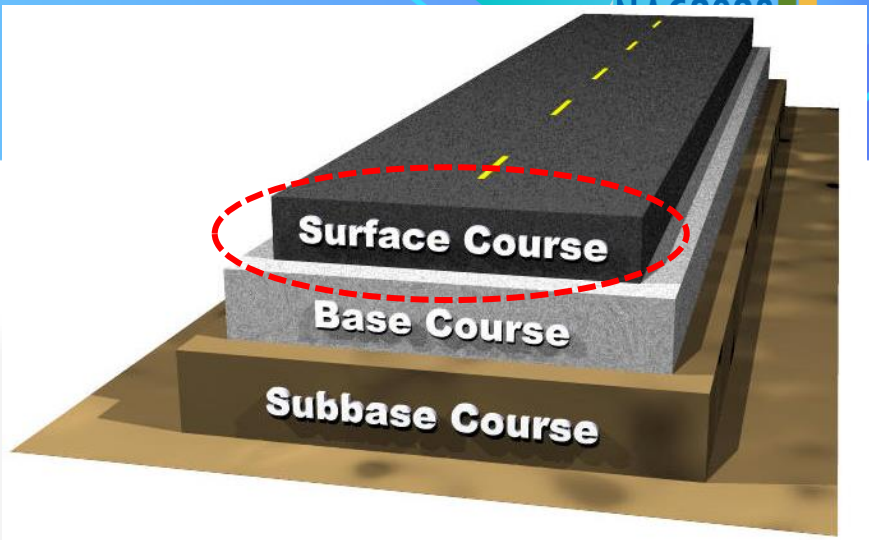
- Confining pressure for the base layer varied between 14 and 70 kPa (Gu et al., 2015)

Stabilized Materials



Materials	7-day Unconfined compressive strength (kPa)	Resilient Modulus (MPa)
- Cement stabilized crushed rock base - Soil cement base - Cement stabilized subbase	2,413 (High traffic volume) (DOH, 1989) 1,723 (Low traffic volume) (DOH, 1990) 689 (DOH, 1989)	393 (AASHTO, 1993) 379 (AASHTO, 1993) 345 (AASHTO, 1993)
RCA : Lateritic soil = 70:30 + 5% cement (Hoy et al., 2023)	4,100	2,700
RCA : Lateritic soil = 70:30 + 5% cement + 5% natural rubber latex (Hoy et al., 2023)	4,500	3,100
RAP + 2% cement (Mohammadinia, 2014)	1,450	1,600

RAP-RCA-PET-Asphalt Concrete



Asphalt concrete

Concrete

Plastic bottle

RAP

RCA

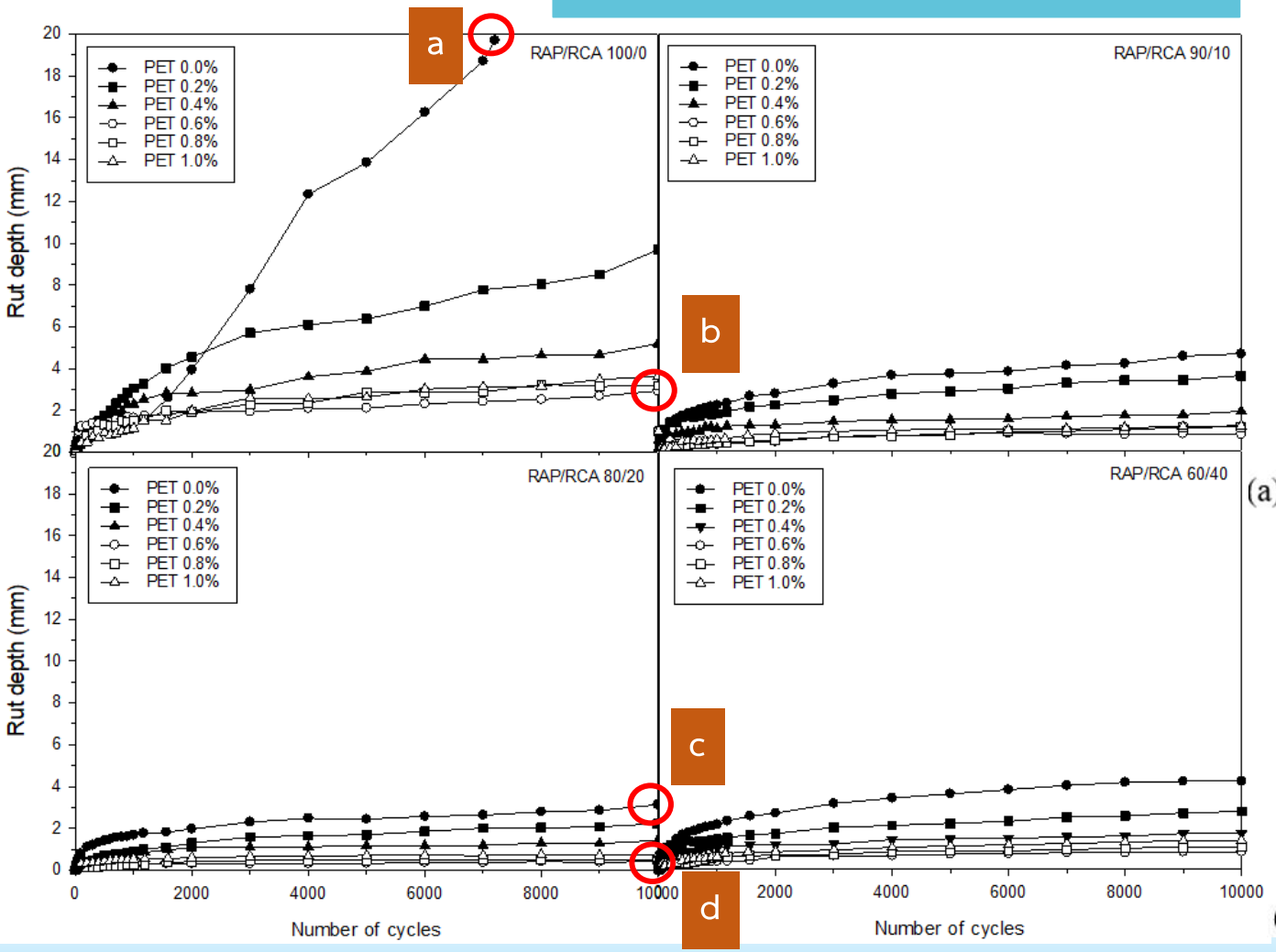
PET

AC60/70

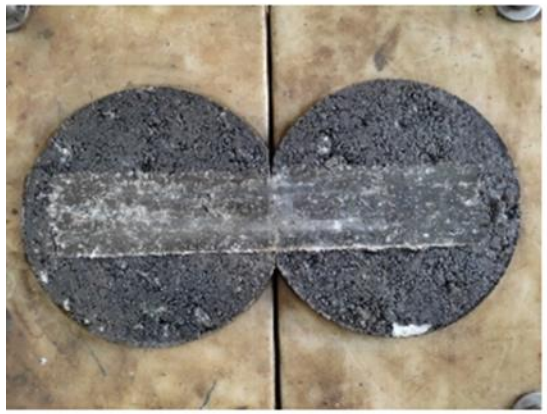
Asphalt Concrete

RAP-RCA-PET-Asphalt Concrete

Wheel Tracking Test (Rutting Resistance)

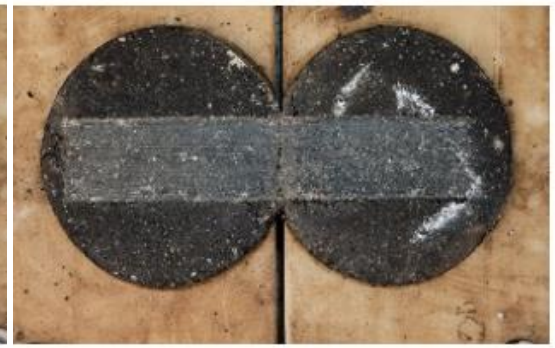


(a) RAP/RCA = 100/0, PET = 0.0%



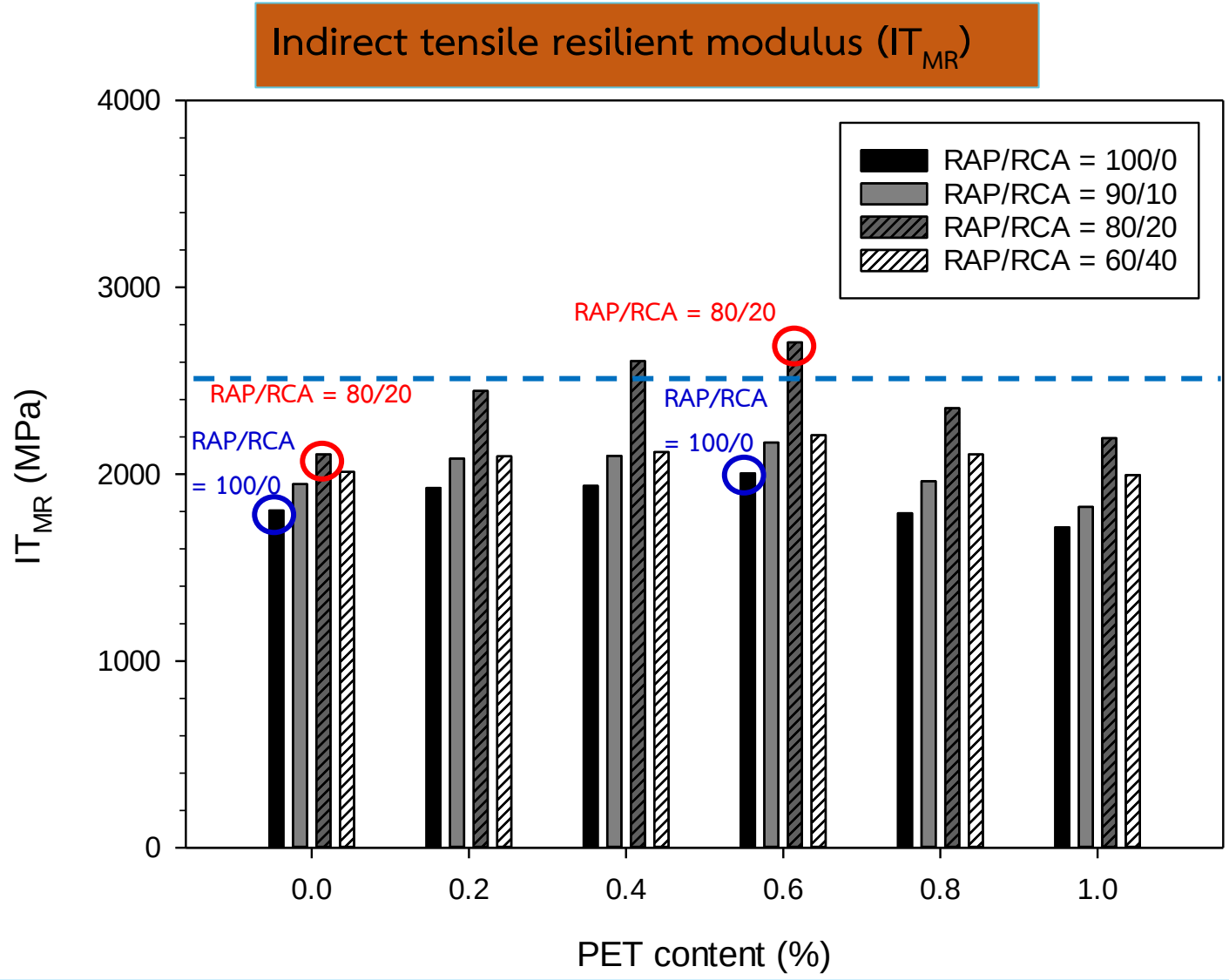
(b) RAP/RCA = 100/0, PET = 0.6%

(c) RAP/RCA = 80/20, PET = 0.0%



(d) RAP/RCA = 80/20, PET = 0.6%

RAP-RCA-PET-Asphalt Concrete

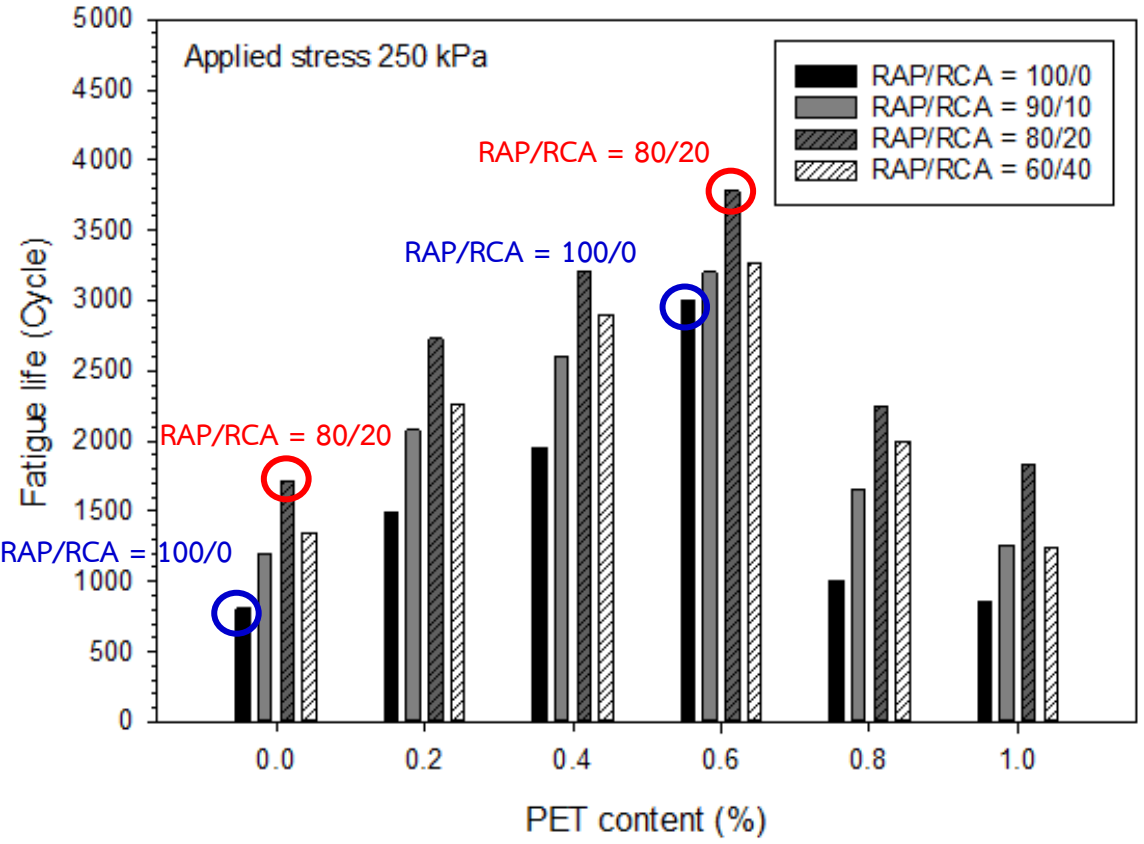


2,500 MPa (typical value for asphalt concrete in Thailand)

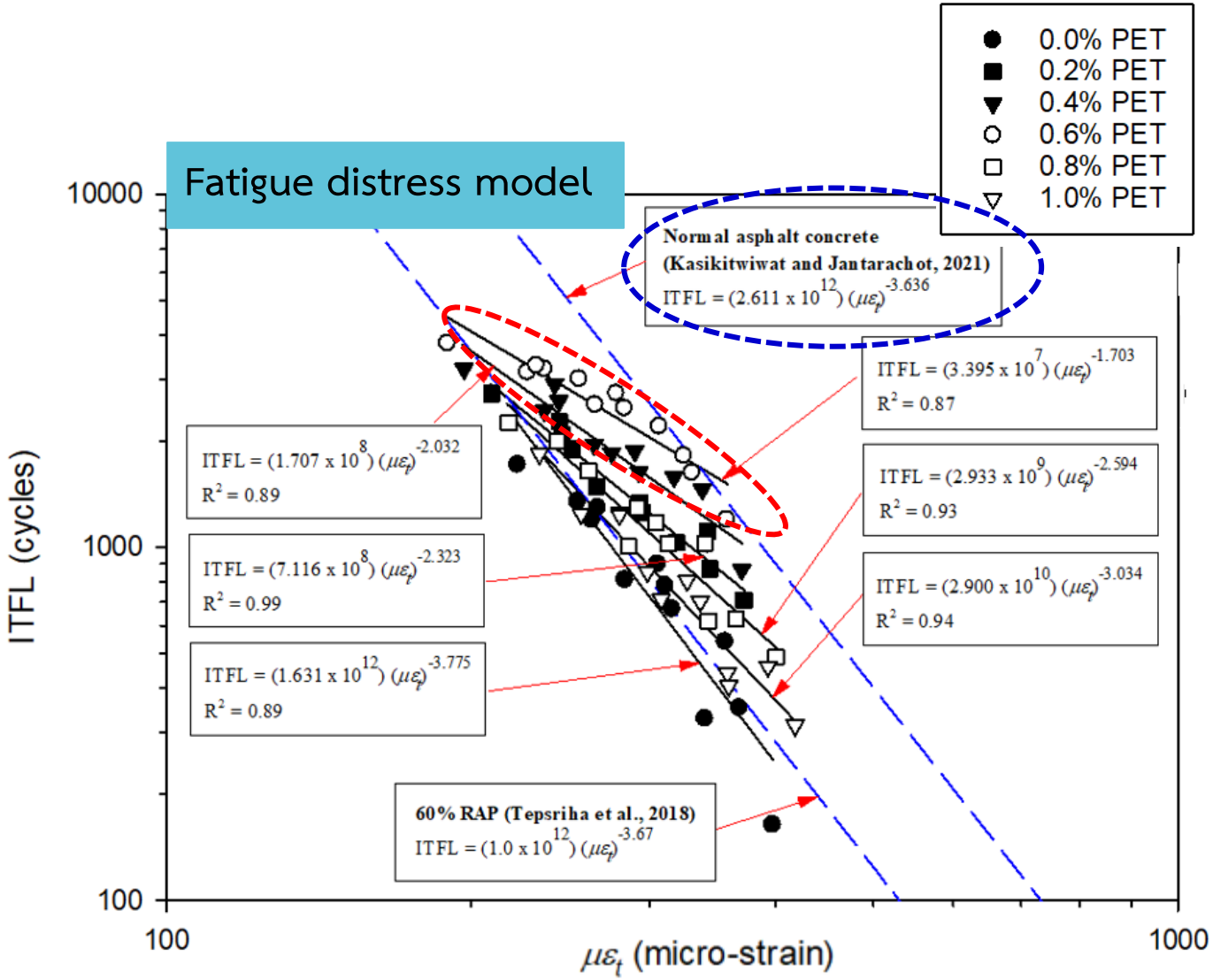
RAP-RCA-PET-Asphalt Concrete

Indirect Tensile Fatigue Test

Indirect tensile fatigue life (ITFL)



Fatigue distress model

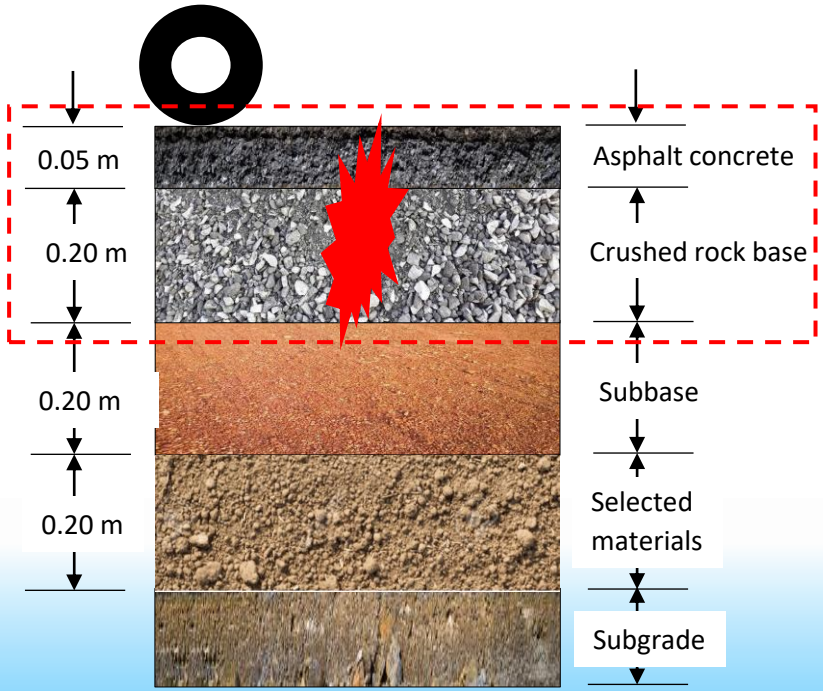


Applications

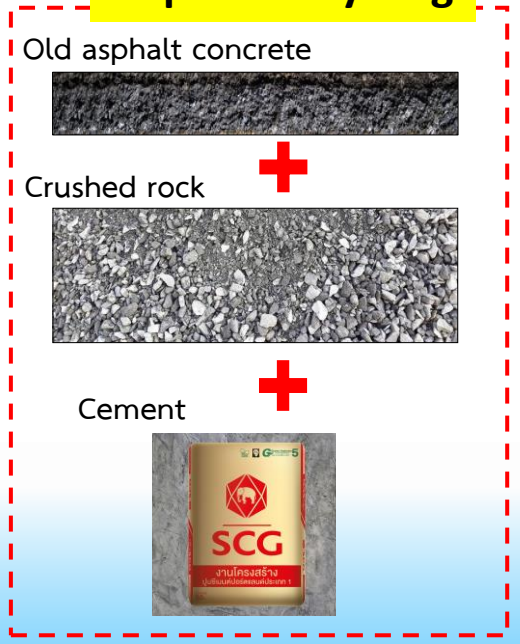
RAP-RCA-PET-Asphalt Concrete

Conventional method

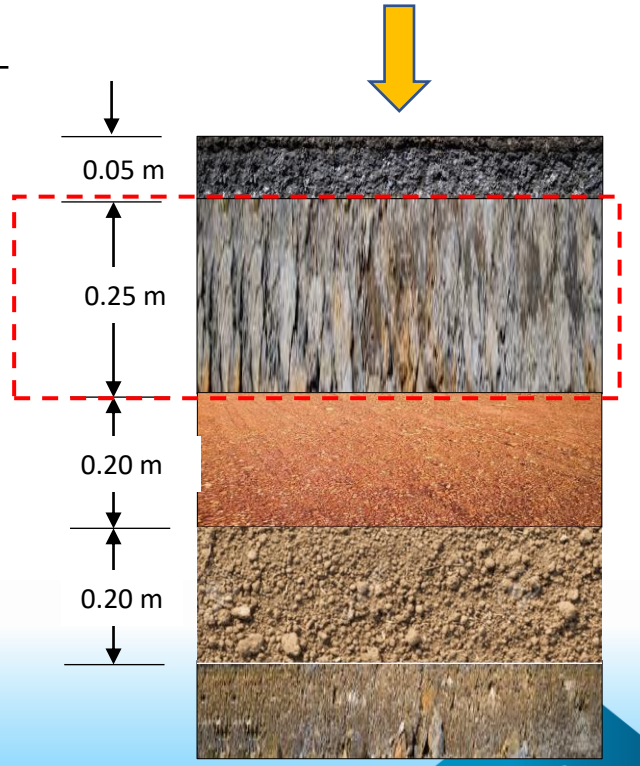
Design conditions	Descriptions
Average daily traffic (ADT)	1500 unit/day
Percentage of truck	18%
Type of truck	Class 6, 3 axles single unit truck (Gross weight 25 tons)
Growth rate	4%
Design period	7 years



In-place recycling

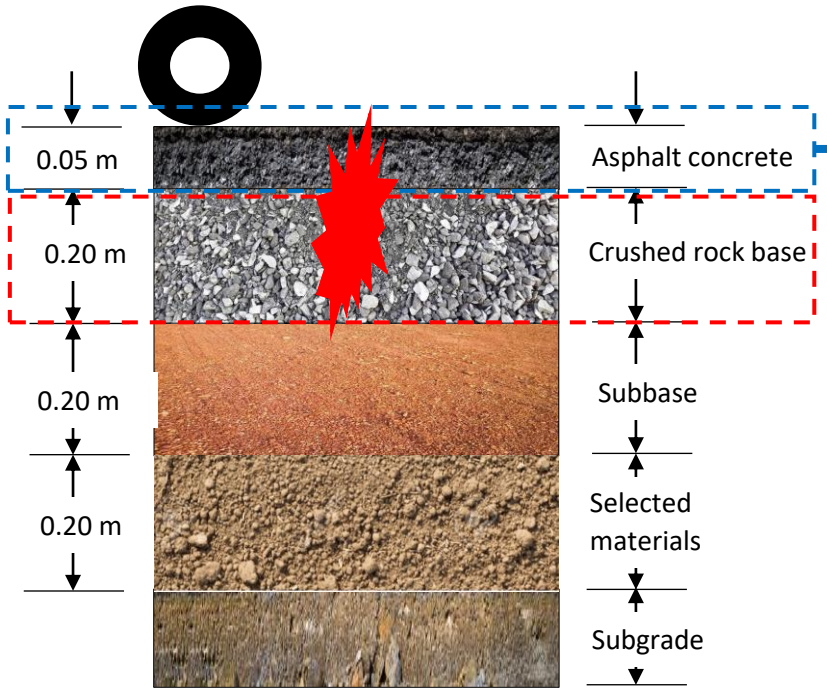


New asphalt concrete



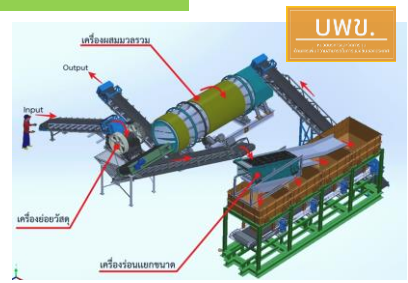
RAP-RCA-PET-Asphalt Concrete

New method



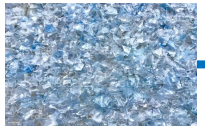
C&D Waste Recycling Plant

Old asphalt concrete



RAP = 80%

RCA = 20%



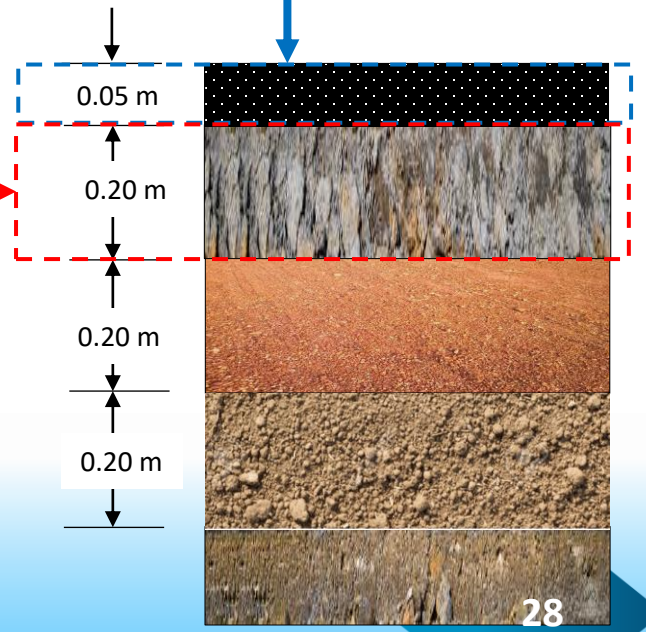
Crushed PET = 0.6%

Asphalt concrete plant

In-place recycling

Crushed rock base

Cement



RAP-RCA-PET-Asphalt Concrete

Project:

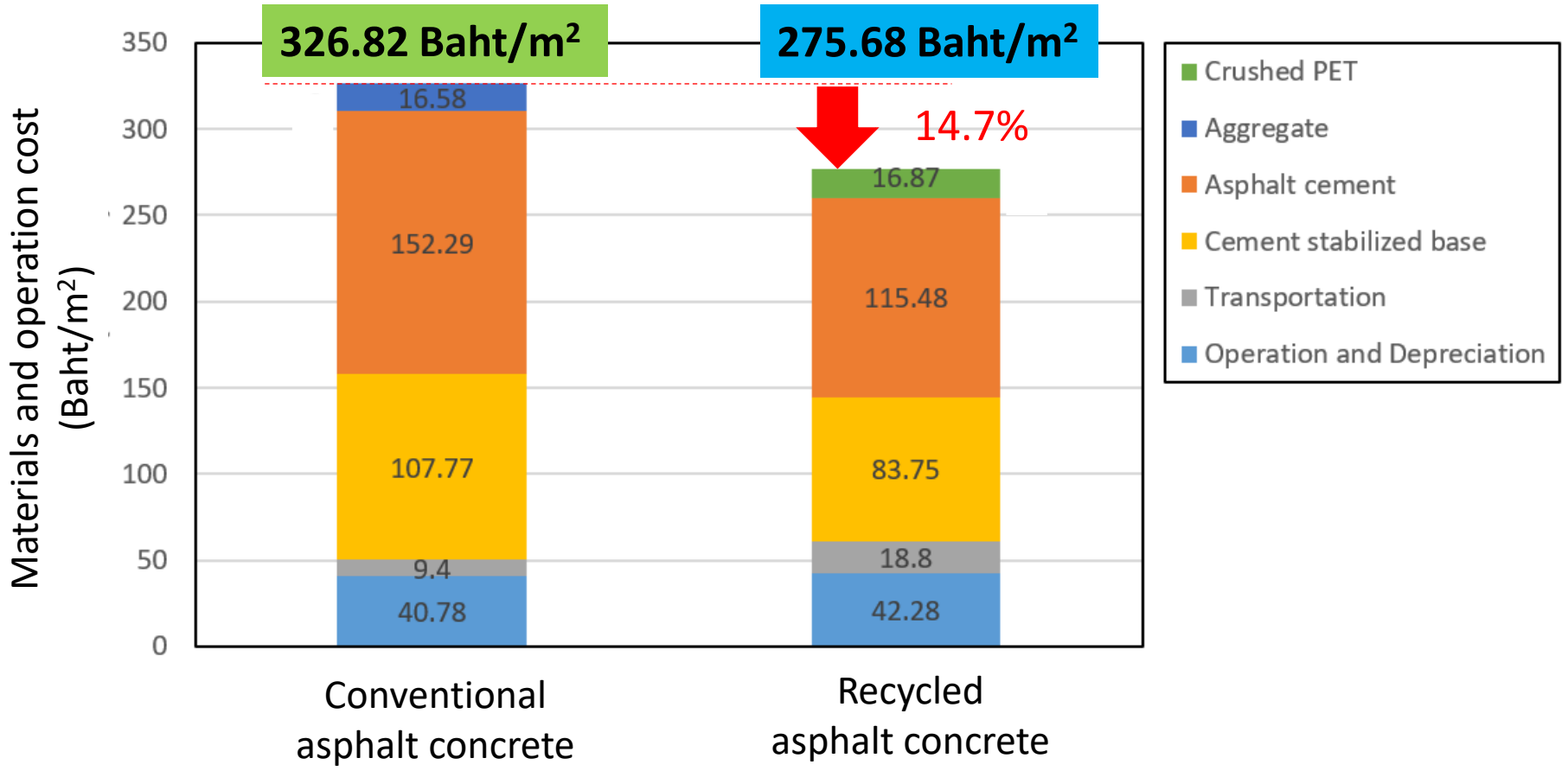
Replacing asphalt pavement (Baan Krok - Mittraphap Road, Mueang District, Nakhon Ratchasima Province)

Pavement dimension:

6 m of width, 320 m of length and 0.05 m of surface thickness

Asphalt plant distance:

94 km



สวทช NSTDA

NAC2023
18th NSTDA Annual Conference
การประชุมวิชาการประจำปี สวทช. ครั้งที่ ๑๘

ขอบคุณครับ

ศ.ดร.สุขสันต์ หอพิบูลสุข

28-31
มีนาคม 2566