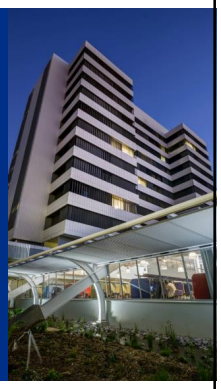
SARF RIDING QUALITY COURSE



5 November 2015

Contents

- **8:30 to 9:00**
  Introduction to road riding quality
  Definitions and concepts involved in riding quality
- 9:00 to 10:00
  Measuring riding quality
- 10:30 to 12:30
  Analysing riding quality data
- 13:30 to 15:00
  Interpreting riding quality data
  Riding quality and Vehicle-Pavement Interaction
- 15:30 to 16:30
  Effects of riding quality on road users and costs

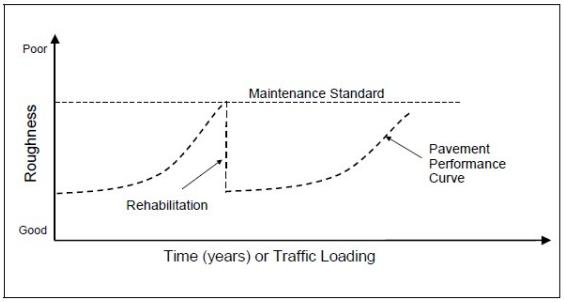
Introduction to road riding quality

- Why
- Short history
- Course materials
- Supporting materials

Why?

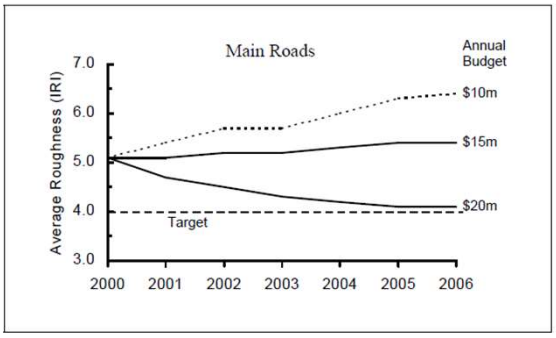
Road Roughness / Riding Quality similar to blood pressure or fever – indicating overall health of the road

6



Concept of Life-cycle analysis

7



Effect of funding levels on road network performance

8

What Is Road Roughness?

- "The deviations of a pavement surface from a true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads, and drainage, for example, longitudinal profile, transverse profile, and cross slope "
- Roughness involves variation in surface elevation that induces vibrations in traversing vehicles
- Roughness is defined over an interval of profile
- Different types of roughness are associated with different wavelengths

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Short history

- Early 1980s
  - highway engineering community identified road roughness as primary indicator of the utility of a highway network to road users
  - Existing methods used to characterize roughness were not reproducible by different agencies using different measuring equipment and methods
- US National Cooperative Highway Research Program (NCHRP) and World Bank initiated research project
  - help state agencies improve their use of roughness measuring equipment
  - how to compare or convert data obtained from different countries
  - most equipment in use could produce useful roughness measures on a single scale if methods were standardized
  - roughness scale defined and tested - International Roughness Index

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Rating scales

- Numerous scales available
- Pavement Serviceability Rating / Index (PSI)
  - 1 to 5: 1 imperfect, 5 perfect
  - Factors affecting PSI – rut, uneveness, cracking
- Quarter-Car Index
- Half-car Index
- Ride number
- TRRI (Truck Road Roughness Index)
- HATI (Heavy Articulated Truck Index)
- International Roughness Index (IRI)
  - Range: 0 to 20+
  - 0 perfect, upper scales undriveable

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Profile Indices

- Profile measurement
  - series of numbers representing elevation relative to some reference
  - thousands of numbers per km of measured profile
- Profile index
  - summary number calculated from numbers that make up profile
  - details of calculation determine significance and meaning of index
  - number might be related to
    - motion of mathematical vehicle model
    - summary of grinding requirements
    - index used in the past
    - abstract concept of roughness

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Profile Indices

- Calculated index only valid if profile data are valid
- Portable and reproducible
- Stable with time

- Calculated with a basic 4-step method
  - How many profiles are needed to capture surface conditions of interest?
  - How is profile filtered?
  - How is filtered profile accumulated (and reduced)
  - How is summary number scaled?

Statistics

Present Serviceability Rating (PSR)

- Engineers attempted to estimate general opinion of traveling public of specific roadways
- Most direct method - drive people over sections of road and ask them what they think
- Reflect opinions and are subjective
- Reflects
  - condition of the road
  - panel's standards, beliefs, and mood at time opinion is given
- Usually go from 0 to 5
- Ratings from original AASHO test – PSR
- Predictions of PSR – PSI

Present Serviceability Rating (PSR)

- "The judgment of an observer as to the current ability of a pavement to serve the traffic it is meant to serve"

- $PSI = 5.03 - 1.91 \log(1+SV) - 1.38\, RO^2 - 0.01\,(c+p)^{0.5}$

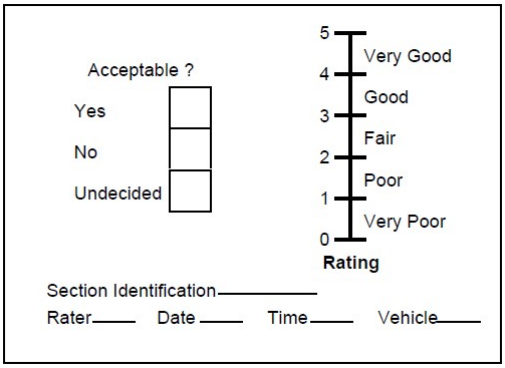
  Where

  SV – slope variance

  RO – average rut depth in inches

  c – cracking (per 1 000 ft^2)

  p – patching (per 1 000 ft^2)



Ride Number

- Profile index intended to indicate rideability on a scale similar to PSI
- Studies - determine how features in road profiles were linked to subjective opinion about the road from members of the public
- Profile-based analyses developed to predict Mean Panel Rating (MPR)
- PSD functions calculated for two longitudinal profiles and reduced to provide a summary statistic called PI (profile index)
- PI values for two profiles combined in nonlinear transform to obtain an estimate of MPR
- Ride Number (RN) - estimate of MPR

International Roughness Index (IRI)

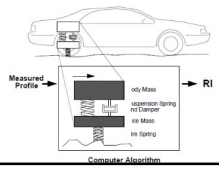
- IRI filter based on mathematical model called a quarter-car
- Calculates suspension deflection of simulated mechanical system with response similar to passenger car
- Simulated suspension motion accumulated and divided by distance travelled
- Index with units of slope [m/km]
- Essentially a computer-based "virtual response-type system"

International Roughness Index (IRI)

- Reproducible, portable, and stable with time
- General pavement condition indicator
- Describes profile roughness that causes vehicle vibrations
- Influenced by wavelengths ranging from 1.2 to 30 meters
- Linearly proportional to roughness
- Calculated for a single profile
- IRI very highly correlated to three vehicle response variables of interest:
  - road meter response (for historical continuity)
  - vertical passenger acceleration (for ride quality)
  - tire load (for vehicle controllability and safety)

International Roughness Index (IRI)

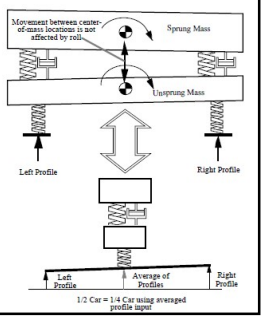
- Quarter-car model
  - model of one corner (a quarter) of a car
  - one tire (represented with a vertical spring)
  - mass of axle supported by tire
  - suspension spring and damper
  - mass of body supported by
  - suspension for tire



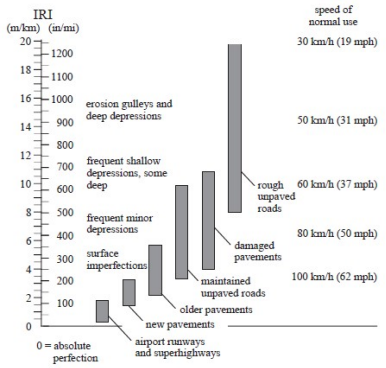
21

Half-car and Quarter-car Indices

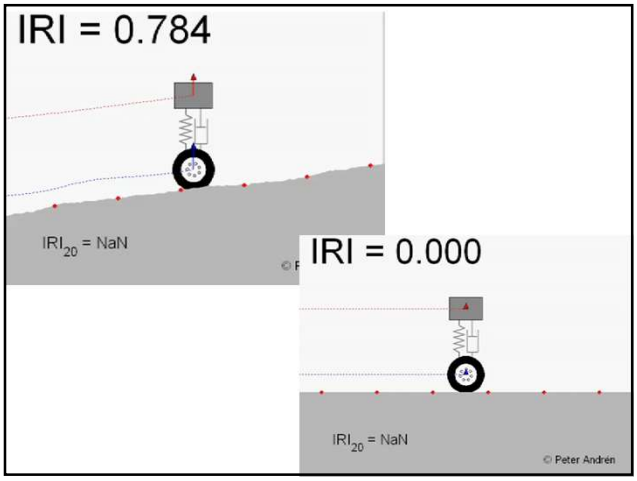
- Half-car roughness Index
  - Model of half car
- Quarter car roughness
  - Model of quarter car
  - Used in IRI analysis



22



23



Summary of Measurement Devices

Data Collection Device	Principle of Measurement	Relative Initial Cost	Relative Data Collection Cost (Network)	Relative Degree of Accuracy	Extent of Current Use	Projected Extent of Use
Dipstick	Direct Differential Measurement	Low	Impractical	Very High	Limited, Used for Calibration	Same as Current Use
Profilographs	Direct Profile Recordation	Low	Impractical	Medium	Extensive for Const. Acceptance	Same as Current Use
BPR Roughometer	Device Response	Low	Low	Medium	Limited	None
Mays Meter	Vehicle Response	Low	Low	Medium	Extensive	Decreasing Continuously
Non-Contact Profiling Device	Direct Profile Recordation	High	Medium	Very High	Medium	Increasing Continuously

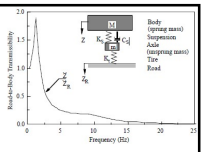
Course materials and supporting materials

- Course materials
  - These notes
- Supporting materials
  - Little book of profiling (www.umtri.umich.edu/content/LittleBook98R.pdf)
  - Guidelines for Network Level Measurement of Road Roughness. Version 1.1. July 2007. FJ Jooste. COTO
  - State of Logistics (www.csir.co.za/sol)
  - Proval (www.roadprofile.com)
  - Youtube
  - Various papers
  - HDMIV

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Definitions and concepts involved in riding quality

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA



- Road roughness dominant source of vibration on motor vehicle
- Suspension isolate rider from severe acceleration inputs of road
- Suspension supporting body and compliance in tire help to isolate body from high frequency road excitation
  - At very low frequency
    - body moves up and down exactly as the ground
  - At around 1 Hz
    - body resonates on suspension, amplifying input from road by factor 1.5 to 3.0 for typical cars
  - At higher frequencies
    - suspension absorbs road inputs, isolating body from road
  - At around 10 to 15 Hz
    - wheel resonates, bouncing up and down with motions larger than provided by road

Concepts

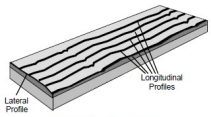
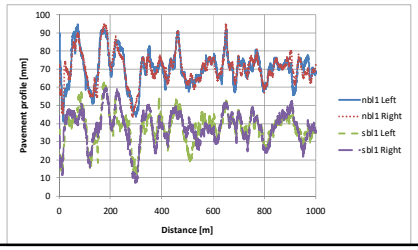


Figure 25. Profiles in a pavement.

- Road profile
  - Longitudinal and transverse
  - Profile and ride quality / comfort



Concepts

New

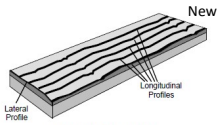


Figure 25. Profiles in a pavement.

PIARC SPECIFICATION OF FREQUENCY RANGES FOR ROAD SURFACE CHARACTERISTICS

Surface Characteristic	Frequency Range	
	Wave Length	Wave Number (cycle/m)
Microtexture	< 0.5 mm	> 2,000
Macrotexture	0.5 - 50 mm	20 - 2,000
Megatexture	50 - 500 mm	2 - 20
Roughness	0.5 - 50 m	0.02 - 2

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Terminology / Glossary

- Calibration: Process of determining relationship between output of a measuring device and value of the input quantity.
- DGPS: Differential Global Positioning System. A system that uses a network of fixed ground based reference stations to broadcast the difference between the positions indicated by the GPS satellite systems and the known fixed positions
- Dipstick: Commonly used term for the slow moving profiling device named the Face DipstickTM
- Filter: A mathematical function used to process a measured profile, normally with the objective of removing certain wavelengths from the profile. The moving average is an example of a simple filter.
- GPS: Global Positioning System.
- HRI: Half Car Index. A roughness index calculated by means of the IRI transform, but using the point-by-point average of the two profiles measured in both wheelpaths. The HRI is always lower than the IRI.
- IRI: International Roughness Index. A roughness parameter determined from a measured road profile in a single wheeltrack. In the IRI calculation, the measured profile is processed using a mathematical transform which filters and cumulates the wavelengths encountered in the profile.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Terminology / Glossary

- LDI: Linear Displacement Integrator. A response type device manufactured in South Africa.
- Profilometer: A mobile device used for measuring the longitudinal profile of a road. The measured profile may or may not be the true road profile, depending on the wavelengths that have been filtered out of the measured profile. High speed profilometers are capable of measuring at normal road speeds. Static profilometers operate at walking speeds or slower.
- Repeatability: The expected standard deviation of measures obtained in repeated tests, when using the same instrument and measurement team on a single, randomly selected test section.
- Reproducibility: A measure of the ability to reproduce a measured result (such as the IRI measured over a 100 m segment of road) by another measurement device or measurement team working independently.
- Resolution: The resolution of a device specifies the smallest measurement increment that the device is capable of.
- Riding Quality: Term used to describe the relative degree of comfort or discomfort a road user experiences when using a road. The terms riding quality and roughness are often used interchangeably. In these guidelines, the term roughness is preferred.
- Roughness: Term used to describe the relative degree of comfort or discomfort a road user experiences when using a road.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Terminology / Glossary

- True Profile: The actual profile of the road, relative to a fixed reference point, without any filtering out of certain wavelengths.
- Validation: The process of determining if a measurement device, when operated according to a established procedure and within established operating ranges, can operate effectively and reproducibly.
- Verification: The process of proving or disproving the correctness of a system or measurement device with respect to a certain formal specification.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA