METODS OF MEASURING DISTRESS

The pavement performance is largely defined by evaluation in the following categories:

Roughness

Surface distress

Skid resistance

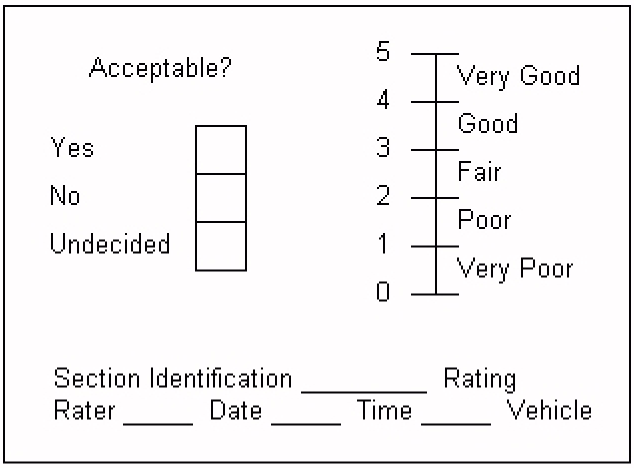
Structural evaluation – Deflection

ROUGHNESS

Pavement roughness is generally defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle (and thus the user). Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle delay costs, fuel consumption and maintenance costs.

Subjective measurement of Roughness

Pavement Roughness can be measured subjectively or objectively. In subjective measurement, a set of road users can be asked to rate the riding quality on a 0-5 scale as shown below.



Present Serviceability Rating (as suggested by AASHTO on a scale of 0-5) can be worked out from these subjective ratings.

Objective Measurement of Roughness

In the objective measurement, the roughness is indicated in terms of cumulative measure of vertical displacements as recorded by a recording wheel due to the unevenness in the longitudinal profile of the road. This cumulative measure of ups and downs in road profile is termed as roughness index or unevenness index and is normally represented in m/km or mm/km.

Roughness Measurement Equipment

Following are the methods/equipment that can be used for computing roughness index.

Rod and level survey A survey can provide an accurate measurement of the pavement profile. The use of surveys for large projects, however, is impractical and cost prohibitive.

Dipstick profiler This instrument can record the pavement profile measurement very accurately. The device records 10 to 15 readings per minute. Software analysis provides a profile accurate to ± 0.127 mm. However, measurements by dipstic are time consuming and therefore, it is commonly used to measure a profile for calibration of more complex instruments.

Profilographs Profilographs have a sensing wheel, mounted to provide for free vertical movement at the center of the frame. The deviation against a reference plane, established from the profilograph frame, is recorded on graph paper from the motion of the sensing wheel. Profilographs can detect very slight surface deviations or undulations up to about 6 m in length. However, they are not practical for network condition surveys due to slow speed.

Response type road roughness meters (RTRRMs) These instruments provide indirect measure of longitudinal road profile. The RTRRMs measure the relative movement between the body of the automobile and the centre of the rear axle. The RTRRM measurements are sensitive to the type of tyre, tyre pressure, load, vehicle suspension system, speed of vehicle, etc. Because of such sensitivity they need to be calibrated when any of the above factors change significantly. The CRRI's fifth wheel bump integrator that is normally used in India also falls in this category. The advantage of these RTRRMs is that they can record the road roughness at speeds up to 80 km/hr. Since no to RTRRMs are exactly alike, it is necessary to convert the measures (unevenness index) to a standard common international scale.

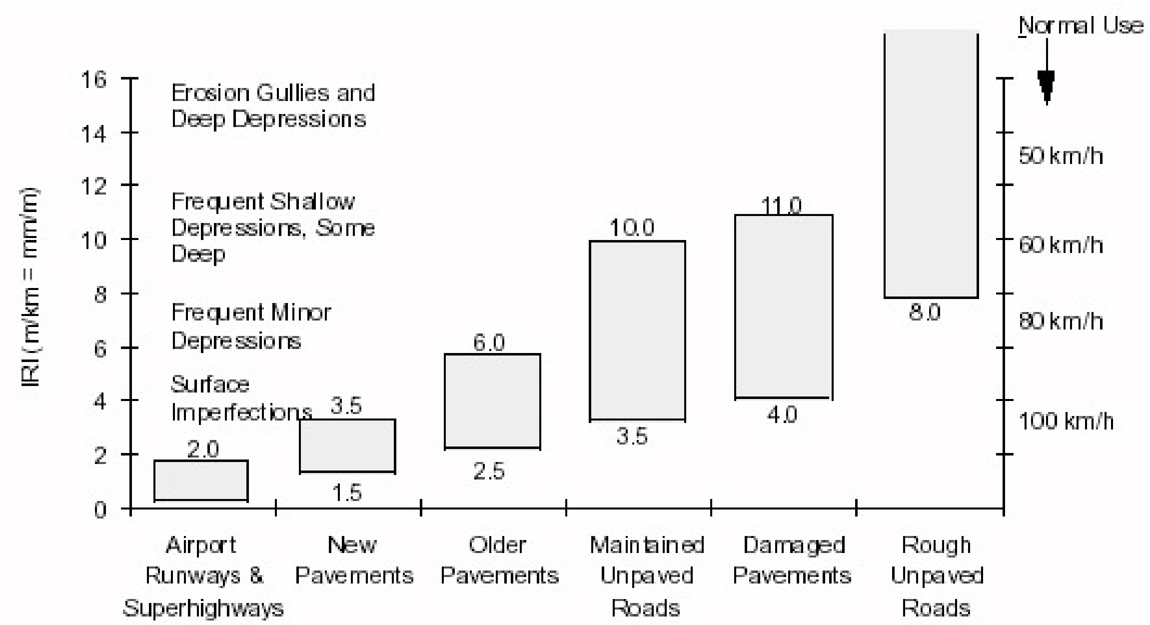
To provide a common quantitative basis on which the different measures of roughness can be compared, the **International Roughness Index** (IRI) was developed by World Bank. The IRI summarises the longitudinal surface profile in the wheel path and is computed from surface elevation data collected by either topographic survey or a mechanical profilometer or a dipstick. IRI is reported in units of m/km.

All the RTRRMs need to be calibrated by measuring the unevenness of a standard stretch for which IRI values are known.

Profiling devices These devices very accurately can establish the longitudinal profile of a pavement by either using contact or non-contact sensor systems. The non-contact systems use laser/ultrasonic devices for mapping the road profile. These profilometers are expensive and are normally used to calibrate RTRRMs.

Range of Roughness Values

The following figure shows the range of IRI values for different pavements and the corresponding speeds.



There are several correlations between PSR and IRI. One of the correlations is presented here.

$$PSR = 5e^{-0.26(IRI)}$$

where,

PSR = present serviceability rating

IRI = international roughness index

Indian Practice

In India the roughness is measured using fifth wheel bump integrator (developed by CRRI) and is reported as Unevenness Index (UI) in mm/km. For arriving at IRI from UI values the bump integrator needs to be calibrated for specific set of parameters using dipstick profiler. A typical relationship between IRI (m/km) and UI (mm/km) is given as

$$IRI = UI / 720$$

SURFACE DISTRESS

Surface distress is any indication of poor or unfavorable pavement performance or signs of impending failure. The general surface distresses can be grouped under the following three broad groups. The distresses under each of the groups are also mentioned along with the unit of measurement in parentheses.

- Fracture – Cracking (% area cracked)
- Distortion - localized settlements and depression (depth in mm), rutting (rut depth in mm) and shoving
- Disintegration - raveling, stripping, potholes and patching (% effected area or no of pot holes per km length)

Surface distress is related to roughness (the more cracks, distortion and disintegration - the rougher the pavement will be) as well as structural integrity (surface distress can be a sign of impending or current structural problems).

Measures of distress can be either subjective or objective. A simple example of a subjective measurement may be rating of each type of defect based on visual inspection on a scale of 0-5 as Very Poor, Poor, Fair, Good and Very Good as in PSR.

Objective measurements, which are generally more expensive to obtain, use different types of automated distress detection equipment.

Older techniques, used teams of individuals who drove across every km of pavement to be measured. The measurements were made using simple instruments and by visual estimation. The rut depths were measured using straight edge and the area of cracking, patching, raveling, etc were visually estimated. Based on the objective measurements the Present Serviceability Index (PSI) could be obtained using the AASHTO equation.

Current methods record pavement surface distresses using video imaging using a specially equipped van that is fitted with high-resolution cameras. The van can travel at the usual highway speeds. Evaluation is either done manually by playing the video back on specially designed workstations while trained crews rate the recorded road surface or automatically by computer image processing software. In more advanced Integrated Pavement Analysis Units, in addition to high resolution video cameras, other instruments such as non-contact (laser) profilometers for mapping longitudinal as well as transverse pavement profile, distance measuring instrument and computer workstations for processing the data are fitted. Automatic Road Analyser and Laser Road Surface Tester fall in this category.

Using Integrated Pavement Analysis Units one can obtain the following measurements.

- Roughness
- Distress (cracking, rut depth)
- Gradients, camber, curvature
- Pavement texture

The rating suggested by IRC in its guidelines for maintenance management of primary, secondary and urban roads is given in the following table.

Pavement Condition Rating Based on Different Types of Defects

Defects	Range of Distress				
Cracking (%)	>30	21 to 30	11 to 20	5 to 10	<5
Ravelling (%)	>30	11 to 30	6 to 10	1 to 5	0
Pothole (%)	>1	0.6 to 1.0	0.1 to 0.5	0.10	0
Shoving (%)	>1	0.6 to 1.0	0.1 to 0.5	0.10	0
Patch (%)	>30	16 to 30	6 to 15	2 to 5	<2
Settlement and depression (%)	>5	3 to 5	Up to 2	Up to 1	0
Rutting (mm)	>50	21 to 50	11 to 20	5 to 10	<5
Rating	1	2	3	4	5
Condition	Very Poor	Poor	Fair	Good	Very Good

(Source: Guidelines for Maintenance Management of Primary, Secondary and Urban Roads, IRC, 2004)

SKID RESISTANCE

Skid resistance is the force developed when a tyre that is prevented from rotating slides along the pavement surface (Highway Research Board, 1972). Skid resistance is an important pavement evaluation parameter because inadequate skid resistance will lead to higher incidences of skid related accidents. Skid resistance depends on pavement surface texture. Skid resistance changes over time. Typically it increases in the first two years following construction as the roadway is worn away by traffic and rough aggregate surfaces become exposed, then decreases over the remaining pavement life as aggregates become more polished.

Skid resistance is generally quantified using some form of friction measurement such as a friction factor or skid number.

Friction factor (like a coefficient of friction): $f = F/L$

Skid number: SN = 100(f)

where:

F = frictional resistance to motion in plane of interface

L = load perpendicular to interface

Measurement Techniques

- Portable Pendulum Skid tester
- The locked wheel tester
- The spin up tester
- Pavement surface texture measurement

Portable Pendulum Skid tester it is a dynamic pendulum impact type tester for measuring the resistance offered by a surface under test. It is used for measuring spot values of surface friction at representative locations. Though, it provides good information on the skid resistance of the pavement, it cannot provide data with different speeds.

The locked wheel tester This method uses a locked wheel skidding along the tested surface to measure friction resistance. It is possible to measure skid resistance at different speeds in this method.

The spin up tester A spin up tester has the same basic setup as a locked wheel tester but operates in an opposite manner. For a spin up tester, the vehicle (or trailer) is brought to the desired testing speed (typically 64 km/hr) and a locked test wheel is lowered to the pavement surface. The test wheel braking system is then released and the test wheel is allowed to "spin up" to normal traveling speed due to its contact with the pavement. The friction force can be computed by knowing the test wheel's moment of inertia and its rotational acceleration. This avoids the use of costly force measuring equipment.

Pavement surface texture measurement In this method the pavement skid resistance is correlated with the pavement macrotexture. By measuring the pavement texture and using the established correlation between the macrotexture and the skid resistance, the skid resistance is obtained.

DEFLECTION

Pavement surface deflection measurements are the primary means of evaluating a flexible pavement structure. Although other measurements can be made that reflect (to some degree) a pavement's structural condition, surface deflection is an important pavement evaluation method because the magnitude and shape of pavement deflection is a function of traffic (type and volume), pavement structural section, temperature affecting the pavement structure and moisture affecting the pavement structure. Deflection measurements can be used in backcalculation methods to determine pavement structural layer stiffness and the subgrade resilient modulus. Furthermore, pavement deflection measurements are non-destructive destructive in nature which adds on to the overall viability of usage.

Measurement Technique

The pavement surface deflections can be measured using either static deflection equipment or impact load deflection devices. Static deflection equipment measure pavement deflection in response to a static load. Benkelman Beam falls in this category. Impact load devices deliver a transient impulse load to the pavement surface. The subsequent pavement response (deflection basin) is measured by a series of sensors. The most common type of equipment is the falling weight deflectometer (FWD).

Benkelman Beam is a simple device that operates on the lever arm principle. The Benkelman Beam is used with a loaded truck - typically 80 kN on a single axle with dual tires inflated to 480 to 550 kPa. Measurement is made by placing the tip of the beam between the dual tires and measuring the pavement surface rebound as the truck is moved away. The Benkelman Beam is low cost but is also slow, labor intensive and does not provide a deflection basin. The procedure of measuring rebound deflection and finding the characteristic deflection using Benkelman Beam is documented in the following standard.

IRC:81-1997 Guidelines for strengthening of flexible road pavements using Benkelman Beam deflection technique.

Using the above standard one can design the overlays after arriving at the pavement characteristic rebound deflection.

Falling Weight Deflectometer (FWD) is an impact load device that delivers a transient impulse load to the pavement surface and the resulting pavement response (deflection basin) is measured by a series of sensors (geophones). Vertical deflection of the pavement in multiple locations is recorded by the geophones, which provides a more complete characterization of pavement deflection. The area of pavement deflection under and near the load application is collectively known as the "deflection basin". One of the advantages of FWD is that multiple tests can be performed on the same location using different weight drop heights. The advantage of FWD over BB is that it is quicker, the impact load can be easily varied and it more accurately simulates the standard loading of trucks, both with respect to time of application of the load as well as the magnitude of the load. Therefore, using FWD deflection data one can characterize the existing pavement layers in terms of their layer modulii using backcalculation procedures with the help of mechanistic structural models.

Once the pavement layers are characterised in terms of their present resilient modulii, overlays can be designed using mechanistic procedures.

The characteristics of important equipment for the pavement performance evaluation is documented in “Guidelines for Maintenance Management of Primary, Secondary and Urban Roads,” IRC, 2004. The same is provided in Table 12-A.1.

Table 12-A.1 Important Characteristics of Recommended Equipment for Data collection

Name of Equipment	Principal of Operation	Output	Operating Speed	Multiple Measurement	Merits	Limitations	Recommendations
Benkelman Beam	Elastic deflection under static load	Rebound deflection at single point under load	Crawling	NA	Simple, quick, cheap	Single point deflection	Can be used for routine overlay requirements for all categories of roads
Falling Weight Deflectometer	Elastic deflection under impulse load	Deflection basin	200-300 stations per day	NA	Easy to operate relatively fast, complete deflection profile is measured	Expensive	Recommended for use on primary / secondary road network
Loadman	Elastic deflection under impulse load	Single point deflection	80-100 stations per day	NA	Simple, portable	Single point deflection	Recommended on thin pavements with smooth surfaces subject to good correlations with already established methods
Automatic Road Analyser (ARAN)	Continued images one forward and two straight down	Video tapes	30-100 kmph	Distress (Crack rut depth) profile, roughness, gradients, curveture, etc	Covers about 600 km a day with good accuracy	Expensive, dry surface measurements, processing is manual	Recommended for use on primary / secondary road network with dry surface
Laser Road Surface Tester (LRST)	Measures slope profile in the time domain	Distress unevenness IRI long, profile	Upto 90 kmph	Distress rut depth, profile, macro texture	Suitable for all weather condition	Calibration needed daily for laser and accelerometer	Recommended for all categories of roads

Table 12-A.1 Contd.

Towed fifth wheel bump integrator/vehicle mounted bump integrator	Response type measurement	Unevenness index	30 kmph	NA	Simple, Reliable data collection	Can not measure profile needs frequent calibration	Recommended for all categories of roads
DIPSTICK	Measures vertical profile by slope measurements	International roughness index(IRI)	Slow walking	NA	Measures true profile	Very slow	Recommended for more accurate surface profile measurements and for calibration of response type equipments(towed / vehicle mounted bump integrators)
British Pendulum Skid Tester	Measures lateral friction by swing action	Skid resistance	Very slow	NA	Simple, portable	Noting and recording manual spots measurements only	Recommended for all categories of roads
Mu Meter	Measures side force coefficient	Friction value	Upto 150 kmph	NA	Requires little traffic control	Ineffective in winter, sharp curves and steepgrades	Recommended for primary roads
Static Weigh Pads	Load measured through load cells/load bars	Static loads	Normal	NA	Any traffic conditions	Vehicles need to be stopped and aligned	Recommended for medium and low traffic loads
Weigh-In-Motion	Piezo electric sensors and capacitor type sensor	Weights of moving vehicles	Normal	Speed, vehicle type	Traffic is not interrupted during studies	Proper calibration checks are required	Recommended for primary / secondary roads with smooth surfaces, steel rimed tyres should be avoided
Instrumented Car	Mesurement of upgrade downgrade and directional change of vehicle	Cumulative rise/fall curvature	32 kmph	Unevenness, gradients, curves	Capturing of more parameters in single run	Low speed, sudden jerks adversely effect the	Recommended for all categories of roads