DEPARTMENT OF CIVIL ENGINEERING

MAULANA AZAD NATIONAL INSTITUTE OF TECHNOLOGY, BHOPAL

LAB MANUAL

TRF 523
PAVEMENT DESIGN & EVALUATION LABORATORY

Program- M.Tech

Transportation Engineering - II Semester

CONTENTS

LIGHT WEIGHT DEFLECTOMETER

Aim: Determination of dynamic deflection modulus using light weight Deflectometer.

Apparatus Required:

Light Weight Deflectometer
GPS Device
Printing Device

IS Standards used: IRC:117-2014, ASTM E2583-07(2020).

Theory:

Light Weight Deflectometer (LWD) is a type of dynamic plate load test, used in earthworks and traffic route construction. It determines the bearing capacity of soil, degree of compaction of soils and non-cemented base course and assists in soil improvement (HMP LFG Manual, Germany). For this study we are using LWD having load plate diameter is 300mm and weight of drop weight is 10 kg while total weight is 15 kg. LWD can be divided into three groups.

1. Loading Mechanism
2. Load Plate
3. Electronic Settlement measuring instrument.

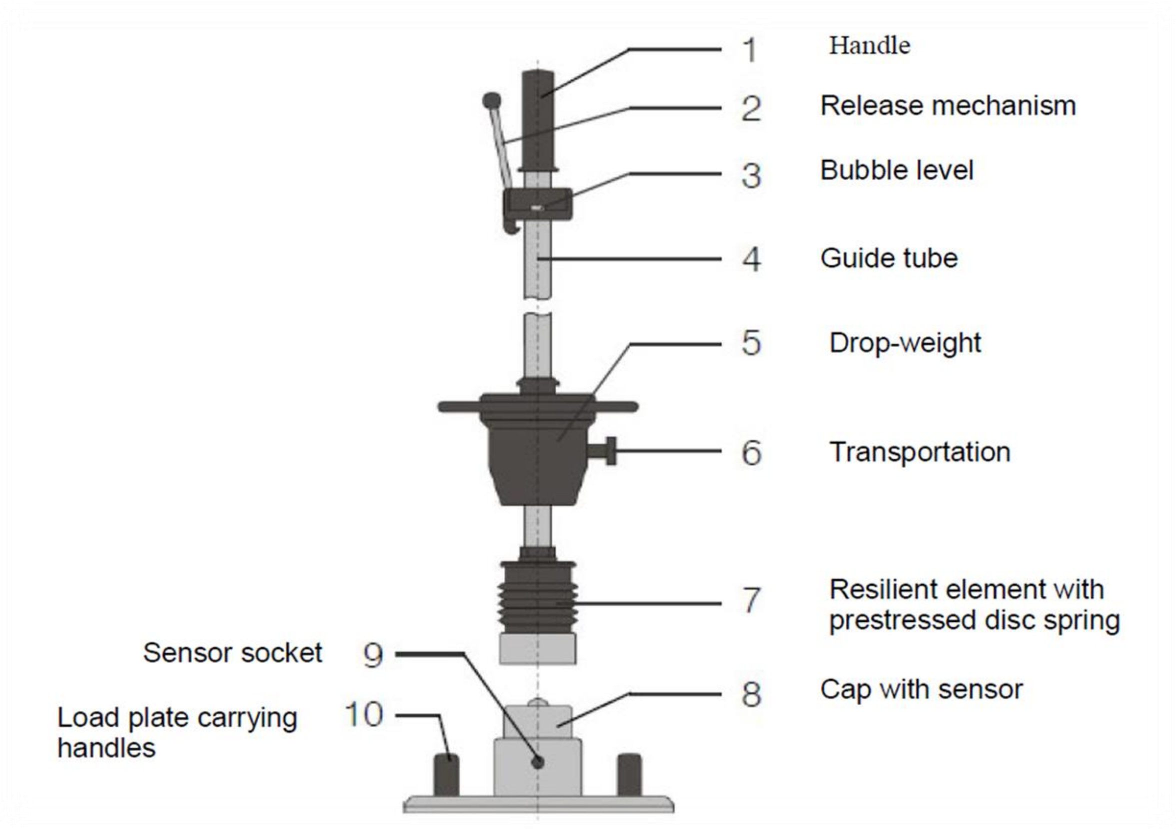

Fig. 1 Configuration of LWD

Pre compaction is necessary before running the test. To get the deflection value, first of all, put the load plate on the testing ground. Connect the loading mechanism and the measuring cable onto the load plate. The guide tube and bubble level help to keep the shaft vertical. Next along the shaft is a release mechanism, which holds the mass in place prior to dropping, thereby, ensuring a standard drop height. The mass is dropped to provide an impact force. Buffers, made of either rubber pads or steel springs, catch the falling mass and transfer the impact force to the loading plate. Below this measurement device is connected with cable that measures the deflection value in mm, deflection modulus, settlement versus velocity ratio, and settlement curve. Impact load imposed to the plate are measured by a load cell and a geophone sensor mounted at the bottom of the plate measures the resulting deflection.

The measured center deflection is used to estimate the dynamic deformation modulus as follows:

$$E_{vd} = \frac{2 * (1 - \mu 2) * \sigma}{\delta}$$

Where,

E_{vd} = LWD dynamic modulus

μ = Poisson's Ratio

σ = Stress under load

δ = Deflection in mm

Deflection (mm)	E-modulus (MPa)	Pavement Quality	Action Required
0.0 - 0.5	1000 - 2000	Excellent / Very Good	No action required
0.5 - 1.0	600 - 1000	Good	Routine maintenance may be required
1.0 - 2.0	300 - 600	Fair	Further investigation recommended
2.0 - 3.0	100 - 300	Poor	Urgent repair or rehabilitation needed
> 3.0	< 100	Very Poor	Immediate remedial work required

Procedure:

- First, place the loading device on magnetic stand.
- Position the magnetic plate with full contact on the soil to be tested. Afterwards position the loading device on loading plate.
- Connect the mechanical and electronic systems with the measuring cable.
- Switch ON the device and check the displayed status. If OK then ready to go.
- Now the weight can be freely moved.

- Fully pullup the weight until it engages. Now follow the instructions on the display.
- Press the release. The weight falls and springs back. Catch it at the handle. Carry out 3 Impacts. These are pre-loading impacts.
- Afterwards 3 measuring impacts are performed.
- Lay down the falling weight. Press OK. The ZFG automatically determines the value for Evd Deflection modulus.
- All measuring results are internally saved and can be printed immediately if required.

Observation:

Deflection after 1st Pulse, S_1 = ………..mm

Deflection after 2nd Pulse, S_2 = ………..mm

Deflection after 3rd Pulse, S_3 = ………..mm

Mean Value of Deflection, S_m = ………mm

S/v = ………. Degree of compatibility, which gives information about whether the existing soil can be compacted further or not.

Evd =………… Dynamic deflection modulus in MN/m^2

Limitations

1. To get the GPS data on the test location GPS signal must be displayed on status line.
2. Drop height should be determined for the drop weight by calibration. Re calibration on drop height is required at least annually and after any repair
3. In this LWD lithium polymer battery pack is used which must be charged when battery condition is equal or lower than 15%.
4. The readiness for measurement only insists after acoustic signal. The weight is allowed to drop within 6 seconds after the acoustic signal.
5. Failure to catch the rebounding drop-weight will produce undesired result.
6. Sensor could be damaged, if the load plate immersed in water.

DYNAMIC CONE PENETROMETER TEST

Objective: Determination of Dynamic Cone Penetrometer test.

Apparatus:

Handle

Hammer

Upper Shaft

Anvil

Lower Shaft

Cone

IS Standards used: IS : 4968 (Part II) 1976; ASTM D 6951

Theory: IS : 4968 (Part II) 1976; ASTM D 6951
The dynamic cone penetration test (DCPT) was originally developed as an alternative for evaluating the properties of flexible pavement or subgrade soils. The conventional approach to evaluate strength and stiffness properties of asphalt and subgrade soils involves a core sampling procedure and a complicated laboratory testing program such as resilient modulus, Marshall tests and others. Due to its economy and simplicity, better understanding of the DCPT results can reduce significantly the effort and cost involved in the evaluation of pavement and subgrade soils.

$$CBR = \frac{292}{\left(DPI^{1.12}\right)}$$

Where:
CBR = California Bearing Ratio
DPI = DCP Penetration Index

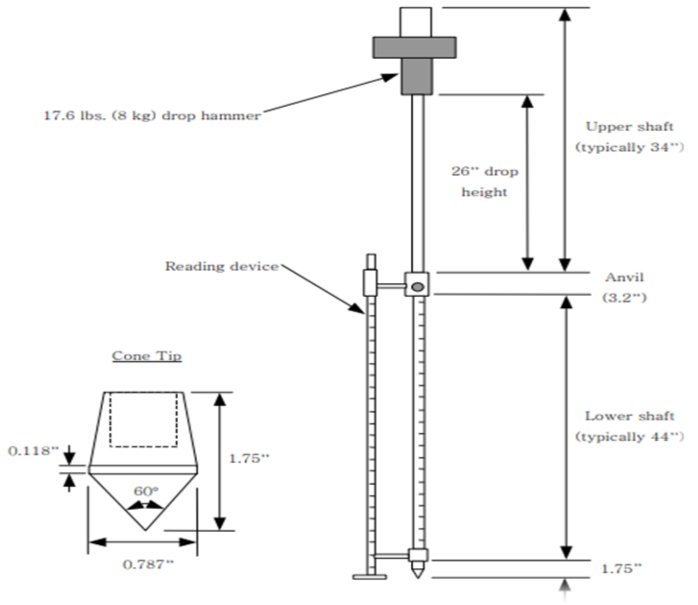

Fig. 2 Structure of Dynamic Cone Penetrometer

Figure 1 shows a typical configuration of the dynamic cone penetrometer (DCP). As shown in the figure, the DCP consists of upper and lower shafts. The upper shaft has an 8 kg (17.6 lb) drop hammer with a 575 mm (22.6 in) drop height and is attached to the lower shaft through the anvil. The lower shaft contains an anvil and a cone attached at the end of the shaft. The cone is replaceable and has a 60 degree cone angle. As a reading device, an additional rod is used as an attachment to the lower shaft with marks at every 5.1 mm (0.2 in).

Procedure

- Once the test apparatus is assembled the DCP is placed at the test location and the initial penetration of the rod is recorded to provide a zero scale.
- While holding the rod vertically, the weight is raised to the top of the rod 575 mm above the anvil.
- Drop the hammer to drive the hammer on the lower shaft through the underlying pavement layers.
- The penetration of the rod is measured after each drop.
- Plot a graph between Cumm. Blows vs Penetration.

Observation:

Location:

No. of Blows	Cum. Blows	Penetration(mm)	[a]Penetration per blow (mm)	[b]Hammer Factor	DCP index (a*b)	CBR %

Limitations:

- There will be considerable variation in the rate of penetration or the DCP values from spot to spot depending on the presence of relatively large stone particles beneath the cone.
- Penetration rates as low as 0.5 mm / blow are acceptable, but when there is no measurable penetration after 20 consecutive blows, it can be considered that the DCP will not penetrate the material.
- The DCP can be driven through surface dressing and thin bituminous surfacing layers, but it is recommended that thick layers bituminous surface and binder courses should be removed by core drilling, prior to starting the DCP test.
- It is generally recommended that the cone is replaced when the diameter of the cone is reduced by 10%. Typically, the cone will need replacement after about 15 tests in hard material.

BUMP INTEGRATOR

Aim: Determination of roughness using Bump Integrator

Apparatus Required:

Bump Integrator Trailer
Towing vehicle
Safety equipments like cones, warning signs.

IS Standards used: IRC: SP: 16-2004.

Theory:

A bump integrator is used to measure road roughness index by capturing the dynamic response of a vehicle moving at 32±1 km/h along a wheel path. The bump integrator sums the upward and downward movements of the axle relative to the chassis. The observer activates the main switch fitted on panel board at the beginning of the section and switch it off at the end of the section. The readings of the revolution counter and integrating counters are noted and entered in the data sheet. The bump integrator values are recorded when the wheel revolution counter records 460 units which correspond to 1 km.

Fig. 3 Fifth Wheel Bump Integrator

Procedure:

1. Tow the bump integrator at a constant speed of 32 ± 1 km/h over the test section.
2. Record the total vertical displacement (in mm) for the length of the road section .
3. From this Road Roughness Index(RI) is determined.

Road Roughness Index(RI):

- Roughness Index (RI)=Cumulative Vertical Displacement (mm)/ Test Length (km)
- The result is expressed in **mm/km**.

Calculation:

- The absolute values of displacements are summed to find the total vertical movement.
- This total is divided by the distance traveled, then multiplied by 1000 to convert the roughness to millimeters per kilometer (mm/km).

Assumption:

- Displacement data is sampled at regular intervals.
- The vehicle's speed and suspension characteristics are constant during measurement.
- The input distance is accurately measured.

Maximum Permissible Values of Roughness Index(mm/km) as per IRC Standards:

Serial Number	Type of Surface	Condition of Road Surface		
		Good	Average	Poor
1.	Surface Dressing	<3500	3500-4500	>4500
2.	Open Graded Premix Carpet	<3000	3000-4000	>4000
3.	Mix Seal Surfacing	<3000	3000-4000	>4000
4.	Semi- Dense Bituminous Concrete	<2500	2500-3500	>3500
5.	Bituminous Concrete	<2000	2000-3000	>3000
6.	Cement Concrete	<2200	2200-3000	>3000

Observations:

Track Section	Length(km)	Total Displacement(mm)	Roughness Index(mm/km)	Remarks
Section 1				
Section 2				
Section 3				

Results:

1. The total integrated displacement for the track was **______** mm.
2. The calculated roughness index for the track was **______** mm/km.
3. The track roughness can be classified as **(Good / Average / Poor)** based on IRC Standards.

Discussion:

Based on the experiment, the roughness index of the given track was found to be **______** mm/km. The surface roughness can be compared with standard values to assess the quality of the track. The experiment successfully demonstrated how a bump integrator quantifies roughness.

Limitations:

1. Sensitivity to speed.
2. Lack of Precision for Low Roughness Levels.
3. Dependency on Road and Tire Conditions.
4. Not suitable for High- Speed Applications.

SKID RESISTANCE TEST

Objective: To determine the Skid resistance for the pavement surface.

Apparatus:

Skid Resistance tester.

Ruler

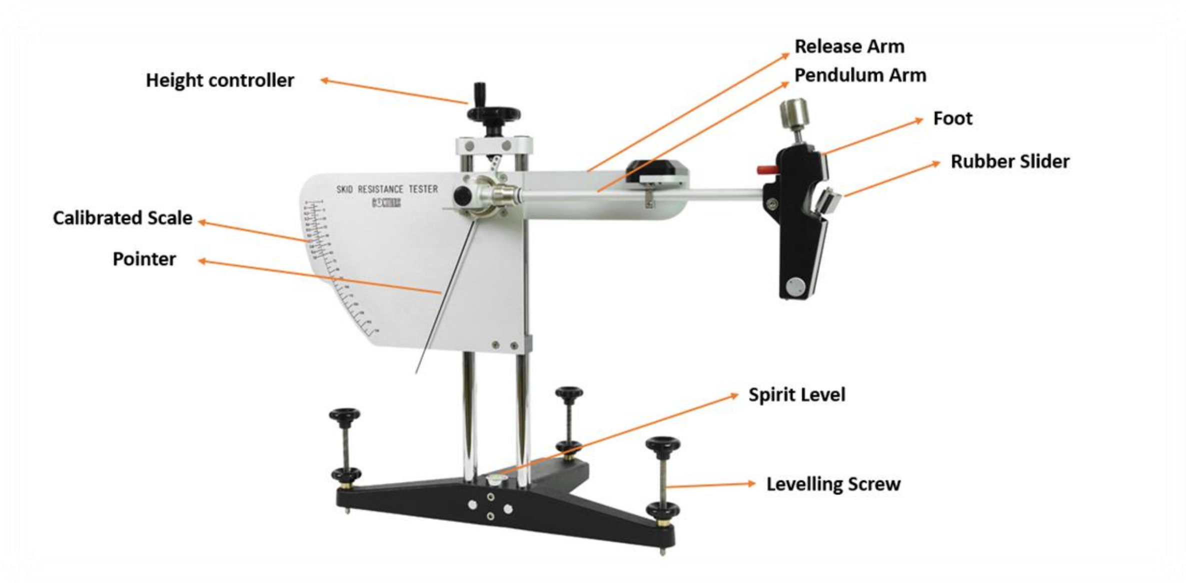

Fig. 4 British Pendulum tester

IS Standards used: IRC:82-2015.

Theory: IS 9103: 1999

This method describes the procedure for determining the frictional properties (skid resistance value) of a Pavement using Portable Skid Resistance Tester. The instrument gives a direct reading i.e. measure of the friction between skidding tire and the pavement surface in low-speed situation (< 50 km/hr). It provides the highway engineer with the practical means of obtaining reliable scientific evidence on which to take appropriate measures to reduce skidding.

Its value is denoted is denoted by BPN (British Pendulum Number) which gives the details of surface as:

BPN	Pavement Condition
45-55	OK Surface
55-65	Good
65<	Excellent

Procedure

- The skid resistance tester was setup; the centre Column is kept vertical (this is done by adjusting the three levelling screws at the base).
- Adjust the height of the pivot so that the arms swing freely through its arc without touching the road surface.
- Lower the pivot height so that the friction foot is in contact with the road surface over the precise distance (50mm) as shown by the scale rule placed alongside
- Raise the pendulum arm to the starting position and engage the retaining catch.
- Release the pendulum arm.
- Take and note the reading on the scale.
- Repeat the test to obtain a minimum of three readings.
- Now, water the road surface where the test is to be taken
- Again, repeat the test and obtain readings.

Observation:

Sl. No	BPN (Dry Pavement)	BPN (Wet Pavement)
1		
2		
3		
…		

Calculations:

Average BPN for Dry Pavement= $\frac{B1+B2+B3+\cdots\ldots\ldots+Bn}{n}$ =

Average BPN for wet Pavement= $\frac{b1+b2+b3+\cdots\ldots\ldots+bn}{n}$ =

Limitations:

- After it had swing through, catch the arm to prevent a back swing which could disturb the apparatus reading.
- Testing should be carried out in accordance with the relevant standard or guidelines.
- Wipe all flooring materials received for testing in the laboratory, with a clean, dry paper towel to remove all dust prior to testing.
- It is necessary that at the time of testing the flooring material is flat and securely fixed so as to avoid movement of the sample during testing.

BENKELMAN BEAM

Aim: Evaluation of flexible pavement using Benkelman beam deflection technique

Apparatus Required:

Benkelman Beam
Dial Gauge
Loading Vehicle
Measuring Tape

IS Standards used: IRC:81-1997.

Theory:

A Benkelman deflection technique manual outlines the procedure for measuring pavement deflection using a Benkelman beam, which involves placing the beam's tip between the dual tires of a loaded truck, and recording the pavement's rebound deflection as the vehicle moves forward, essentially assessing the structural integrity of the pavement by measuring how much it deflects under a known load; key steps include selecting test points, positioning the beam, adjusting the dial gauge, recording deflection readings, and ensuring proper tire pressure and vehicle weight are maintained throughout the test. .

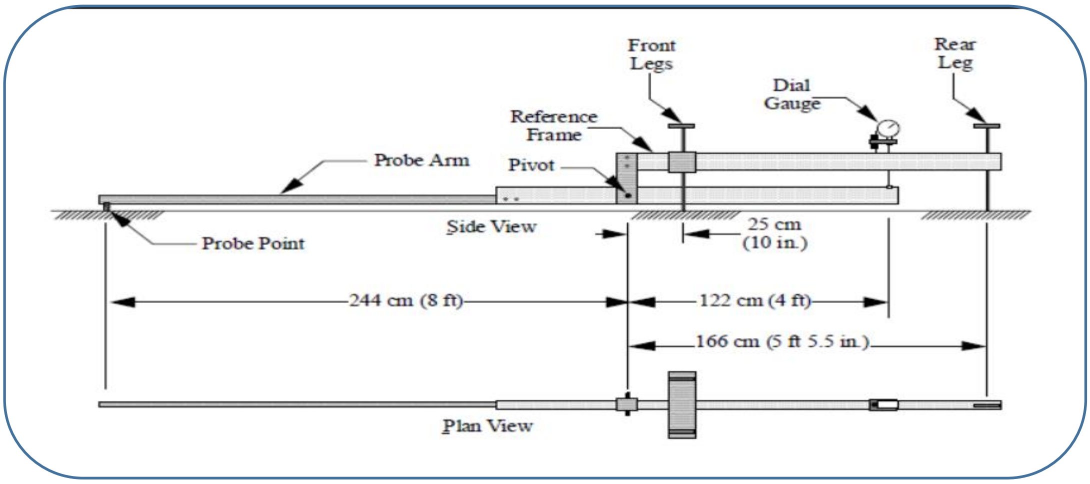

Fig. 5 Benkelman Beam

Procedure:

1. **Preparation**:

- Mark test points along the pavement at regular intervals of 50m
- Highest and lowest values of reading should be compared with the mean value .If It is more tha 1/3rd of mean value , extra measurement should be taken at 25m of that location.
- Ensure the pavement surface is clean and free from debris.

2. **Setting up the Benkelman Beam**:

- Place the probe of the Benkelman beam between the dual wheels of the loaded truck.
- Align the beam so the dial gauge rests firmly on the pavement surface.

3. **Measurement**:

- Drive the truck slowly over the test point, stopping when the rear axle is at the test location.
- Note the initial reading on the dial gauge.
- Move the truck forward so the axle is 2.7m away from the test point, and another at 9m away from 2.7m the difference in reading at 9m and 2.7m location gives the characteristic deflection.
- Record the final dial reading, which represents the rebound deflection.

4. **Repeat Measurements**

- Conduct at least three measurements at each test point to ensure accuracy.
- Record the pavement temperature during testing, as temperature affects deflection.

Corrections in measurements:

1. **Temperature Correction**

- If temperature>35°C then reduce deflection by 0.01*(Temperature-35).
- If temperature<35°C then reduce deflection by 0.01*(35-Temperature).

2. **Seasonal Variation**

- Depending upon the annual rainfall, type of subgrade and moisture content, a sample is taken and tested in lab and based on the seasonal correction factor graphs given in IRC 91 correction is applied.
- From this the corrected deflection value is obtained.

Pavement Condition Classification:

Classification	Pavement Condition
Good	No Cracking
	Rut depth less than 10m
Fair	No Cracking or Cracking confined to single crack
	Rut depth between 10mm to 20mm
Poor	Extensive Cracking
	Rut depth≥20mm

Observations:

Test Point	Initial Reading(mm)	Final Reading(mm)	Deflection(mm)	Corrected Deflection(mm)	Remarks
1					
2					
3					

Results:

1. The maximum deflection observed **______** mm.
2. The corrected deflection after temperature adjustments**______** mm.
3. Based on the deflection values, the pavement is classified as (**Good/ Fair/ Poor).**

Discussion

The deflection values obtained from the Benkelman Deflection Test indicate the structural integrity of the pavement. The results help in deciding whether maintenance or strengthening measures are required.

Limitations

1. Time Consuming
2. Traffic Disruptions
3. Influence of temperature and moisture
4. Limited to Flexible Pavements

WHEEL RUT SHAPER AND TESTER

Aim: Evaluation of rutting using wheel rut shaper and tester

Apparatus Required:

Wheel Rut Shaper and Tester
Loading Wheel
Measuring Tools
Heating Systems

Materials Required:

1. Asphalt concrete samples (slabs or compacted specimens).
2. Binder and aggregate mix as per specified design standards.

IS Standards used:

1. IS 12082(Part 1 and 2): 2022 for rutting of Bituminous mixes.
2. AASHTO T 324 for Hamburg Wheel- Track Testing

Theory:

Wheel Rut Shaper is used to prepare the bitumen specimen for wheel rut testing used in research and road construction. It compacts asphalt slabs to a target density in a size of 300x300x50 mm. The machine has a bearing car which has a mould for sample preparation loaded by rolling wheel vertically. The bearing car moves 300 mm in and out for homogenous compaction of specimen by rolling wheel. The rolling wheel is compacted thru pneumatic cylinder and has in built heater to heat up the specimen thru top cover of mould. The bearing car moves in and out on crank shaft, gear wheel with eccentric shaft mechanism. Automatically controlled compaction, Start and Emergency stop switches are provided in the machine.
Following are the main technical index of the machine-

- Radius of roller- 500 mm
- Width of roller- 300 mm
- Speed of velocity model- 6 times round trip/min
- Pressure of roller- within 20 kN
- Warm-up temperature- 20 to 200 degree

Wheel Rut Tester is used as to find out rut depth in bituminous concrete mix for different number of passes and for different temperatures under the loading similar to what the pavement surface is applied. Wheel rut tester with the reciprocating motion of loaded wheel on bituminous specimens determines the potential of asphalt pavement rutting. Following are the main technical index of Equipment-

- Pressure wheel speed: 42±1 time/min (single way)

• Moulds size: 300x300x50mm(standard),here the moulds height can be in a range between 30- 100mm
• Displacement measuring range: 0-30mm
• Displacement measuring precision: less than ±0.005mm

Fig.6 Wheel Rut Shaper

Fig.7 Wheel Rut Tester

Procedure:

Sample Preparation:

1. Prepare asphalt concrete specimens as per the required specifications (e.g., thickness, mix design).
2. Allow the specimens to cure for 24 hours before testing.
3. If temperature control is required, precondition the specimens in the testing chamber for 2 hours at the specified temperature.

Calibration:

1. Calibrate the Wheel Rut Shaper and Tester to ensure accurate load application.
2. Verify that the measuring system is functioning correctly.

Testing:

1. Place the prepared sample in the testing apparatus.
2. Set the load intensity, wheel speed, and test temperature as per the standard testing protocol.
3. Start the machine, allowing the loaded wheel to pass over the specimen repeatedly.
4. Record the rut depth at specified intervals (e.g., every 100 cycles or 5 minutes).
5. Continue the test until a pre-determined number of cycles or maximum rut depth is reached.

Observation:

1. Record initial sample dimensions.
2. Note test parameters – Load Intensity, Wheel Speed and Test Temperature
3. Record rut depth measurements at defined intervals.

Calculations:

1. Plot a graph of **Rut Depth (mm)** vs. **Number of Cycles**.
2. Determine the rate of rutting: Rutting rate (mm/cycle) = Total rut depth / Total number of cycles.
3. Calculate average rut depth from multiple specimens if required.

Result & Discussion:

1. Compare the rutting performance of tested specimens to standard thresholds.
2. Analyze the effect of variables (e.g., temperature, material composition) on rutting resistance.
3. Provide recommendations for improving pavement material design based on test results.

Limitations:

1. Performed in Laboratory, can not be performed in field conditions
2. Limited Load and Traffic Simulation.
3. Temperature Control Issues.
4. Does not consider Subgrade effects.