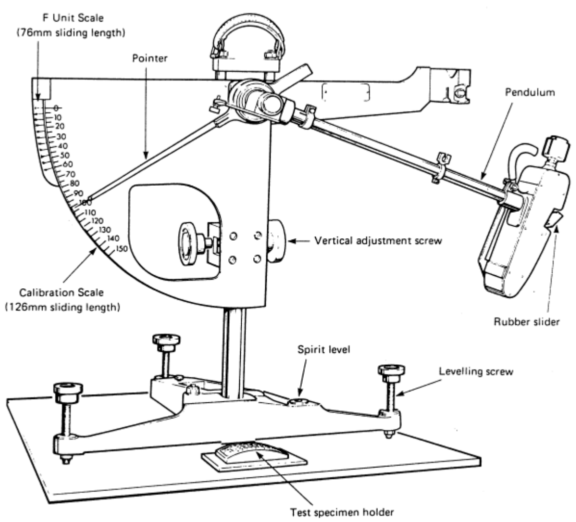
Skid Resistance

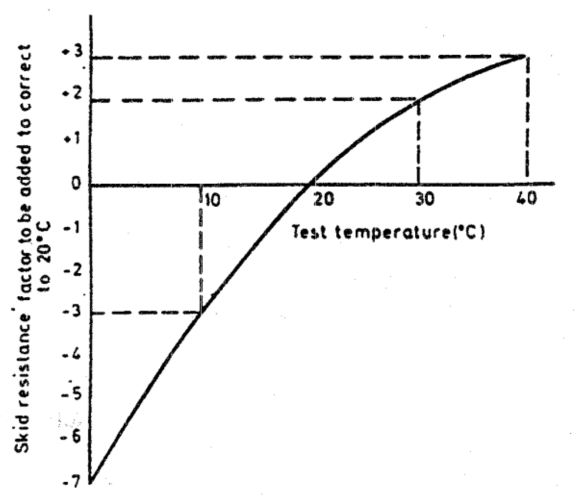
British Pendulum Tester and Full Scale Tire Friction Test

- Aim: To measure surface frictional property of field pavement or laboratory samples.

- Reasons of low skid resistance:
  With time during service and under the effect of repeated traffic:
  - Bleeding of asphalt to the surface may take place. Especially in case of low voids and high temperature.
  - Aggregate may suffer from polishing effect. Especially weak limestone.
- 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, it decreases over the remaining pavement life as aggregates become more polished.

- British pendulum procedure:
  - Apply water to the test area.
  - Execute one swing without recording.
  - Rewet and execute five more times and record.
  - Calculate the average.



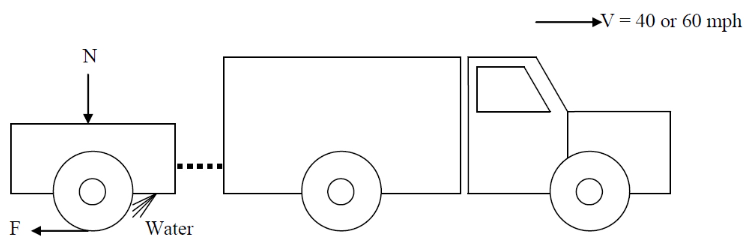


- The skid resistance value (SRV) is the mean of five readings or the constant of three readings.
- As the stiffness of the rubber slider will vary with temperature, a correction has to be made if the temperature is not 20^{o} C.

- Suggested minimum values of skid resistance (measured with the pendulum tester)

	Type of site	Minimum skid resistance (surface wet)
A	Difficult sites such as: 1. Roundabouts 2. Bends with radius less than 150 m on unrestricted roads 3. Gradients 1 in 20 or steeper of lengths greater than 100 m 4. Approaches to traffic lights on unrestricted roads	65
B	Heavy traffic roads in urban areas (carrying more than 2000 vehicles per day)	55
C	All other sites	45

- Full Scale Tire Friction Test is also called Locked Wheel Tester
- This method uses a locked wheel skidding along the tested surface to measure friction resistance.
- Full Scale Tire Friction Test procedure:
    - The trailer is brought to the desired testing speed (40 or 60 mph).
    - Water is sprayed ahead of the test tire to create a wetted pavement surface.
    - The test tire braking system is then actuated to lock the test tire.
    - Instrumentation measures the friction force acting between the test tire and the pavement and reports the result as a Skid Number (SN).



Pavement Construction

- Constructing a pavement can be done in many different ways, each of which may be appropriate for a specific combination of factors such as:
    - Temperature.
    - Pavement thickness,
    - Material properties.
    - Subgrade … etc.
- There are so many variables involved in construction; it is not a simple set of rules and equations. However, there are equipment and methods common to almost all pavement construction and there are accepted best practices.

1. HMA Manufacturing

- HMA is produced in a plant that that has many functions such as:
    - Proportioning aggregate and asphalt.
    - Blending aggregate and asphalt.
    - Heating aggregate and asphalt.
- There are two basic types of HMA plants:
    - Batch plants. Produce HMA in individual batches.
    - Drum plants. Produce HMA in a continuous operation.

2. Site Preparation

2.1 Subgrade Preparation for New Pavements

- The overall strength and performance of a pavement is dependent upon its design and the load-bearing capacity of the subgrade soil.
- Greater subgrade structural capacity can result in thinner (but not excessively thin) and more economical pavement structures.

Increasing Subgrade Support – Compaction

- A subgrade soil must be compacted to an adequate density.
- Generally, adequate density is specified as a relative density for the top 150 mm of subgrade of not less than 95 percent of maximum density.
- Subgrade below the top 150 mm is often considered adequate if it is compacted to 90 percent relative density.
- In order to achieve these densities the subgrade must be at or near its optimum moisture content.

Increasing Subgrade Support – Alternative Means

- Stabilization materials.
  - Lime is used with highly plastic soils (plasticity index greater than 10).
  - Cement is used with less plastic soils (plasticity index less than 10).
  - Emulsified asphalt can be used with sandy soils.
- Over-excavation. Replace poor load-bearing in situ subgrade with better load-bearing fill.
  - 0.3 – 0.6 m of poor soil may be excavated and replaced with better load-bearing fill such as gravel borrow.
  - Add a base course or a subbase course over the subgrade.

Subgrade Elevation

- The subgrade elevation should generally conform closely to the construction plan.
- Large elevation differences should not be treated by varying base thickness and not the pavement because :
  - HMA, and aggregate are more expensive than subgrade
  - HMA compacts differentially – thicker areas compact more than thinner areas.

Primecoat

- A primecoat is a sprayed application of a cutback or emulsion asphalt applied to the surface of untreated subgrade or base layers.
- Primecoats have three purposes:
  - Fill the surface voids and protect the subbase from weather.
  - Stabilize the fines and preserve the subbase material.
  - Promotes bonding to the subsequent pavement layers.

Other Subgrade Preparation Practices

- Ensure the compacted subgrade is able to support construction traffic.
- Remove all debris, large rocks, vegetation and topsoil from the area to be paved.
- Treat the subgrade under the area to be paved with an herbicide.

2.2 Existing Surface Preparation for Overlays

- The degree of surface preparation for an overlay is dependent on the condition and type of the existing pavement.
- The existing pavement should be structurally sound, level, clean and capable of bonding to the overlay.
- To meet these prerequisites, the existing pavement is usually repaired, leveled (by milling, leveling or both), cleaned and then coated with a binding agent.

Repair

- To maximize an overlays useful life, failed sections of the existing pavements should be patched or replaced and existing pavement cracks should be filled.
- Badly cracked pavement sections, especially those with pattern cracking (e.g., fatigue cracking) or severe slab cracks, must be replaced because these distresses are often symptoms of more extensive pavement or subgrade structural failure.
- Cracks other than those symptomatic of structural failure should be cleaned out and filled with a crack-sealing material.
- Cracks less than about 10 mm in width may be too narrow for crack-sealing material to enter. These narrow cracks can be widened with a mechanical router before sealing.
- If the existing pavement has an excessive amount of fine cracks but is still structurally adequate, it may be more economical to apply a general bituminous surface treatment (BST) or slurry seal instead of filling each individual crack.

Leveling Course

- The first lift applied to the existing pavement is used to fill in ruts and make up elevation differences.
- The top of this lift, which is relatively smooth, is used as the base for the wearing course.

Milling

- Milling can be used to smooth an existing HMA pavement prior to HMA overlays.
- Milling removes the high points in an existing pavement to produce a relatively smooth surface.
- Milling machines are the primary method for removing old HMA pavement surface material prior to overlay.
- The primary advantages of milling are:
    - Eliminates the need for complicated leveling courses and problems with quantity estimates.
    - Provides a highly skid resistant surface suitable for temporary use by traffic until the final surface can be placed.
    - Allows curb and gutter lines to be maintained or reestablished before flexible overlays.

HMA Overlays on PCC Pavement

- Placing a HMA overlay on a jointed or cracked PCC pavement involves some special considerations.

3. HMA Transport

- The goal of mix transport should be to maintain mix characteristics between the production facility and the paving site.
- Transport practices can have a profound effect on mix temperature at the paving site, aggregate and/or temperature segregation of the mix and mat quality.

Truck Types

- End dump. Unload their payload by raising the front end and letting the payload slide down the bottom. They are the most popular transport vehicle type because they are plentiful, maneuverable and versatile.
- Bottom dump (or belly dump). Unload their payload by opening gates on the bottom of the bed. Internal bed walls are sloped to direct the entire payload out through the opened gates.
- Live bottom (or flo-boy). Have a conveyor system at the bottom of their bed to unload their payload. They can reduce segregation problems.

Situation	**Truck Type**	**Reason**
Paving on congested city streets	End Dump	Better maneuverability because it has no trailer and is smaller than a bottom dump or live bottom truck.
Paving using a mix highly vulnerable to segregation	Live Bottom	Live bottom trucks deliver the HMA by conveyor, which minimizes segregation
Paving on rural highways	Bottom Dump	Usually has a larger capacity than end dump trucks (therefore fewer trucks are needed) but requires space and equipment for windrows

Loading at the Production Facility

- Truck bed cleanliness and lubrication. Prevent the introduction of foreign substances into the HMA and prevent the HMA from sticking to the truck bed.
- Aggregate segregation. Dropping HMA in several smaller masses at different points in the truck bed will largely prevent the collection of large aggregate in one area and thus minimize aggregate segregation.

Truck Transport

- Minimize haul distance. Closer production facilities create shorter haul times and result in less HMA cooling during transport.
- Insulate truck beds. This can decrease HMA heat loss during transport. Insulation as simple as a sheet of plywood has been used.
- Place a tarpaulin over the truck bed. Provides additional insulation, protects the HMA from rain and decreases heat loss.

Unloading at the Paving Site

- HMA should be unloaded quickly when it arrives at the paving site. This will minimize mix cooling before it is placed.
- Before HMA is loaded into the paver, the inspector should be certain it is the correct mix.

Operation Synchronization

- Truck transport should be planned such that the HMA transport rate (expressed in tons/hr) closely matches plant production rate and laydown rate. Some factors to consider are:
    - Number of trucks to be used.
    - Truck type.
    - Average truck hauling capacity.
    - Production facility output rate.
    - Availability and condition of storage silos at the production facility.
    - Time to lubricate the truck bed before transport.
    - Waiting time at the production facility.
    - Loading, weighing and ticketing time at the production facility.
    - Time to cover the load (when tarpaulins are used).
    - Distance between the production facility and the paving site.
    - Average truck speed.

4. Placement

- Lift thickness. A "lift" refers to a layer of pavement as placed by the asphalt paver.
    - In order to avoid mat tearing (which generally shows up as a series of longitudinal streaks) a good rule-of-thumb is that the depth of the compacted lift should be at least twice the maximum aggregate size and three times the nominal maximum aggregate size.
    - Overly thick final lifts have a tendency to shove or displace during compaction making it difficult to achieve a smooth finish.
- Longitudinal joints. The interface between two adjacent and parallel HMA mats.
    - Improperly constructed longitudinal joints can cause premature deterioration of multilane HMA pavements in the form of cracking and raveling.
- Handwork. HMA can be placed by hand in situations where the paver cannot place it adequately. This can often occur:
    - Around utilities.
    - Around intersection corners.
    - Other tight spaces.

5. Compaction

- Compaction is important because it reduces air content. Air content causes many problems such as:
    - Decreased stiffness and strength.
    - Reduced Fatigue Life.
    - Accelerated Aging/Decreased Durability.
    - Raveling.
    - Rutting.
    - Moisture Damage.
- Factors affecting compaction:

Environmental Factors	**Mix Property Factors**	**Construction Factors**
<u>Temperature</u>	<u>Aggregate</u>	<u>Rollers</u>
Ground temperature	Gradation	Type
Air temperature	Size	Number
	Shape	Speed and timing
<u>Others</u>	Fractured	Number of passes
Wind speed		Lift thickness
Solar flux	<u>Asphalt</u>	
	binder	<u>Other</u>
	Chemical properties	HMA production temperature
	Physical properties	Haul distance
	Amount	Haul time
		Foundation support

- Compaction Measurement. Percent air voids is the critical HMA characteristic with which compaction is concerned. It can be measured using:
    - Pavement core. Generally considered the most accurate but is also the most time consuming and expensive.
    - Nuclear density gauge.
    - Electrical density gauge

6. Specifications

- Product Specifications.
- Method Specifications.
- End-Result Specifications.
- Performance Specifications.