www.civiconcepts.com

VISCOSITY TEST ON BITUMEN

Absolute, Kinematic, Industrial Viscosity

CIVICONCEPTS.COM

All the 3 Viscosity Tests of Bitumen are described here with their test procedure and calculation of result. The significance and conclusion of viscosity test are also mentioned in this document.

Viscosity Test for Bitumen

Viscosity test of Bitumen is carried out to determine the viscosity of bitumen specimen indirectly with the help of different viscometers available.

The procedure of determining the viscosity of bitumen along with apparatus, materials, and precautions is described below. The significance and conclusion of this test are also described.

[Different types of viscometers are used to determine different kinds of viscosity as discussed below. The types viscosity measured are:

- *Industrial viscosity*
- *Dynamic/Absolute viscosity*
- *Kinematic viscosity]*

Significance of the Viscosity Practical

Viscosity test of the bitumen sample is one of the important tests on bitumen to be conducted before road construction.

Viscosity measures the degree of fluidity of the bitumen sample. It ensures the quality of the bitumen used as a binder by giving a measure of fluidity at a particular temperature.

If the bituminous binder used in the pavement has much lower viscosity value, then it will act as a lubricant only. It will not help in the binding of the particles, which is its primary purpose.

A highly viscous binder will restrict the flow, thus it restricts the ability of binder to spread and fill up the voids between the aggregates during pavement construction. Also, it will require more efforts comparatively, and there is also a possibility of it forming a heterogeneous mix. Workability will also be affected of a highly viscous bitumen specimen.

Therefore, it is essential to select a binder with appropriate viscosity so that it can form a uniform coat and fill up the voids between aggregates effectively.

CIVICONCEPTS.COM

DETERMINATION OF ABSOLUTE VISCOSITY

Aim

To determine the absolute viscosity of bitumen and cutbacks.

In this practical, the absolute viscosity is determined by **vacuum capillary viscometers** at any stated temperature.

This method is valid for materials having a viscosity range of 42-200000 poises.

Important Terms related to Absolute Viscosity of Bitumen

Absolute/dynamic viscosity of Newtonian liquid-

Absolute Viscosity: If a tangential force equal to 1 dyne is, acting on planes of unit area separated by a unit distance of liquid produces tangential velocity of one unit, and then the internal friction acting at that time is called absolute or dynamic viscosity.

CGS unit of dynamic viscosity is Poise. (1 dyne = 0.00001 N)

Newtonian liquid: It is a liquid in which shear stress is directly proportional to the rate of shear strain.

Alternatively, it is the liquid in which the coefficient of viscosity is constant.

Coefficient of viscosity: It is a ratio of shear stress to the rate of shear strain.

Apparatus

Any of the 3 viscometers discussed below shall be used for determining viscosity.

- **Viscometer- Capillary type**: It is made up of borosilicate glass. There are three types of capillary type viscometers as discussed below:
    - **Cannon Manning Vacuums Viscometer-** The range of the viscosity that this viscometer is able to measure depends on the size of the viscometer. It has two measuring bulbs- B and C.
    - **Asphalt Institute Vacuum Viscometer-** The range of the viscosity that this viscometer is able to measure depends on the size of the viscometer. It has three measuring bulbs- B, C, and D of length 2 cm. The three bulbs are situated on viscometer arm M. This arm is a precision bore glass capillary.
    - **Modified Koppers Vacuum Viscometer**- The range of the viscosity that this viscometer is able to measure depends on the radii of the viscometer. It has a separate filling tube joined to a precision bore glass capillary vacuum tube with a borosilicate ground glass joint that has 24/40 standard taper. The glass capillary has 2 cm long 3-bulbs separated by timing marks.

CIVICONCEPTS.COM

- **Bath:** It is used for the immersion of viscometer. The viscometer is so immersed in the bath that the liquid reservoir or the capillary top- whichever is the uppermost- is at least 20 mm below the top level of the bath. It has a provision that allows the viscometer and thermometer to be visible. Firm support is also present on the bath to hold the viscometer.
  The accuracy of viscometer should be 0.1 °C over the length of viscometer or from two different viscometer positions in the bath.

- **Thermometer or Temperature indicator**- Its range should be from 0 to 44 °C. Its least count should be 0.2 °C.

- **Vacuum System**- A vacuum or aspirator pump can be used as the source of vacuum in the vacuum system. All the glass joints of the vacuum system should be airtight so that no vacuum is lost in the duration of the experiment. It should be capable of maintaining the vacuum within ± 0.05 cm.

Other accessory apparatus include:

- Timing device like stopwatch or stop clock- It should be able to measure up to 0.5 seconds.
- Stirrer
- Oven

Materials

- Bitumen or cutback to be tested
- Solvent
- Distilled water
- Acetone
- Chromic acid

Precaution

Following precautions should be taken while performing the viscosity of bitumen test to obtain accurate results:

- Rotate the stirrer when the sample is heated in tar cup
- The temperature should be strictly adhered to during the entire test
- Local heating should be prevented by stirring the sample
- Viscometer should be cleaned periodically with chromic acid so that organic deposits are removed
- Calibration of thermometer should be done periodically

CIVICONCEPTS.COM

Procedure

Sample Preparation:

- Take the bitumen sample in a beaker and heat it to a temperature, not more than 60 °C- for tars and pitches while the temperature should not exceed 90°C- for bitumen. Allow the bitumen to melt at slightly above the softening points of the material until it achieves a pouring consistency.
- Pour 20 ml of melted bitumen in a suitable container and maintain it to a temperature of 135 °C with ± 5.5 °C tolerance.
- Stir the bituminous material occasionally so that local heating can be avoided. Also, the entrapped air can also escape in this while.
- Charge the viscometer. For charging, pour the prepared sample into the cup within ± 2 mm of the fill line E.
- Place the viscometer into bath or oven after charging and maintain it to 135 ± 5.5 °C. maintain this temperature for 10 ± 2 min to facilitate the escape of air bubbles.

Testing of the Specimen:

- Maintain the temperature of the bath at 135 °C as done previously, however, tolerance is reduced from 5.5 °C to 1.0 °C.
- Place the charged viscometer in the water bath vertically with the help of a holder. Adjust the depth of thermometer such that the uppermost timing mark remains a minimum of 2 cm below the liquid surface.
- Connect the vacuum system to the viscometer after establishing a vacuum of 30 ± 0.05 cm of mercury. Keep the valve of the vacuum system closed.
- Allow the assembly to stand in the water bath for 30 ± 5 min.
- Open the valve and allow the asphalt to flow into the viscometer.
- Measure the time required for the leading edge of the meniscus to pass between the two consecutive pairs of the timing marks in seconds. Accuracy of 0.5 seconds is required.

Cleaning of Viscometer After testing

- Remove the viscometer from the bath.
- Place the viscometer in the oven at 135 ± 5.5 °C in an inverted position. Allow the viscometer to stand in the oven until all the asphalt has drained off thoroughly.
- Rinse the viscometer several times with an appropriate solvent.
- Pass a slow stream of dried air through the capillary for about 2 minutes so that the tube is completely dry.
- Once in a while, clean the viscometer with chromic acid. It helps in the removal of organic deposits.

CIVICONCEPTS.COM

- Rinse the instrument thoroughly with distilled water and acetone.
- Dry the instrument with clean air.

Observation

As the valve of the viscometer is opened, the asphalt starts flowing into the viscometer.

The time taken by the leading edge of the meniscus to pass between two successive pairs of timing marks is to be noted down in seconds.

Observation Table

(A sample observation table is drawn below)

Test temperature =		
Constant K =		
Description	**Test Trial**	
	1	**2**
Efflux time (t) in sec		
Viscosity (K * t) in poise		

Absolute Viscosity of the sample = Average value of 1 and 2.

Calculation

Absolute viscosity of the sample is calculated and reported to the three significant figures.

Following equation is used for calculating absolute viscosity:

$$Viscosity = K.t$$

K = selected calibration factor; in poise/second

t = time of flow; in seconds

absolute viscosity is obtained in Poise

Result

The value of absolute viscosity is recorded to the three significant figures.

The result is reported along with the test temperature as follows:

Absolute viscosity at 60 °C temperature = 'X' poise

CIVICONCEPTS.COM

DETERMINATION OF KINEMATIC VISCOSITY

Aim

To determine the kinematic viscosity of paving grade and cutback bitumen and distillation residues of cutbacks.

This method is valid for materials having a viscosity range of 30-100,000 poises.

Important Terms related to Kinematic Viscosity of Bitumen

Kinematic viscosity of Newtonian liquid-

Kinematic Viscosity: It is the quotient of the dynamic viscosity divided by the density of the liquid under consideration, both taken at the same temperature.

CGS unit of kinematic viscosity is Stoke. (1 stoke = 1 cm^2/s)

Newtonian liquid: It is a liquid in which shear stress is directly proportional to the rate of shear strain.

Alternatively, it is the liquid in which the coefficient of viscosity of a liquid is constant.

Dynamic Viscosity: If a tangential force equal to 1 dyne is acting on planes of unit area separated by a unit distance of liquid produces tangential velocity of one unit, then the internal friction acting at that time is called absolute or dynamic viscosity.
CGS unit of dynamic viscosity is Poise. (1 dyne = 0.00001 N)

Coefficient of viscosity: It is a ratio of shear stress to the rate of shear strain.

Density: It is the ratio of mass per unit volume.
CGS unit of density is g/cm^3.

Apparatus

Either of the 2 viscometers discussed below shall be used for determining viscosity.

- **Viscometer- Capillary type**: It is made up of borosilicate glass. There are three types of capillary type viscometers as discussed below:
    - **Cannon-Fenske Viscometer (for Opaque liquids)-** This is a reverse flow annealed viscometer.
    - **BS U-Tube Modified Reverse-flow Viscometer-** It is made up of borosilicate or other heat-resisting glass that does not have any visible defects. All the glass tubes of a single viscometer should be similar in composition. The instrument should be thoroughly annealed after finishing.

CIVICONCEPTS.COM

- **Bath:** It is used for the immersion of viscometer. The viscometer is so immersed in the bath that the liquid reservoir or the capillary top- whichever is the uppermost- is at least 20 mm below the top level of the bath. It has a provision that allows the viscometer and thermometer to be visible.
  The stirring efficiency and balance between heat losses and its input should be such that the temperature of viscometer is maintained within ± 0.1 °C over the length of viscometer.

- **Thermometer or Temperature indicator**- Its range should be from 0 to 44 ˚C. Its least count should be 0.2 ˚C.

Other accessory apparatus include:

- Timing device like stopwatch or stop clock- It should be able to measure up to 0.5 seconds.
- Stirrer
- Oven

Materials

- Bitumen of known grade
- Non-corroding Solvent, e.g. Phenol-free light tar oil

Precaution

Following precautions should be taken while performing the viscosity of bitumen test to obtain accurate results:

- Rotate the stirrer when the sample is heated in tar cup
- The temperature should be strictly adhered to during the entire test
- Test temperature should not be lower than 20 ˚C and it should be in the multiples of 5 ˚C
- Care should be taken while using the tar cup during its cleaning- it should be cleaned gently
- Calibration of thermometer should be done periodically
- Non-corroding solvents should be used such as light tar oils free from phenols
- Do not use duster for cleaning as it may lead to abrasion of the metal
- The orifice at the top of the tar cup should be checked for its diameter frequently with a gauge

CIVICONCEPTS.COM

Procedure

Sample Preparation:

- **For Cutback bitumen and Oil distillates**

- Open the sample container. Thoroughly mix the sample by stirring it for 30 sec. Ensure that the entrapped air is avoided.
- If the sample is too viscous: Take the bitumen sample in a sealed container and heat it in a bath or oven at about 60°C temperature.
- Pour 20 ml of melted sample in a clean and dry container of 30 ml capacity and seal the container immediately.

- **For Bitumen**

- Heat the sample to a temperature, not more than 90° C- for tars and pitches while the temperature should not exceed 60° C- for bitumen. Allow the bitumen to melt at slightly above the softening points of the material until it achieves a pouring consistency.
- Pour 20 ml of melted bitumen in a 30 ml container.
- Avoid local heating and the entrapped air in the sample.

Testing of the Specimen:

- **For Cannon-Fenske Viscometer**

  - Charge the viscometer by inverting it and applying the suction to the tube CL. Immerse the tube N in the liquid sample.
  - Draw liquid through the N tube so that the bulb D is filled to the fill mark- G.
  - Wipe off the excess sample from the tube N.
  - Invert the viscometer so that it is in a normal position.
  - Align the viscometer in the water bath so that it is vertical. The verticality can be checked by visual inspection, which is sufficient, but for accuracy, a plumb bob can be suspended in the tube L.
  - Maintain a constant temperature of the water bath in which viscometer is placed to such a time that the sample reaches equilibrium in terms of temperature. For 38 °C, heating is to be done for 20 min, for 100 °C 25 min is required, and for 135 °C 30 min is required to attain temperature equilibrium.
  - Remove the stopper in the tubes N and L consecutively after the test temperature is obtained.
  - Allow the sample to flow by gravity.

CIVICONCEPTS.COM

- Measure the time required for the leading edge of the meniscus to pass between the two consecutive pairs of the timing marks- E to F in seconds. Accuracy of 0.1 seconds is required.
- If this efflux time comes less than 60 sec, select a smaller capillary diameter viscometer and repeat the above procedure.

- **For BS U-Tube Modified Reverse-flow Viscometer**

- Adjust the BS U-tube viscometer in the bath maintained at a constant temperature such that the L tube is kept vertical.
- Pour the sample through the tube N until it reaches up to the filling mark G.
- Allow the sample to flow freely through capillary R ensuring that the liquid remains continuous or unbroken until it reaches the lower filling mark H.
- When it reaches the filling mark, close the timing tube with a cork/rubber-stopper in tube L so that the flow is arrested.
- Add more liquid, if needed, so that the level reaches slightly above the mark G.
- Allow the sample to attain the bath temperature. Also allow the air bubbles to rise to the surface if any. Usually, this takes 20-30 min.
- Loosen the stopper gently and allow the sample to flow until it reaches the lower filling mark H. At this point, arrest the flow by pressing back the stopper.
- Remove the excess of the sample above the filling mark G. The sample can be removed with the help of a special pipette. Insert it until its cork rests on the top of tube N.
- Apply suction gently so that air is completely drawn and the upper meniscus shall coincide with mark G.
- Allow the viscometer to stand in the bath maintained at a constant temperature for duration such that the sample reaches temperature equilibrium.
  For 38 °C, heating is to be done for 20 min, for 100 °C 25 min is required, and for 135 °C 30 min is required to attain temperature equilibrium.
- Remove the stopper in the tubes N and L consecutively after the test temperature is obtained.
- Allow the sample to flow by gravity.
- Measure the time required for the leading edge of the meniscus to pass between the two consecutive pairs of the timing marks- E to F in seconds. Accuracy of 0.1 seconds is required.
- If this efflux time comes less than 60 sec, select a smaller capillary diameter viscometer and repeat the above procedure.

CIVILCONCEPTS.COM

Observation

As the valve of the viscometer is opened, the asphalt starts flowing into the viscometer.

The time taken by the leading edge of the meniscus to pass between two successive pairs of timing marks is to be noted down in seconds.

Observation Table

(A sample observation table is drawn below)

Test temperature =		
Constant K =		
Description	**Test Trial**	
	1	**2**
Efflux time (t) in sec		
Viscosity (K * t) in poise		

Absolute Viscosity of the sample = Average value of 1 and 2.

Calculation

Kinematic viscosity of the sample is calculated and reported to the three significant figures.

Following equation is used for calculating kinematic viscosity:

$$Viscosity = cSt = Ct$$

C = calibration constant of viscometer; in centistokes/second

t = efflux time; in seconds

absolute viscosity is obtained in centistokes

Result

The value of kinematic viscosity is recorded to the three significant figures.

The result is reported along with the test temperature as follows:

Kinematic viscosity at 60 ˚C temperature = 'X' cSt

CIVICONCEPTS.COM

DETERMINATION OF INDUSTRIAL VISCOSITY

Aim

To determine the industrial viscosity of bitumen, road tar, and cutback bitumen.

The industrial viscosity is measured by determining the time taken by 50-cm3 volume of material to flow from a cup through a specified orifice in standard conditions of temperature and a specified temperature.

Important Terms related to Industrial Viscosity of Bitumen

Industrial viscosity: It is the property of a fluid by virtue of which it is able to resist the flow caused by internal friction.

Apparatus

Tar viscometer is used for determining industrial viscosity of bitumen whose parts are discussed below:

- **Cup**: It is also known as a 10-mm cup and has a specified orifice and valve. It is made up of hard brass tube.
  It has an external brass collar at the upper open end of the cylindrical cup. The collar helps in supporting the cup in the sleeve of the water bath.
  While a phosphor-bronze plate, which is circular in shape is screwed into the cylinder and made conical. It has centrally located extensions made up of same material and cylindrical in shape. The plate helps in the drainage of tar after use.
  The extension is drilled and polished to form an orifice of 10 mm diameter. If the upper rim of the orifice is not perfectly circular, then the valve cannot be properly seated.
  Internal Diameter of cup = 40.0 ± 0.5 mm
  External Diameter of cup = 42.0 ± 0.5 mm
  Diameter of orifice = 10.000 ± 0.025 mm
  Length of jet = 5.000 ± 0.025 mm
  [**For CUTBACK BITUMEN**, 4-mm cup is used instead of 10-mm. Dia of the orifice is reduced to 4.000 ± 0.025 mm.]

- **Water bath:** It is cylindrical in shape and is made of a copper sheet. Heating of the bath is done electrically. Ensure that local heating is avoided. The water bath is placed on three equidistant legs riveted to the wall of the bath. The legs are of such length that a 100-mm cylinder can be placed below the cup orifice.
  Diameter of water bath = 160 mm
  Depth of water bath = 105 mm

CIVICONCEPTS.COM

- **Valve:** It is in the shape of a sphere and is made up of phosphor-bronze. It is attached to a metal rod provided with a levelling peg at upper part and hemisphere by which valve is held. It helps in closing the orifice attached to the 10-mm cup.

- **Sleeve**: It is in the form of a stout brass tube, which is bronzed into a central hole cut in the bottom of the water bath. It helps in receiving the cup so that the cup remains in position. It has an easing sliding fit.
  Internal Diameter of sleeve = 45 mm
  Height of sleeve = 105 mm

- **Stirrer:** It has 4 vertical vanes. The upper and lower portions of the stirrer can be turned in opposite directions. The stirrer is mounted on a cylinder slipping on the sleeve through an easy sliding fit. The cylinder is cut between the vanes so that heat can be transferred from water in the bath to the tar in the cup. To prevent the water from the water bath from entering the tar cup on raising the stirring system, vertical grooves are provided on the inner surface of the cylinder.

- **Curved shield:** It is fixed at the upper edge of the cylinder. It is extended to a distance within 5 mm of the walls of the water bath. An insulating handle to facilitate rotation of stirrer, a swivelled support for the valve, and support for thermometer are present on this curved shield.

- **Receiver**: It is a measuring cylinder with graduations at 20, 25, and 75 ml capacities. Its total capacity is 100 ml.
  Internal Diameter ≯ 29 mm

- **2-Thermometer**- Two standard thermometers are required- one is placed in the water bath and another in the cup. The range of both the thermometers should be from 0 to 44 °C. The least count is 0.2 °C.

Other accessory apparatus include:

- Timing device like stopwatch or stop clock- It should be able to measure up to 0.5 seconds.

Materials

- Bitumen sample to be tested
- Non-corroding Solvent, e.g. Phenol-free light tar oil

CIVICONCEPTS.COM

Precaution

Following precautions should be taken while performing the viscosity of bitumen test to obtain accurate results:

- Rotate the stirrer when the sample is heated in tar cup
- The temperature should be strictly adhered to during the entire test
- Test temperature should not be lower than 20 °C and it should be in the multiples of 5 °C
- Care should be taken while using the tar cup during its cleaning- it should be cleaned gently
- Non-corroding solvents should be used such as light tar oils free from phenols
- Do not use duster for cleaning as it may lead to abrasion of the metal
- The orifice at the top of the tar cup should be checked for its diameter frequently with a gauge
- Calibration of thermometer should be done periodically

Procedure

- Adjust the tar viscometer in such a way that the top of the tar cup is levelled.
- Heat the water bath to the specified temperature of the test and maintain it at the same temperature throughout the test duration. Tolerance of ± 0.1 °C is allowed. [The specified test temperatures are 35 °C, 45 °C, 55 °C, and 65 °C.]
- Rotate the stirrer gently at frequent intervals. Continuous rotation is preferred.
- Clean the orifice of the tar cup of viscometer with a suitable solvent and allow it to dry completely.
- Heat the bitumen sample to a temperature of about 20 °C above the specified test temperature and allow it to cool. Meanwhile, rotate the stirrer continuously.
- Allow the sample to cool up to a temperature slightly above than the specified test temperature.
- Pour the tar into the tar cup then after till the levelling peg on the valve is just immersed. During this, the valve rod should be kept vertical.
- Take 20 ml of mineral oil or 1 % by weight solution of soft soap and pour it into the graduated receiver.
- Place the graduated receiver under the orifice of tar cup.
- Place the second thermometer in the tar.
- Continue stirring the tar until the temperature falls within ± 0.1 °C of the specified test temperature.
- Then, suspend the thermometer co-axially to the cup with its bulb at the geometric centre of the tar approximately.

CIVICONCEPTS.COM

- Allow the assembly of the apparatus to stand for 5 minutes. During this time, the thermometer reading should remain within 0.5 °C of the specified test temperature.
- Remove the thermometer.
- Also, remove the excess of tar, if any quickly. This ensures that the final level is on the centre line of the levelling peg when the valve is vertical.
- Suspend the valve on the valve support by lifting it.
- Start the stopwatch or stop-clock or any other time recording device when the reading on the cylinder is 25 ml.
- Note the time in seconds when the reading on the cylinder is 75 ml by stopping the stopwatch.
- Repeat the test for a few times with the same material and note down the results.

Report

The time at which the reading of the cylinder reaches 75 ml from 25 ml is to be noted down for all the three samples along with the specified test temperature.

Whether the sample is tested as received or dried before testing is also reported. If drying is done, then the method of drying is also noted.

If the sample is tested as received, then water is present in it. And the presence of water has a notable effect on viscosity.

Observation Table

(A sample observation table is drawn below)

Specified test temperature = __ °C	**Test Number**		
	1	**2**	**3**
Time in sec			

Industrial Viscosity of the sample = Average value of 1, 2 and 3.

Result

The time taken by 50 ml of tar to flow out is recorded to the nearest whole number as the viscosity of the tar sample.

The time taken by the three tar samples should lie within ±4 % of the mean value of the three readings.

While using **CUTBACK BITUMEN**, the tolerance in the difference in readings is tabulated below:

CIVICONCEPTS.COM

Viscosity	Repeatability
< 20 sec	2 sec
20-40 sec	2 sec
> 40 sec	5 % of the mean

CIVICONCEPTS.COM