North South University

Department of Civil and Environmental Engineering

CEE 250L

TRANSPORTATION ENGINEERING LABORATORY MANUAL

(Updated in 2023)

Compiled and Edited by:

Professor Dr. Javed Bari

TABLE OF CONTENTS

COURSE OUTLINE

COURSE

Course Code *Course Title* *Course Type*	**CEE250L** **Transportation Engineering Lab** Junior level undergraduate course
Credit hours	**1 (One)**
Contact Hours per Week *Contact hours per credit per semester*	2 hours of lab class (includes Lecture, demonstration of experiments and lab works). There are 12 labs (excluding introductory and review labs, and the Final Exam (written and viva). 1680 minutes lab
Prerequisite Courses	CEE250: Introduction to Transportation Engineering
Online Platform	CANVAS
In-campus classroom	B115 (Transportation Engineering Lab), NSU Main Campus, Bashundhara

COURSE DESCRIPTION

Laboratory experiments on highway materials (soil, aggregates and asphalt) and characterization of those materials.

LAB EXPERIMENTS

1. Angularity Number.
2. Elongation Index.
3. Aggregate Crushing Value.
4. Ten Percent Fines Value.
5. Aggregate Impact Value.
6. Resistance to Degradation (Los Angeles Abrasion Test).
7. Viscosity of Asphalt (using Rotational Viscometer).
8. Softening Point of Bituminous Material (Ring and Ball Method).
9. Penetrations of Bituminous Material.
10. Flash and Fire Point of Bitumen (Cleveland Open Cup Method).
11. Marshall Mix Design tests (sample preparation, mix volumetrics and stability test).
12. Advanced Asphalt Characterization tests (demo and lecture only).

TEXT BOOK(S):

- CEE Lab Manual – by: DCEE, NSU

REFERENCE BOOK(S):

- Materials for Civil and Construction Engineers (3rd or latest Edition) – by: Michael S. Mamlouk and John P. Zaniewski. Publisher: Pearson Prentice-Hall, USA.
- Hot Mix Asphalt Materials, Mixture Design and Construction (2nd or 3rd edition) – by: E R Brown, Prithvi S Kandhal, Freddy L Roberts, Y Richard Kim, and Dah-Yinn Lee. Publisher: NAPA Research and Education Foundation (NCAT), USA.

COURSE INFORMATION:

- Credit hour: 1 (one).
- Contact hours: 1680 minutes per credit per semester (weekly 2 hours of lab class includes lectures, demonstration of experiments and actual lab experiments).
- The course requires knowledge on engineering materials and transportation engineering.
- The semester will be conducted on a hybrid basis (combination of offline, i.e. in-campus and online, i.e. off-campus), in which the lectures, virtual lab demo, report submission and written exams will be conducted online, while the actual lab experiments and viva voce will be conducted offline in the lab.

COURSE OBJECTIVES:

Provide the students a hands-on experience of conducting laboratory experiments on highway materials needed for the materials' characterization and conformation to the specifications.

COURSE OUTCOMES (COs):

On successfully completing the course requirements, the students should be able to:

CO1: Conduct common laboratory experiments on highway materials (soil, aggregates and asphalt) used in transportation projects and use the test data to characterize those materials in order to conform to standard specifications.

MAPPING OF COURSE OUTCOMES TO BSCEE PROGRAM OUTCOMES

L: Slightly maps (low); M: Moderately maps (medium); H: Substantially maps (high)

POs	(a) Engineering Knowledge	(b) Problem analysis	(c) Design/development of solutions	(d) Investigation	(e) Modern tool usage	(f) The engineer and society	(g) Environment and sustainability	(h) Ethics	(i) Individual work and teamwork	(j) Communication	(k) Project management and finance	(l) Life-long learning
CO1				H								

CO DELIVERY AND ASSESSMENT OF OUTCOMES

Course Outcomes	Bloom's taxonomy, domain/level *(C: Cognitive, P: Psychomotor A: Affective)*	Delivery methods and activities	Assessment tools (AT)
CO1	P1, P2, P3	Lecture, Demonstration (virtual and in-lab)	Participation (AT1), Report (AT2), Exam (AT3)

Cognitive domain (knowledge-based): C

1: Knowledge, 2: Comprehension, 3 Application, 4 Analysis, 5: Synthesis, 6: Evaluation

The affective domain (emotion-based): A

1: Receiving, .2: Responding, 3: Valuing, 4: Organizing, 5: Characterizing

The psychomotor domain (action-based): P

1: Perception, 2: Set, 3: Guided response, 4: Mechanism, 5: Complex overt response, 6: Adaptation, 7: Origination

TEACHING/LEARNING STRATEGIES

Lectures

- Attend all classes and labs punctually.
- Use the reference books to learn about the theoretical background of the experimental labs that are not precisely described in the lab manual.

Tutorials & Group work

- Contact lab instructor whenever required.
- Attend the lab demonstration sessions.
- Work in groups in the lab and share the test data as necessary.
- Work with peers to solve problems, discuss with friends.

Private study

- Review lecture material, textbook and reference books.

COURSE ASSESSMENT

- Assignments will be given for to ensure "learning by doing".
- Active participation individually and in groups in the laboratory experiments and other tasks will be assessed as "participation".
- Exams (written and viva) will be taken to check if the student is attaining course objective.

COURSE EVALUATION

Distribution of numerical scores:		
AT1: Participation	35%	Includes a combination of 20% on lab attendance and 15% on participation (individual and group)
AT2: Report	35%	Based on lab reports
AT3: Exam	30%	Based on exams (combination of MCQ, short questions, viva voce)

GRADING POLICY

Generally, NSU grading policy will be followed. However, minor deviation is still possible depending on the situation.

EXAM POLICY

Generally, no makeup for exam and laboratory experiment is possible. <u>ANY MAKE UP MAY BE ARRANGED ONLY IF AN ABSOLUTELY UNAVOIDABLE VALID REASON FOR ABSENCE IS FOUND</u>. For such unavoidable circumstances, written explanation of the situation must be submitted beforehand. If any exam cannot be held on the due date, it will be automatically shifted to the very next available class, unless otherwise announced.

CLASS/LAB SCHEDULE

***** One Day = 2 hours, Total 14 classes

Day*	Outcome/ Material Covered	Reference Reading	Activity	Due
Day-1	Course overview & ab visit	Course outline	Discussion	-
Day-2	Experimental error, Sampling, Accuracy and Bias	Handout	Lecture	-
Day-3	Measuring devices	Handout	Lecture	Assignment report due
Day-4	Angularity Number test and Elongation Index test	Lab Manual	Lecture & demonstration	-
Day-5	Aggregate Crushing Value test and Ten Percent Fines Value test	Lab Manual	Lecture & demonstration	Lab report due
Day-6	Resistance to Degradation (Los Angeles Abrasion Test).	Lab Manual	Lecture & demonstration	-
Day-7	Viscosity of Asphalt test (using Rotational Viscometer).	Lab Manual	Lecture & demonstration	Lab report due
Day-8	Softening Point of Bituminous Material (Ring and Ball Method)	Lab Manual	Lecture & demonstration	-
Day-9	Penetrations of Bituminous Material	Lab Manual	Lecture & demonstration	Lab report due
Day-10	Flash and Fire Point of Bitumen (Cleveland Open Cup Method)	Lab Manual	Lecture & demonstration	-
Day-11	Marshall Mix Design Specimen Preparation and Volumetric Analysis	Lab Manual	Lecture & demonstration	Lab report due
Day-12	Marshall Stability and Flow test	Lab Manual	Lecture & demonstration	-
Day-13	Advanced Asphalt Characterization tests	Lab Manual	Lecture & demonstration	Lab report due
Day-14	Advanced Asphalt Characterization tests	Lab Manual	Lecture & demonstration	Lab report due

CODE OF CONDUCT

- The course instructor or lab assistant/coordinator must be consulted before using any lab facility.
- Students are strongly advised to follow the general lab safety rules. Note that closed toe shoes are mandatory in all Civil Engineering laboratories. No sandals will be allowed in the lab.
- It is a student's responsibility to read the test procedures and text assignments before the scheduled labs.
- It is highly requested to maintain discipline in the lab like not to be late, refrain from making noise during lab time, not to leave the lab early.
- The student must use their authentic NSU email address in all online communications related to the academic matters, including logging into the CANVAS.
- The student must participate in all the activities of the labs as would be instructed by the course instructor.
- The student must not do anything that can potentially disturb the labs, including lectures, exams, presentations, etc., related to this course.
- Breaching of any of the above-stated terms and conditions from the student's end may result in moderate to severe disciplinary actions against the student (depending on the severity of the case).
- Adopting unfair means in the exams will be considered as a serious crime and the student shall be placed to the university disciplinary committee.
- In the lab works (lab reports, assignments, exams, etc.), any direct duplication of the work of another person is a big offense and may result in "F" grade.
- Paraphrasing another person's work with minor changes keeping the meaning same is also plagiarism and will be treated as an offense.
- If a student is detected in committing academic dishonesty, it may result in an "F" grade for the course or even dismissal from the university.
- In University premises, student must abide by the Code of Conduct for the Students. The latest codebook can be found from the following webpage: http://www.northsouth.edu/proctoroffice

BSCEE PROGRAM OUTCOMES (PO)

(a) Engineering knowledge: Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in K1 to K4 respectively to the solution of complex engineering problems.

(b) Problem analysis: Identify, formulate, research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. (K1 to K4)

(c) Design/development of solutions: Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. (K5)

(d) Investigation: Conduct investigations of complex problems using research-based knowledge (K8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.

(e) Modern tool usage: Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering problems, with an understanding of the limitations. (K6)

(f) The engineer and society: Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems. (K7)

(g) Environment and sustainability: Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts. (K7)

(h) Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice. (K7)

(i) Individual work and teamwork: Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.

(j) Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

(k) Project management and finance: Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

(l) Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

KNOWLEDGE PROFILE

Code	Attribute
K1	A systematic, theory-based understanding of the **natural sciences** applicable to the discipline
K2	Conceptually based **mathematics, numerical analysis, statistics** and the formal aspects of computer and information science to support **analysis and modeling** applicable to the discipline
K3	A systematic, theory-based formulation of **engineering fundamentals** required in the engineering discipline
K4	**Engineering specialist knowledge** that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline
K5	Knowledge that supports **engineering design** in a practice area
K6	Knowledge of **engineering practice (technology)** in the practice areas in the engineering discipline
K7	Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the engineer's professional responsibility to public safety; the impacts of engineering activity; economic, social, cultural, environmental and sustainability
K8	Engagement with selected knowledge in the **research literature** of the discipline

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB

WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-01: DETERMINATION OF AGGREGATE IMPACT VALUE

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO-01: DETERMINATION OF AGGREGATE IMPACT VALUE

OBJECTIVE

The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact‖, which in some aggregates differs from its resistance to a slowly applied compressive load. With aggregate of aggregate impact value (AIV) higher than 30 the result may be anomalous. In addition, aggregate sizes larger than 15 mm are not appropriate to the aggregate impact test.

The standard aggregate impact test shall be made on aggregate passing a 15 mm BS test sieve and retained on a 10 mm BS test sieve. If required, or if the standard size is not available, smaller sizes may be tested but owing to the non-homogeneity of aggregates, the results are not likely to be the same as those obtained from the standard size. In general, the smaller sizes of aggregate will give a lower impact value but the relationship between the values obtained with different sizes may vary from one aggregate to another.

APPARATUS

An impact testing machine of the general form and complying with the followings-

Total mass not more than 60 kg or less than 45 kg. The machine shall have a circular metal base weighing between 22 kg and 30 kg., with a plane lower surface of not less than 300 mm diameter, and shall be supported on a level and plane concrete or stone block or floor at least 450 mm thick. The machine shall be prevented from rocking either by fixing it to the block or floor or by supporting it on a level and plane metal plate cost into the surface of the block or floor.

A cylinder steel cup having an internal diameter of 102 mm and an internal depth of 50 mm. The walls shall be not less than 6 mm thick and the inner surfaces shall be case hardened. The cup shall be rigidly fastened at the center of the base and be easily removed for emptying.

A metal hammer weighing 13.5 kg to 14.0 kg the lower end of which shall be cylindrical in shape, 100.00 mm diameter and 50 mm long, with a 1.5 mm chamfer at the lower edge, and case hardened. The hammer shall slide freely between vertical guides so arranged that the lower (cylindrical) part of the hammer is above and concentric with the cup.

Means or raising the hammer and allowing it to fall freely between the vertical guides from a height of 380±5 mm on to the test sample in the cup, and means for adjusting the height of fall within 5 mm.

1. Means for supporting the hammer whilst fastening or removing the cup.
2. A straight metal tamping rod of circular cross section, 10 mm diameter, 230 mm long, rounded at one edge.
3. A balance of capacity not less than 500 gm, and accurate to 0.1 gm.

PREPARATION OF THE TEST SAMPLE

The material for the standard test shall consist of aggregate passing a 15.0 mm BS test sieve and retained on a 10.00 mm BS test sieve, and shall be thoroughly separated on these sieves before testing. For smaller sizes, the aggregate shall be prepared in a similar manner using the appropriate sieves given in table 1. The quantity of aggregate sieved out shall be sufficient for two tests.

The aggregate shall be tested in a surface dry condition. If dried by heating, the period of drying shall not exceed 4 h, the temperature shall not exceed 110^0c and the samples shall be cooled to room temperature before testing.

The measure shall be filled about one third full with the aggregate by means of a scoop, the aggregate being discharged from a height not exceeding 50mm above the top of the container. The aggregate shall then be tamped with 25 blows of the rounded end of the tamping rod, each blows being given by allowing the tamping rod to fall freely from a height of about 50 mm above the surface of the aggregate and the blows being evenly distributed over the surface. A further similar quantity of aggregate shall be added in the same manner and a further tamping of 25 times and the surplus aggregate removed by rolling the tamping rod across, and in contact with, the top of the container, any aggregate which impedes its progress being removed by hand and aggregate being added to fill any obvious depressions. The net mass of aggregates in the measure shall be recorded (mass A) and the same mass used for the second test.

TEST PROCEDURE

Rest the impact machine, without wedging or packing, upon the level plate, black or floor, so that it is rigid and the hammer guide columns are vertical.

Fix the cup firmly in position on the base of the machine and place the whole of the test sample in it and compact by a single tamping of 25 strokes of the tamping rod as above.

Adjust the height of the hammer so that its lower face is 380±5 mm above the upper surface of the aggregate in the cup and then allow it to fall freely on to the aggregate. Subject the test sample to a total of 15 such blows, each being delivered act an interval of not less than 1 s. No adjustment for hammer height is required after the first blow.

Then remove the crushed aggregate by holding the cup over a clean tray and hammering on the outside with a suitable rubber mallet until the sample particle s are sufficiently disturbed to enable the mass of the sample to fall freely on to the tray. Transfer fine particles adhering to the inside of the cup and the underside of the hammer to the tray by means of a stiff bristle brush. Sieve the whole of the sample in the tray, for the standard test, on the 2.5 mm BS test sieve until no further significant amount in 1 min.

Weigh the fraction passing and retained on the sieve to an accurately of 0.1 gm (mass B and mass C respectively) and if the total mass B+C is less than the initial mass (mass A) by more than 1 gm, discard the result and make afresh test.

Repeat the whole procedure starting from the beginning using a second sample of the same mass as the first sample.

CALCULATIONS

The ratio of the mass of fines formed to the total sample mass in each test shall be expressed as a percentage, the result being recorded to the first decimal place.

Percentage fines: B/A x 100

Where,

A is the a mass of surface dry sample, gm

B is the fraction passing the sieve for separating the fines, gm

REPORTING OF RESULTS

The means of the two results shall be reported to the nearest whole number as the aggregate impact value.

EXPERIMENT NO: 01

DETERMINATION OF AGGREGATE IMPACT VALUE

Name: Student No:

Type of material:

Rock Sample Size : 15 mm to 10 mm

CALCULATIONS

DISCUSSION

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB

WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-02: DETERMINATION OF AGGREGATE CRUSHING VALUE

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 02

DETERMINATION OF AGGREGATE CRUSHING VALUE

GENERAL

Aggregate used in road construction, should be strong enough to resist crushing under traffic wheel load. If the aggregate are weak, the stability of the pavement structure is likely to be adversely affected. The strength of coarse aggregate is assessed by aggregate crushing test. The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied compressive load. To achieve a high quality of pavement, aggregate possessing low aggregate crushing value should be preferred.

With aggregate of an aggregate crushing value higher than 30 the result may be anomalous and in such as the ten percent fines value should be determined instead

SAMPLING

The standard aggregate crushing test shall be made on aggregate passing a 14.0 mm BS test and retained on a 10.0 m BS test sieve

APPARATUS

The following apparatus is required for the standard test.

An open ended steel cylinder of nominal 150 mm internal diameter with plunger and base plate, of the general from and diameter shown in the figure. The surfaces in contact with the aggregate shall be machined and case hardened, and shall be maintained in a smooth condition.

A straight metal tamping rod of circular cross section, 16 mm diameter and 450 mm to 600 mm long. One end shall be rounded.

A balance of at least 3 kg capacity and accurate to 1 gm.

BS test sieves of sizes 14.0 mm, 10.0 mm and 2.36 mm.

A compression testing machine capable of applying a force of 400 KN and which can be operated to give a uniform rate of loading so that this force is reached in 10 minute.

A cylindrical metal measure (optional) for measuring the sample, of sufficient rigidity to remain its form under rough usage and having an internal diameter of 115 mm and an internal depth of 180 mm.

PREPARATION OF TEST SAMPLE

The material for the standard test shall consist of aggregate passing the 14.0 mm BS test sieve and retained on the 10.0 mm BS test sieve and shall be thoroughly separated on these sieves before testing. The quality of aggregate shall be cooled to room temperature before testing.

The aggregate shall be tested in a surface-dry condition. If dried by heating the period of drying shall not exceed 4 h, the temperature shall not exceed 110^0 c and the aggregate shall be cooled to room temperature before testing.

The quantity of aggregate for one test shall be such that the depth of the material in the cylinder shall be 100 mm after tamping.

TEST PROCEDURE

Put the cylinder of the test apparatus in position on the base plate, and add the test sample in thirds, each third being subjected to 25 strikes from the tamping rod distributed evenly over the surface of the layer and dropping from a height approximately 50 mm above the surface of the aggregate. Carefully level the surface of the aggregate and insert the plunger so that it rests horizontally on this surface, taking care to ensure that the plunger does not jam in the cylinder.

Place the Apparatus, with the test sample and plunger in position, between the plates of the testing machine and load it at as uniform a rate as possible so that the required force is reached in 10 minutes. The required force shall be 400 kN.

Release the load and remove the crushed material by holding the cylinder over a clean tray and hammering on the outside with a suitable rubber mallet until the sample particles are sufficiently disturbed to enable the mass of the sample to fall freely on to the tray. Transfer fine particles adhering to the inside of the cylinder, to the base-plate and the underside of the plunger to the tray by means of a stiff bristle brush. Sieve the whole of the sample on the tray on the 2.36 mm BS test sieve until no further significant amount passes in 1 minute. Weight the fraction passing the sieve (mass B). Take care in all of these operations to avoid loose of the fines.

Repeat the whole procedure, starting from the beginning of 2.5, using a second sample of the same mass as the first sample.

CALCULATION

The ratio of the mass of fines formed to the total mass of the sample in each test shall be expressed as a percentage, the result being recorded to the first decimal place.

Percentage Fines: B/A x 100

Where,

A is the mass of surface dry sample (gm)

B is the mass of the fraction passing the 2.36 mm BS test sieve (gm)

EXPERIMENT NO: 02

DETERMINATION OF AGGREGATE CRUSHING VALUE

Name: Student No:

Type of material: Brick Chips/ Stone Chips/ Gravels/ Boulder/

Rock Sample Size: 14 mm to 10 mm

Test Method: BS 812 (part 3) 1975

Test No	1	2
Wt. of Sample (Surface Dry), A gm		
Wt. of materials passing 2.36 mm sieve, B gm		
Aggregate Crushing Value (%) = B/A x 100% (to the first decimal place)		
Average Aggregate Crushing Value (ACV) = (to the nearest whole number)		

Calculation:

DISCUSSION

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB

WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-03: DETERMINATION OF THE TEN PERCENT FINES VALUE

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 03

DETERMINATION OF THE TEN PERCENT FINES VALUE

OBJECTIVE

The ten percent fines value gives a measure of the resistance of an aggregate to crushing which is applicable to both weak and strong aggregate.

SAMPLING

The standard aggregate crushing test shall be made on aggregate passing a 15.0 mm BS test and retained on a 10.0 m BS test sieve.

APPARATUS

Same as the Aggregate Crushing Value.

PREPARATION OF THE TEST SAMPLE

Same as the previous except in case of weak materials, particular care shall be taken not to break the particles when filling the measure and the cylinder.

TEST PROCEDURE

Put the cylinder of the test apparatus in position on the base-plate and add the test sample in thirds, each third being subjected to 25 strokes from the tamping rod distributed evenly over the surface of the layer and dropping from a height approximately 50 mm above the surface of the aggregate, particular care being taken in the case of weak materials not to break the particles. Carefully level the surface of the aggregate and insert the plunger so that it rests horizontally on this surface, taking care to ensure that the plunger does not jam in the cylinder.

Then place the apparatus, with the test sample and plunger in position, between the plates of the testing machine. Apply forces at as uniform a rate as possible to cause a total penetration of the plunger in 10 min of about:

a) 15 mm for rounded or partially rounded aggregate (e.g. uncrushed gravels)

b) 20 mm for normal crushed aggregate

c) 24 mm for honeycombed aggregate (e.g. some slags)

The figures may be varied according to the extent of the rounding or honeycombing.

NOTE: When an aggregate impact value is available, the force required for the first ten percent fines test can be estimated by means of the following more conveniently than by the use of the dial gauge.

Required force (KN) = 4000/ Aggregate Impact Value

This value of force will nearly always gives a percentage fines within the required range of 7.5 to 12.5.

Record the maximum force applied to produce the required penetration. Release the force and remove the crushed material by holding the cylinder over a clean tray and hammering on the outside with a suitable rubber mallet until the sample particles are sufficiently disturbed to enable the mass of the sample to fall freely on to the tray. Transfer fine particles adhering to the inside of the cylinder and the underside of the plunger to the tray by means of a steel bristle brush. Sieve the whole of the sample in the tray on the 2.5 mm BS test sieve until no further significant amount passes in 1 minute. Weight the fraction passing the sieve, and express this mass as percentage of the mass of the test sample. Normally this percentage of fines will fall within the range 7.5 to 12.5, but if it does not, make a further test loading to a maximum value adjusted as seems appropriate to bring the percentage fines within the range of 7.5 to 12.5. The formula given which may be used for calculating the force required.

In all of these operations take care to avoid loss of the fines. Make a repeat test at the maximum force that gives a percentage fines within the range 7.5 to 12.5.

The mean percentage fines from the two tests at this maximum force shall be used in the following to calculate the force required to produce ten percentage fines.

Force required to produce ten percent fines = 14 x / (y+4)

Where,

x is the maximum force (kN)

y is the mean percentage fines from two tests at –x kN forces.

EXPERIMENT NO: 03

DETERMINATION OF THE TEN PERCENT FINES VALUE

Name: Student No:

Type of material:

Rock Sample Size : 15 mm to 10 mm

Force required to produce T.F.V = 4000kN / A.I.V = kN.

Used Force x = kN

Test No Data	1	2	3 (if required)
Wt. of Sample (Surface Dry), A gm			
Wt. of materials retained on 2.5 mm sieve, C gm			
Wt. of materials passing 2.5 mm sieve, B gm			
Percent Fines = B/A x 100% (to the first decimal place)			
Mean percentage fines (y), at x = kN force			

CALCULATIONS

Ten Percent Fines Value (T.F.V) = 14x / (y+4) =

(to the nearest 5 kN, if < 100 kN & 10kN, if ≥ 100 kN)

DISCUSSION

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB
WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-04: DETERMINATION OF FLAKINESS INDEX

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 04

DETERMINATION OF FLAKINESS INDEX

OBJECTIVE

Aggregate particle may have three types of shapes, namely rounded, angular and flaky. Round shape is good for use in cement concrete as it produces more workable concrete with comparatively less quantity of water. Angular particles are good for bituminous pavements as they have better interlocking property.

Flaky particles are comparatively thin as compared to their length. Flakiness Index is the percentage by weight of particle in it, whose least dimension is less than three fifth of its mean dimension. Those particles whose least dimension is less than 0.6 of their mean size and whose greatest dimension is more than 1.8 times their mean size, are respectively termed as flaky and elongated particles. The shape of the particles is evaluated in terms of flakiness index.

FLAKINESS INDEX

This test is carried on aggregate of having particles larger than 6.3mm. Let a particle of aggregate passes through 20mm sieve but retained on 10mm sieve. The mean size of this particles is (20+10)/2 = 15mm. When this mean size multiplied by 0.6, 9mm size is obtained. Hence for this aggregate if thickness of the particles is less than 9mm it is said to be flaky.

APPARATUS

The following apparatus is required,

a. A metal thickness gauge.
b. A balance accurate to 0.5% of the mass to the test sample.

SAMPLE FOR TEST

Aggregate passing through 63.0mm BS test sieve and retained on the 6.30mm BS test sieve.

PROCEDURE

1. A sample of aggregate to be tested is sieved through set of sieves (63.0mm, 50.0mm, 37.5mm, 28.0mm, 20.0mm, 14.0mm, 10.0mm, 6.3mm) and separated into specified size ranges.
2. The particles retained on each sieve are then made to pass through appropriate slot, (0.6 time of the mean size) of standard thickness gauge.
3. The material that passes through the appropriate slot of the gauge is said to be flaky. The flaky material that has passed through the appropriate slots of standard gauge, for each size of range of the test aggregate, are added up and weighted.

DATA TABLE

Sieve Size, mm		Wt. of the material retained, gm	Wt. of the flaky particles (amount passed), gm
Passing	Retained		
63.0	50.0		
50.0	37.5		
37.5	28.0		
28.0	20.0		
20.0	14.0		
14.0	10.0		
10.0	6.30		
x	x	W=	W1=

CALCULATIONS

Flakiness Index is determined as follows,

- W1/W x 100%

Where, W1= Weight of flaky material from whole test sample
W= Total weight of sample

DISCUSSION

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB
WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-05: DETERMINATION OF ELONGATION INDEX

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 05

DETERMINATION OF ELONGATION INDEX

OBJECTIVE

Aggregate particle may have three types of shapes, namely rounded, angular and flaky. Round shape is good for use in cement concrete as it produces more workable concrete with comparatively less quantity water. Angular particles are good for bituminous pavements as they have better interlocking property.

Flaky and elongated particles may have adverse effects on concrete and bituminous mix. For instance, flaky and elongated particles tend to lower the workability of concrete mix that may impair the long-term durability. For bituminous mix, flaky particles are liable to break up and disintegrate during the pavement rolling process.

Elongation Index is the percentage by weight of particles in it, where the largest dimension (i.e. length) is greater than one and four-fifths times its mean dimension. Those particle whose least dimension is less than 0.6 of their mean size and whose greatest dimension is more than 1.8 times their mean size, are respectively termed as flaky and elongated particles. The shape of the particles is evaluated in terms of flakiness index, elongation index and angularity number.

ELONGATION INDEX

This test is carried on aggregate of having particles larger than 6.3mm. Let a particle of aggregate passes through 20 mm sieve but retained on 10mm sieve. The mean size of this particles is (20+10)/2 = 15mm. When mean size (15 mm) is multiplied by 1.8, 27.00 mm size is obtained. Hence, a particle that is longer than 27 mm, for this particular range of size, is termed as elongated particle.

APPARATUS

The following apparatus is required,

c. A metal length gauge.
d. A balance accurate to 0.5% of the mass to the test sample.

SAMPLE FOR TEST

Aggregate passing through 63.0mm BS test sieve and retained on the 6.30mm BS test sieve.

PROCEDURE

1. A sample of aggregate to be tested is sieved through set of sieves (63.0mm, 50.0mm, 37.5mm, 28.0mm, 20.0mm, 14.0mm, 10.0mm, 6.3mm) and separated into specified size ranges.

2. The particles retained on each sieve are then made to pass through appropriate slot, (1.8 times the mean size) of standard length gauge.
3. The material that does not pass through the appropriate slot of the gauge is said to be elongated. The elongated material that has not passed through the appropriate slots of standard length gauge, for each size range of the test aggregate, are added up and weighted.

DATA TABLE

Sieve Size, mm		Wt. of the material retained, gm	Wt. of the elongated particles (amount retained), gm
Passing	Retained		
63.0	50.0		
50.0	37.5		
37.5	28.0		
28.0	20.0		
20.0	14.0		
14.0	10.0		
10.0	6.30		
x	x	W=	W1=

CALCULATIONS

Elongation Index is determined as follows,

W1/W x 100%

Where, W1= Weight of elongation material from whole test sample

W= Total weight of the sample

DISCUSSION

____

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB

WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-06: DETERMINATION OF ANGULARITY NUMBER

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 06

DETERMINATION OF ANGULARITY NUMBER

OBJECTIVE

The angularity number is determined from the proportion of voids in a sample of aggregate after compaction in the specified manner. This property is used mainly in the design of mix proportions and in research. Angularity or absence of rounding of the particles of an aggregate is a property which is of importance because it affects the ease of handling of a mixture of aggregate and binder (e.g. the workability of concrete) or the stability of mixtures that rely on the interlocking of the particles. The least angular (most rounded) aggregates are found to have about 33% voids and the angularity number is defined as the amount by which the percentage of voids exceeds 33. The angularity number ranges from 0 to about 12. The angularity number indicates the voids in excess of the voids in perfectly rounded gravel (33%). More angular is the aggregate the higher will be its angularity number.

SAMPLE FOR TEST

Aggregate passing through 20.00 mm BS test sieve and retained on the 5.00 mm BS test sieve.

APPARATUS

The following apparatus is required:

1. A metal cylinder closed at one end of about 0.003 m^3 volume, the diameter and height of which should be approximately equal (e.g. 150 mm and 150 mm). The cylinder shall be made from metal of a thickness not less than 3 mm and shall be of sufficient rigidity to retain its shape under rough usage.
2. Metal Tamping Rod: 16 mm in dia and 600 mm long with of circular cross section.
3. A balance or scale of capacity 10 kg, accurate to 1.
4. A metal scoop.
5. BS test sieves: 20.0 mm, 14.00mm, 10.00mm, 6.30mm, 5.0 mm.

PREPARATION OF THE TEST SAMPLE

The aggregate to be tested shall be dried for at least 24 hr in shallow trays in a well-ventilated oven at a temperature of 105 ±5^{0}C, cooled in an airtight container and tested.

TEST PROCEDURE

1. The aggregate sample is now filed in the metal cylinder in the three layers. Each layer being tamped 100 times with tamping rod 50 mm above the surface of the aggregate before the next layer is put.

2. The excess material is struck off at level with top of the cylinder.
3. The weight of the aggregate in the cylinder is determined.
4. Now cylinder is emptied and filled with water and weight of the water is determined.
5. The specific gravity of the Aggregate may be separately determined (Here, assume 2.7)

CALCULATIONS

Angularity Number is determined as follows,

$$\text{Angularity Number: } 67 - W \times 100/wG$$

Where, W = Weight of the aggregate filled in the cylinder.

w = Weight of the water filled in the cylinder.

G = Specific Gravity of the aggregate.

The angularity number shall be reported to the nearest whole number.

DISCUSSIONS

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB

WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-07: RESISTANCE TO DEGRADATION OF SMALL SIZE COARSE AGGREGATE BY ABRASION AND IMPACT OF THE LOS ANGLES MACHINE

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 07

RESISTANCE TO DEGRADATION OF SMALL SIZE COARSE AGGREGATE BY ABRASION AND IMPACT OF THE LOS ANGLES MACHINE

RELATED THEORY

Apart from testing aggregate with respect to its resistance to wear or degradation (hardness) is an important test for aggregate to be used for roads, and in floor surfaces subjected to heavy traffic. This test method covers a procedure for testing sizes of coarse aggregate smaller than 1.5in (37.5 mm) for resistance to degradation using the Los Angeles testing machine. This test has been widely used as an indicator of the relative quality or competence of various source of aggregate having similar mineral compositions. The test method conforms to the ASTM standard requirements of specification C131.

OBJECTIVE

Resistance to Degradation of small size course Aggregate by Abrasion and Impact of the Los Angeles Machine.

MATERIAL & EQUIPMENT

a) Los Angeles Machine: The machine shall consist of a hollow a steel cylinder, closed at both ends having an inside diameter of 28#0.2in(711#5 mm),and an inside length of 20#0.2in.(508#5 mm).The cylinder shall be mounted on stub shafts attached to the ends of the cylinder but not entering it, and shall be mounted in such a manner that it may be rotated with the axis in a horizontal position within a tolerance in slope of in 100.An opening in the cylinder shall be provided for the introduction of the test sample .A suitable, dust-tight cover shell be provided for the opening with means for bolting the cover in place. The cover shall be so designed as to maintain the cylindrical contour of the interior surface of the cylinder, in such a way that a plane centered between the large faces coincides with the axial plane .The shelf shall be not of such `thickness and so mounted, by bolts or other suitable means, as to be firm and rigid. The position of the shelf shall be such that cylinder in the direction of rotation, shall be not less than 50 in (1.27m). The machine shall be so driven and so counterbalanced as to maintain a uniform peripheral speed.

b) Sieves: conforming to the specifications for sieves for testing purposes.

c) Balance: Accurate within 0.1% of test load over the range required for the test.

d) Charge: The charge shall consist of steel spheres averaging approximately 1-27/32 in (46.8mm) in diameter and each weighing between 390 and 445g.

The charge depending upon the grading of the test sample shall be as follows.

Grading	Number of spheres	Weight of Charge, g
A	12	5000 ± 25
B	11	4584 ± 25
C	8	3330 ± 20
D	6	2500 ± 15

SAMPLING

The test sample shall be washed and oven- dried at 221 to 230 ---F (105 to 110 C) to substantially constant weight separated into individual size fractions, and recombined to the grading of Table-1 most nearly corresponding to the range of the aggregate as furnished for the work. The weight of the sample prior to test shall be recorded to the nearest 1g.

Table-1 Grading of Test Samples

Sieve Size (Square Openings)		Weight of Indicated Size, g			
Passing	Retained on	Grading			
		A	B	C	D
37.5mm(1.5in)	25.0mm(1in)	1250±25	……..	…….	……….
25.0mm(1in)	19.0mm(3/4in)	1250±25	………	……	……….
19.0mm(3/4in)	12.5mm(1/2in)	1250±10	2500±10	………..	………
12.5mm(0.5in)	09.5mm(3/8in)	1250±10	2500±10	……….	……..
09.5mm(3/8in)	06.3mm(1/4in)	…….	……..	2500±10	…….
06.3mm(1/4in)	04.75mm(No-4)	…..	……..	2500±10	5000±10
04.75mm(No-4)	02.36mm(No-8)	……..	……	……..	……
Total		5000±10	5000±10	5000±10	5000±10

EXPERIMENTAL PROCEDURE

Place the test sample and the charge in Los Angeles testing machine and rotate the machine at a speed of 30 to 33 rpm for 500 revolutions. After the prescribed number of revolutions, discharge the material from the machine and make a preliminary separation of the sample on a sieve coarser than the 1.70mm (NO.12). Sieve the finer portion on a 1.70mm sieve in a manner conforming to Method C 136. Wash the material coarser then the 1.70mm sieve, oven-dry at 221 to 230 F (105to110 C) to a substantially constant weight, and weight to the nearest 1g.

SAMPLE CALCULATION

Express the loss (difference between the original weight and the final weight) of the test sample. Report this value as the percent loss.

DATA SHEET

Sieve Size Passing	Sieve Size Retained	Wt. of Material, W_1	Grading of material	No of Steel Balls Used	Wt. Retained on No 12 Sieve, W_2(gm)	Total Wear (gm) W_1-W_2

CALCULATION

$$\text{Abrasion Value} = \frac{W_1 - W_2}{W_1} \times 100$$

RESULT

Abrasion Value =

DISCUSSION

____

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB

WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-08: SPECIFIC GRAVITY TEST ON BITUMINOUS MATERIALS

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 08

SPECIFIC GRAVITY TEST ON BITUMINOUS MATERIALS

OBJECTIVE

This method covers the determination of the specific gravity of semi-solid bituminous materials, asphalt cements, and soil tar pitches by use of a pycnometer.

The specific gravity of semi-solid bituminous materials, asphalt cements, and soft tar pitches shall be expressed as the ratio of the mass of a given volume of the material at 25^0 C(77^0 F) or at 15.6°C (60°F) to that of an equal volume of water at the same temperature, and shall be expressed thus:

Specific gravity, 25/25°C (77/770F) or 15.6/15.6°C (60/60°F)

APPARATUS

Pycnometer, glass, consisting of a cylindrical or conical vessel carefully ground to receive an accurately fitting glass stopper 22 to 26 mm in diameter. The stopper shall be provided with a hole 1.0 to 2.0 mm in diameter, centrally located in reference to the vertical axis. The top surface of the stopper shall be smooth and substantially plane and the lower surface shall be concave in order to allow all air to escape through the bore. The height of the concave section shall be 4.0 to 18.0 mm at the center. The stoppered pycnometer shall have a capacity of 24 to 30 ml, and shall weigh not more than 40 g.

Water Bath- Constant temperature, capable of maintaining the temperature within 0.1^0C (0.2^0F) of the test temperature.

Thermometers- Calibrated liquid-in-glass of suitable range with graduations at least every 0.2°F (0.1°C) and a maximum scale error of 0.2°F (0.1°C) as prescribed in ASTM specification on El. Thermometers commonly used are 63°F or 63°C. Any other thermometer of equal accuracy may be used.

Balance - a balance conforming to the requirements of M 231, Class B.

Materials- Distilled Water - Freshly boiled and cooled distilled water shall be used to fill the pycnometer and the beaker.

PREPARATION OF EQUIPMENT

Partially fill a 600 ml or larger Griffin low-form beaker with freshly boiled and cooled distilled water to a level that will allow the top of the pycnometer to be immersed to a depth of not less than 40 mm.

Partially immerse the beaker in the water bath to a depth sufficient to allow the bottom of the beaker to be immersed to a depth of not less than 100 mm, while the top of the beaker is above the water level of the bath. Clamp the beaker in place. Maintain the temperature of the water bath within 0.1°C (0.2°F) of the test temperature.

PROCEDURE

1. Thoroughly clean, dry, and weigh the pycnometer to the nearest 1 mg. Designate this mass as A.

2. Fill the pycnometer with freshly boiled distilled water at test temperature and place the stopper in the pycnometer. Do not allow any air bubbles to remain in the pycnometer.

3. Allow the pycnometer to remain in the water for a period of not less than 30 min. Remove the pycnometer, immediately dry the top of the stopper with one stroke of a dry towel (Note 1), then quickly dry the remaining outside area of the pycnometer and weigh to the nearest 1 mg. Designate the mass of the pycnometer plus water as B.

Note-1: Do not re-dry the top of the stopper even if a small droplet of water forms due to expansion. If the top is dried at the instant of removing the pycnometer from the water, the proper mass of the contents at the test temperature will be recorded. If moisture condenses on the pycnometer during weighing, quickly re-dry the outside of the pycnometer (excluding the top) before recording the mass.

Note-2: Calibration should be done at the specific temperature. A pycnometer calibrated at one temperature cannot be used at a different temperature without recalibration, at that temperature.

4. Preparation of Sample - Heat the sample with care, stirring to prevent local overheating, until the sample has become sufficiently fluid to pour. In no case should the temperature be raised to more than 56^0C (100°F) above the expected softening point for tar, or to more than 111°C (200°F) above the expected softening point for asphalt. Do not heat for more than 30 minutes over a flame or hot plate or for more than 2 hours in an oven, and avoid incorporating air bubbles in the sample.

5. Pour enough sample into the clean, dry, warmed pycnometer to fill it about three-fourth to its capacity. Take precautions to keep the material from touching the sides of the pycnometer above the final level, and to prevent the inclusion of air bubbles (Note 3). Allow the pycnometer and its contents to cool to ambient temperature for a period of not less than 40 minutes, and weigh with the stopper to the nearest 1 mg. designate the mass of the pycnometer plus sample as C.

Note-3: If any air bubbles are inadvertently included, remove by brushing the surface of the asphalt in the pycnometer with a high "soft" flame of a Bunsen burner. In order to avoid overheating, do not allow the flame to remain in contact with the asphalt more than a few seconds at any one time.

6. Fill the pycnometer with freshly boiled distilled water at test temperature and place the stopper in the pycnometer. Do not allow any air bubbles to remain in the pycnometer.

7. Allow the pycnometer to remain in the water bath for a period of not less than 30 minutes. Remove the pycnometer from the bath. Dry and weigh using the same technique as that employed in Procedure No.3. Designate this mass of pycnometer plus sample plus water as D.

DATA TABLE

Weight of Pycnometer, M_1

Weight of Pycnometer + Bitumen, M_2

Weight of Pycnometer + Bitumen + Water, M_3

Weight of Pycnometer + Water, M_4

Specific gravity of distilled water, G_T

CALCULATIONS

$$G_S = \frac{(M2 - M1)}{(M4 - M1) - (M3 - M2)} G_T$$

DISCUSSION

____
Signature of the Faculty

North South University
Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB
WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-09: SOFTENING POINT OF BITUMINOUS MATERIAL (RING AND BALL METHOD)

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 09

SOFTENING POINT OF BITUMINOUS MATERIAL

(RING AND BALL METHOD)

GENERAL

The ring and ball softening point is extensively used to evaluate the consistency of bituminous binders. It is a very simple one, consisting of placing a 3/8 in diameter steel ball on a binder sample placed in a steel ring and immersed in a water bath. Heat is applied to the water and its temperature is raised until a value is reached when the test sample has become sufficiently soft to allow the ball, enveloped in binder to fall down. The water temperature at which this occurs is called the ring and ball softening point.

The softening point is not a melting point; bituminous binders do not melt but instead gradually change from semi-solids to liquids on the application of heat. It is useful for determining the temperature susceptibilities of bitumen, which are to be used in thick films, such as in crack fillers. When two bitumen’s have the same penetration value, the one with the higher softening point is normally less susceptible to temperature changes.

STANDARDS

C 670 Practices for Preparing Precision Statements for Test Methods for Construction materials.

- E 1 Specification for ASTM Thermometers.
- T 40 Methods of Sampling Bituminous Materials.

OBJECTIVE

Determine the Softening Point of Bituminous Material by Ring and Ball Method.

APPARATUS AND MATERIALS

Ring- A brass ring of 15.875 mm (5/8 in) inside diameter, 6.35 mm (1/4 in) depth and thickness of wall is 2.38 mm (3/32 in). This ring shall be attached in a convenient manner to a brass with (diameter 1.85 mm = 0.072 in).

Ball- A steel ball 9.53 mm (3/8 in) in diameter having a mass of 3.50 ± 0.05 g.

Container- A glass vessel, not less than 8.5 cm (3.34 in) in diameter and measuring 10.5 cm (4.13 in.) in depth from the bottom of the flare (a 600 ml beaker, low form, meets this requirement).

Thermometer- ASTM Low softening point Thermometer having a range of -2 to +80°C or 30° to 180°F is specified.

Reagent- Freshly boiled distilled water, USP Glycerin or Ethyl Glycol, with a boiling point between 195 and 197°C (383 and 387°F).

PREPARATION OF SAMPLE

Melt and thoroughly stir the sample avoiding incorporating air bubbles in the mass and then pour it into the ring. The ring, while being filled, should rest on a brass plate, which has been amalgamated to prevent the bituminous material from adhering to it. Allow the excess material to cool for 1 hr then cut it off cleanly with a slightly heated knife.

PROCEDURE FOR MATERIALS HAVING SOFTENING POINTS 80^{0}C (176^{0}F) OR BELOW

- Fill the glass vessel to a depth of substantially 8.25 cm (3.25 in) with freshly boiled, distilled water at 5°C (41°F).

- Suspend the ring containing the sample in the water so that the lower surface of the filled ring is exactly 2.54 cm (1 in) above the bottom of the glass vessel and its upper surface is 5.08 cm (2 in) below the surface of the water.

- Place the ball in the water but not on the specimen.

- Suspend the thermometer so that the bottom of the bulb is level with the bottom of the ring and within 0.635 cm (3/4 in) but not touching the ring. Maintain the temperature of the water at 5°C (41°F) for 15 min.

- With suitable force, place the ball in the center of the upper surface of the bitumen in the ring, thus completing the assembly.

- Apply the heat in such a manner that the temperature of the water is raised 5°C (9°F) each minute.

SOFTENING POINT

Report the temperature recorded by the thermometer at the instant the bituminous material touches the bottom of the glass vessel as the softening point. No correction shall be made for emergent stem of the thermometer.

PROCEDURE FOR MATERIALS HAVING SOFTENING POINTS ABOVE 80^{0}C (176^{0}F)

Thermometer- an ASTM high softening point Thermometer having a range of 30 to 200 $^\circ$C or 85 to 392 $^\circ$F is specified Modifications for Hard Materials.

Employ the same procedure as described above except that U.S.P., Glycerin shall be used

instead of water, and the starting point of the Glycerin bath shall be 32 $^\circ$C (89.6 $^\circ$F). Bring the bath to this temperature and thoroughly agitate it, then place the apparatus and specimens in the bath, which shall be maintained, under agitation at the starting temperature for 15 min. In applying the heat, place the ring apparatus of the center of the container and place the burner midway between the center and edge of the beaker away from the specimen.

RESULT

Temperature when the ball touches bottom, ^{o}C =

Average =

Softening Point of Bituminous material =

DISCUSSION

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-10: DETERMINATION OF VISCOSITY OF ASPHALT BY ROTATIONAL VISCOMETER

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 10

DETERMINATION OF VISCOSITY OF ASPHALT BY ROTATIONAL VISCOMETER

GENERAL

This test method is used to measure the apparent viscosity of asphalts at handling, mixing, or application temperatures. The Rotational Viscometer (RV) is used to determine the viscosity of asphalt binders in the high temperature range of manufacturing and construction. This measurement is used in the Superpave performance grade asphalt binder specification. The RV test can be conducted at various temperatures, but since manufacturing and construction temperatures are fairly similar regardless of the environment, the test for Superpave performance grade asphalt binder specification is always conducted at 275°F (135°C).

The basic RV test measures the torque required to maintain a constant rotational speed (20 RPM) of a cylindrical spindle while submerged in an asphalt binder at a constant temperature. This torque is then converted to a viscosity and displayed automatically by the RV.

STANDARDS

The standard Rotational Viscometer procedure is found in:

- AASHTO T 316 and ASTM D 4402

OBJECTIVE

Viscosity Determination of Asphalt Binder Using Rotational Viscometer.

APPARATUS AND MATERIALS

1. Rotational Viscometer

2. Temperature-Controlled Thermal Chamber Heater

BASIC PROCEDURE

1. Preheat spindle, sample chamber, and viscometer environmental chamber (Thermosel) to 275°F (135°C).
2. Heat asphalt binder until fluid enough to pour. Stir the sample, being careful not to entrap air bubbles.
3. Pour appropriate amount of asphalt binder into sample chamber (Figure 8). The sample size varies according to the selected spindle (Figure 9) and equipment manufacturer.
4. Insert sample chamber into RV temperature controller unit and carefully lower spindle into sample

5. Bring sample to the desired test temperature (typically 275°F (135°C)) within approximately 30 minutes and allow it to equilibrate at test temperature for 10 minutes.
6. Rotate spindle at 20 RPM, making sure the percent torque as indicated by the RV readout remains between 2 and 98 percent
7. Once the sample has reached temperature and equilibrated, take 3 viscosity readings from RV display, allowing 1 minute between each reading. Viscosity is reported as the average of 3 readings.
8.

DATA SHEET

Spindle No.	Temperature ^{0}C	RPM	cP	log cP

GRAPH

Draw a graph log cP vs. Temperature.

RESULT

- Kinematic Viscosity =
- Compaction Temperature (log280) =
- Mixing Temperature (log170) =

DISCUSSION

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-11: FLASH AND FIRE POINTS OF BITUMINOUS MATERIAL (CLEVELAND OPEN CUP METHOD)

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 11

FLASH AND FIRE POINTS OF BITUMINOUS MATERIAL

(CLEVELAND OPEN CUP METHOD)

OBJECTIVE

This method describes a test procedure for determining the flash and fire points (Cleveland Open Cup Tester) of all petroleum products except fuel oils and those having an open cup flash below 175^0F. The flash point is the temperature at which a bituminous material, during heating, will evolve vapors that will temporarily ignites or flash when a small flame is brought in contact with them. The fire point is the temperature at which the evolved vapors will ignite and continue to burn.

To make the test, the material is heated in an open cup, and at intervals a small flame is applied near its surface. The lowest temperature at which application of the test flame causes the vapors to ignite is recorded as the flash point while the temperature at which the vapors ignited and burn for at least 5 seconds is recorded as the fire point. The flash and fire point test is purely a safety test. It indicates the maximum temperature to which the material can be safely heated.

APPARATUS

Cleveland Open Tester - The apparatus consists of the test cup, heating plate, test flame applicator, heater, and support.

Shield - A shield 18 inch (46 cm) square and 24 in, (61 cm) high, is recommended but not essential.

Thermometer - ASTM thermometer having a range of 20^0F to 760^0F (-6°C to + 400°C).

PROCEDURE

1. Clean the cup with an appropriate solvent and remove all gums, carbon deposit, and oxide coating from the inside of the cup with fine steel wool until a bright metallic surface is presented.

2. Support the thermometer in a vertical position with the bottom of the bulb 1/4 inch (0.635 cm) from the bottom of the cup and above a point halfway between the center and back of the cup.

3. Fill the cup at any convenient temperature so that the top of the meniscus is exactly at the filling line. When too much sample has been added to the cup, remove the excess, using a spoon or other suitable device; however, if there is sample on the outside of the apparatus, empty, clean. Destroy any air bubbles appear on the surface of the sample.

4. Light the test flame and adjust it to a diameter of 1/8 to 3/16 in. (0.08 cm).

5. Apply heat initially so that the rate of temperature rise of the sample is 25 to 30^0F (13.9 to 16.7°C) per minute. When the sample temperature is approximately 100°F (56^0C) below the anticipated flash point, decrease the heat so that the rate of temperature rise for the last 50^0F (27.8°C) before the flash point is 10 + 1°F (5.5 + 0.6°C) per minute.

6. Record as the flash point the temperature read on the thermometer when a flash appear at any point on the surface of the sample but do not confuse the true flash with the bluish halo that sometimes surrounds the test flame.

7. To determine the fire point, continue heating so that the sample temperature increases at rate of 10 ± 1°F (5.5 ± 0.6^0C) per minute. Continue the application of the test flame at 5^0F (2.8°C) intervals until the vapor ignites and continues to burn for at least 5 sec. Record the temperature at this point as the fire point.

CALCULATION AND REPORT

Observe and record the barometric pressure at the time of the test. When the pressure differs from 760 mm Hg, correct the flash or fire point, or both, by means of the following equations:

- Corrected flash or fire point, or both = F + 0.06(760-P) or
- Corrected flash or fire point, or both = C + 0.03(760-P) Where:

F = observed flash or fire point, or both, to the nearest 5°F

C = observed flash or fire point, or both, to the nearest 2°C.

P = barometric pressure, mm Hg.

Observe Flash Point

Observe Fire Point

DISCUSSION

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-12: PENETRATION OF BITUMINOUS MATERIAL

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 12

PENETRATION OF BITUMINOUS MATERIAL

OBJECTIVE

This test method covers determination of the penetration of semi-solid and solid bituminous materials. Materials having penetrations below 350 can be tested by the standard apparatus and procedure described. Materials having penetrations between 350 and 500 can be determined using the special apparatus and modifications. This is the most widely used method of measuring the consistency of a bituminous material at a given temperature. It is a means of classification rather than a measure of quality. The engineering term consistency is an empirical measure of the resistance offered by a fluid to continuous deformation when it is subjected to shearing stress.

The penetration test is used as a measure of consistency. Higher values of penetration indicate softer consistency.

APPARATUS

Penetration Apparatus - Any apparatus permitting movements of the spindle without appreciable friction and which is accurately calibrated to yield results in accordance with the description of the term penetration will be acceptable. The surface on which the sample container rests shall be flat and the axis of the plunger shall be at approximately 90 degrees to this surface. The spindle shall be detachable without the use of special toots, for checking its mass. When the needle is mounted in a ferrule, the mass of the moving spindle shall be 47.5 ± 0.05 g. Regardless of the type of mounting of the needle, the total mass of the needle and spindle assembly shall be 50.0 ± g. Weights of 50.0 ± 0.05 g and 100.0 ± 0.05 g shall be provided for total loads of 100 g and 200 g (0.9 N and 2 N), depending upon the conditions of test to be applied.

Needle- The needle shall be made from fully hardened and tempered stainless steel, grade 440 C or equal HRC 54 to 60. It shall be approximately 50 mm (2 in.) in length and 1.00 to 1.02 mm (0.039 to 0.040 in) in diameter.

Container- A container, in which the sample is tested, made of metal or glass cylindrical in shape, and having a flat bottom. The container to be used for materials having a penetration of 200 or less shall have a nominal capacity of 3 oz (90 ml). Its inside dimensions shall be essentially as follows: 55 mm (2.17 in) in diameter and 35 mm (1.38 in) in depth. The container to be used for materials having a penetration over 200 shall have a nominal capacity of 6 oz (175 ml). Its inside dimensions shall be essentially as follows: 70 mm (2.75 in) in diameter and 45 mm (1.77 in) in depth.

Water Bath - A water bath maintained at a temperature varying not more than 0.1°C (0.2°F) from the temperature of the test. The volume of water shall not be less than 10 liters. The bath shall have a perforated shelf supported in a position not less than 50 mm from the bottom of the bath and not less than 100 mm below the liquid level in the bath. The water in the bath shall be substantially free from oil and slime or other organic growth. Brine may be used in the water bath for determinations at low temperatures. If penetration tests are to be made without removing the sample from the bath, a shelf strong enough to support the penetration apparatus shall be provided.

NOTE 1- The use of distilled, dematerialized or demonized water is recommended for the bath. Care should be taken to avoid contamination of the bath water by surface active agents, release agents or other chemicals as their presence may affect the penetration values obtained.

Transfer Dish for Container- When used; the transfer dish for the container shall be a cylinder with a flat bottom made of glass, metal or plastic. It shall be provided with some means, which will ensure a firm bearing and prevent rocking of the container. It shall have a minimum inside diameter of 90 mm (3.5 in) and a minimum depth above the bottom bearing of 55 mm (2.17 in).

Thermometers for Water Bath- Calibrated Liquid-in-glass thermometers of suitable range with subdivisions and maximum scale error of 0.1°C (0.2°F) or any other thermometric device of equal accuracy, precision, and sensitivity shall be used.

Timing Device- For hand-operated penetrometers any convenient timing device such as an electric timer, a stopwatch, or other spring-activated device may be used provided it is graduated in 0.1 second or less and is accurate to within ± 0.1 second for a 60 second interval. An audible second counter adjusted to provide 1 beat each 0.5 second may also be used. The time for a count interval must be 5±0.1 second. Any automatic timing device attached to a penetrometer must be accurately calibrated to provide the desired test interval within ± 0.1 second.

Heater- An oven or hot plate, heated by electricity or gas, shall be provided for heating samples.

PREPARATION OF SAMPLE

Heat the sample with care to prevent local overheating until it has become fluid. Then with constant stirring, raise the temperature of the asphalt sample not more than 100°C or l80°F above its expected softening point or the tar pitch sample not more than 56°C or 100°F above its softening point determined in accordance with the Method of test for Softening Point of Bituminous Materials (Ring and Ball Method), T 53. Avoid the inclusion of air bubbles. To reach the pouring temperature, do not heat the softened sample more than 30 minutes.

Then pour it into the sample container to a depth such that, when cooled to the temperature of test the depth of the sample is at least 10 mm greater than the depth to which the needle is expected to penetrate. Pour separate samples for each variation in test conditions.

Loosely cover each container and its contents as a protection against dust and allow to cool in an atmosphere at a temperature not higher than 30°C or 86°F and not lower than 20°C or 68°F for not less than 1-1/2 hours nor more than 2 hours when the sample is in a 175 ml (6 oz) container and for not less than 1 nor more than 1-1/2 hours when the sample is in a 90 ml (3 oz) container. Then place the sample in the water bath maintained at the prescribed temperature of test, along with the transfer dish if used, and allow it to remain for not less than 1-1/2 hours nor more than 2 hours when the sample is in the 175 ml (6 oz) container, and for not less than 1 nor more than 1-1/2hours when the sample is in a 90 ml (3 oz) container.

TEST CONDITIONS

Where the conditions of test are not specifically mentioned, the temperature, load, and time are understood to be 25°C (77°F), 100 g, 5 second, respectively. Other conditions of temperature, load and time may be used for special testing, such as:

Temperature	Load, g	Time, Sec
0^0C/(32°F)	200	60
4^0C/(39.2°F)	200	60
46.1^0C/(115F)	50	5

In such cases, the specific conditions of test shall be reported.

PROCEDURE

Examine the needle holder and guide to establish the absence of water and other extraneous matter. Clean a penetration needle with toluene or other suitable solvent, dry with a clean cloth, and insert the needle in the penetrometer. Unless otherwise specified, place the 50 g weight above the needle, making the total load of 100 g ± 0.1g for the needle and attachment. If tests are made with the penetration apparatus mounted in the bath, place the sample container directly on the submerged stand of the penetration apparatus. If tests are made with the sample in the bath and the penetration apparatus outside the bath, place the containers on the shelf provided in the bath. In the above procedures the container shall be kept completely submerged during the complete test. If tests are made using the transfer dish with the penetration apparatus outside the bath, place the sample in a dish filled with water from the bath to a depth to cover completely the sample container. Then place the transfer dish containing the sample on the stand on the penetration apparatus and penetrate immediately. In each case, adjust the needle loaded with the specified weight to just making contact with the surface of the sample. Accomplish this by making contact of the actual needle point with its image reflected by the surface of the sample from a properly placed source of light (Note 2). Either note the reading of the dial or bring the pointer to zero. Then quickly release the needle for the specified period of time and adjust the instrument to measure the distance penetrated. Observe the sample container as the needle is applied, and if any movement of the container is noted, ignore the result.

NOTE 2- The positioning of the needle can be materially aided by using an illuminated methyl methacrylate rod.

Make at least three penetrations at points on the surface of the sample not less than 10 mm (3/8 in) from the side of the container and not less than 10 mm (3/8 in) apart. If the transfer dish is used, return the dish and sample to the water bath after each penetration. Before each test, clean the needle with a clean cloth moistened with toluene or other suitable solvent to remove all adhering bitumen, and then wipe with a clean dry cloth. For penetration values greater than 200, use at least three needles, leaving them in the sample until completion of the penetrations.

The needles, containers, and other conditions described in this method provide for determinations of penetrations up to 350. However, the method may be used for direct determinations up to 500 provided special containers and needles are used. The container shall be at least 60 mm in depth. The overall volume of material in the container should not exceed 125 ml to permit proper temperature adjustment of the sample.

Specially made needles for such determination shall meet all the requirements of Section 6.2 for dimensions and weight except that the minimum exposed length of the needle shall be 50 mm.

An approximation of the penetration of such high penetration materials may also be obtained by determining the penetration using the standard needle and 6 oz container but with a 50 g loading. The penetration is then calculated by multiplying the result for the 50 g load by the square root of 2. That is:

Penetration under 100g load = (Penetration under 50g load) x 1.414

The report of results obtained by this procedure shall indicate the basis of the test.

REPORT

Report to the nearest whole unit the average of at least three penetrations whose values do not differ by more than the amount shown:

Penetration	0-49	50-149	150-249	≥ 250
Maximum difference between highest and lowest determinations	2	4	6	8

If the appropriate tolerance is exceeded, ignore all results and repeat the test.

DATA SHEET

No. of Observation	Penetration	Average Penetration

DISCUSSION

Signature of the Faculty

North South University

Department of Civil and Environmental Engineering

CEE 250L TRANSPORTATION ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO-13: ADVANCED ASPHALT CEMENT BINDER CHARACTERIZATION

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 13

ADVANCED ASPHALT CEMENT BINDER CHARACTERIZATION

By: Prof. Dr. Javed Bari

INTRODUCTION

Asphalt cement is one of the oldest engineering materials. Its adhesive and waterproofing properties were known at the dawn of civilization back in around 6000 B.C. in Sumeria. Worldwide over 95% roads have asphalt surface. As the main function of the asphalt cement in a pavement is to bind aggregates, it is often known as "asphalt cement binder", "AC binder" or simply "binder" in the pavement industry. Unfortunately, the chemical properties of asphalt are so complex that historically AC binder has been characterized by its physical properties. The conventional tests of asphalt usually test consistency, durability, purity, safety, specific gravity etc. often using empirical test methods. With the recent advancement in the AC binder characterization techniques, fundamental rheological properties of the binder have become very important to ensure targeted pavement performances.

CHARACTERIZATION PARAMETERS

AC binder characterization parameters are as follows:

1. Aging behavior (unaged, short-term and long-term aging).
2. Low medium temperature properties described by Penetration (15°C-25°C);
3. Medium high temperature properties described by Softening Point (40°C-70°C);
4. High temperature properties described by Viscosity (100°C-180°C);
5. Intermediate to high temperature properties described by Complex Shear Modulus and Phase Angle (35°C-70°C);
6. Low temperature Creep Stiffness (0°C or below); and
7. Low temperature fracture behavior described by Tensile Strength (0°C or below).

CHARACTERIZATION TESTS

Advanced AC binder characterization tests are as follows:

1. **Rolling Thin Film Oven (RTFO):** Used for short-term aging;
2. **Pressure Aging Vessel (PAV):** Used for mid-term and long-term aging;
3. **Penetration Test:** Used to characterize low medium temperature properties (15°C-25°C) - the penetration value is converted to viscosity using a model;
4. **Softening Point Test:** Used to characterize medium high temperature properties described by Softening Point (40°C-70°C) - the viscosity at softening point temperature is taken as 13,000 Poise;
5. **Rotational Viscosity Test:** Used to characterize high temperature properties described by Viscosity (100°C-180°C);

6. **Dynamic Shear Rheometer (DSR):** Used to characterize intermediate to high temperature properties described by Complex Shear Modulus (G*) and Phase Angle (δ) between 35°C-70°C;
7. **Bending Beam Rheometer (BBR):** Used to characterize low temperature Creep Stiffness (0°C or below); and
8. **Direct Tension Test (DTT):** Used to characterize low temperature fracture behavior described by Tensile Strength (0°C or below).

ROLLING THIN FILM OVEN (RTFO) TEST

Scope

This test simulates the asphalt aging occurred during the blending and agitation in the hot mixing facility and during construction. This procedure exposes the thin binder films to heat and air in designated test environment.

Test Apparatus

A double-walled electrically heated convection type oven is used and is shown in Figure 3.1. Other apparatus are the flow meter, thermometer, glass container and balance.

Test Method

The sample is heated to a fluid at or below 163^{o}C (325^{o}F). Thirty five (35 ± 0.5) grams of this liquefied binder is poured into each container, cooled to room temperature and the containers are arranged in the carriage so that the carriage is balanced (Figure 3.1). The carriage assembly is then rotated at 15 ± 0.2 rpm with air flow rate of 4000 ± 300 miles per min. Thus the moving film of asphalt binder is heated and oxidized i.e. aged in the oven for 85 minutes at 163^{o}C (325^{o}F). The effects of aging are determined from changes in physical test values as measured before and after the oven treatment.

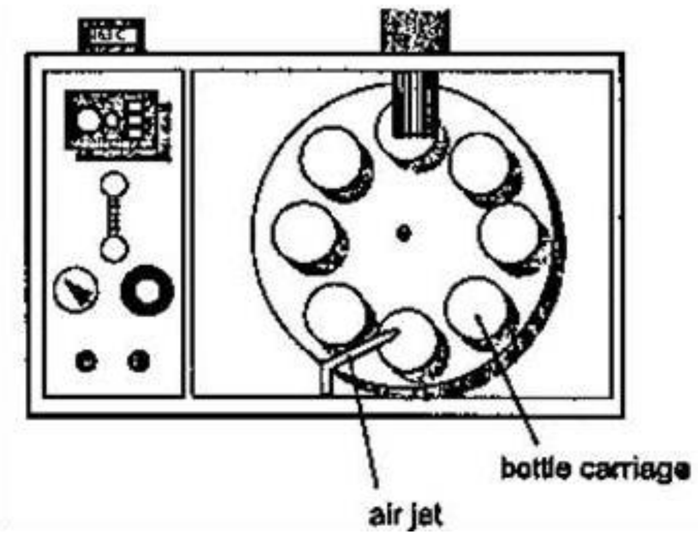

FIGURE 1 Rolling Thin Film Oven

Significance and Use

This test simulates the asphalt aging occurred during the blending and agitation in the hot mixing facility and during construction. This test indicates approximate change in properties of asphalt binder during conventional hot mixing at about 150^{o}C (302^{o}F) as indicated by viscosity measurements. It yields a residue that approximates the binder condition as incorporated in the pavement.

PRESSURE AGING VESSEL (PAV) TEST

Scope

This test covers the accelerated aging (oxidation) of asphalt binders by means of pressurized air and elevated temperature. It simulates the in-service oxidative aging of asphalt binders that occurs in the pavement as a result of the combined effects of time, traffic and the environment. This test is intended for use with residue from RTFO test.

Test Apparatus

The PAV test system is shown in Figure 3.2. This system consists of Pressure Vessel, pressure and temperature controlling device and a vacuum system.

Test Method

The asphalt binder is first aged using the RTFOT (T-240). A specified thickness of residue from RTFOT is then placed in the Thin Film Oven Test (T-179) stainless steel pans. It is then aged at the specified aging temperature for 20 hours in a vessel pressurized with air to 2.10 MPa. The aging temperature is selected according to the grade of the asphalt binder. At completion of the PAV process, the asphalt binder residue is vacuum degassed.

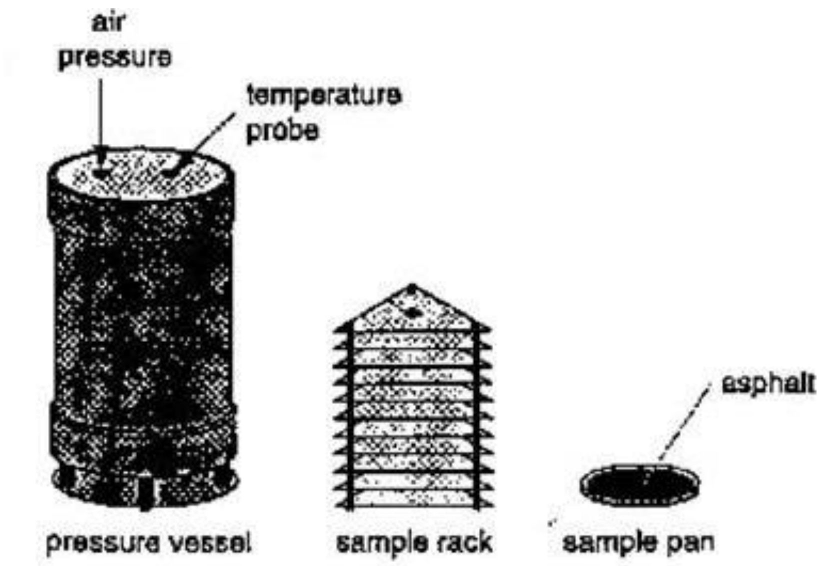

FIGURE 2 Pressure Aging Vessel

Significance and Use

This test is designed to simulate the in-service oxidative aging of asphalt binders that occurs in the pavement during its service period. Residue from this test may be used to estimate the physical or chemical properties of asphalt binders after five to ten years of in-service aging in the field. Asphalt binders aged in the PAV are used to determine specification properties in accordance with Performance Grading (AASHTO MP1-98). For asphalt binders of different grades or from different sources there is no unique correlation between the aging time and temperature in PAV and in-service pavement age and temperature. So, for a given set of in-service climatic conditions it is not possible to select a single PAV aging time and temperature that will predict the properties of all asphalt binders after a specific set of in-service exposure conditions. The relative degree of hardening of different asphalt binders varies at different aging temperatures in the PAV. So, two asphalt binders may age similarly at one temperature but age differently at another temperature.

DYNAMIC SHEAR RHEOMETER TEST

Scope

This test covers the determination of the dynamic shear modulus, G* and the phase angle, δ of asphalt binder when tested in dynamic (oscillatory) shear using parallel plate test geometry. It is applicable to asphalt binders having dynamic shear modulus values in the range from 100 Pa to 10 MPa. This range in modulus is typically obtained between 5°C and 85°C for most conventional binders.

Definitions

Complex Shear Modulus (G^*) is the ratio calculated by dividing the absolute value of the peak-to-peak shear stress (τ) by the absolute value of the peak-to-peak shear strain(γ). Phase Angle (δ) is the angle in degrees between a sinusoidally applied strain and the resultant sinusoidal stress in a controlled-strain testing mode or between the applied stress and the resultant strain in a controlled-stress testing mode.

Background

There are two types of dynamic shear rheometers: controlled stress and controlled strain. Superpave binder tests are conducted in the controlled stress mode. In the DSR operation asphalt is "sandwiched" between two parallel plates, one that is fixed and one that oscillates (see Figure 3.4). As the plate oscillates, the centerline of the plate at point A (indicated by the dark vertical line) moves to point B. From point B, the plate centerline moves back and passes point A to point C. From point C the plate centerline moves back to point A. This oscillation is one cycle and is continuously repeated during the DSR operation. The speed of oscillation is frequency. All Superpave DSR binder tests are performed at a frequency of 10 radians per second, which is equal to approximately 1.59 Hz (cycle per second).

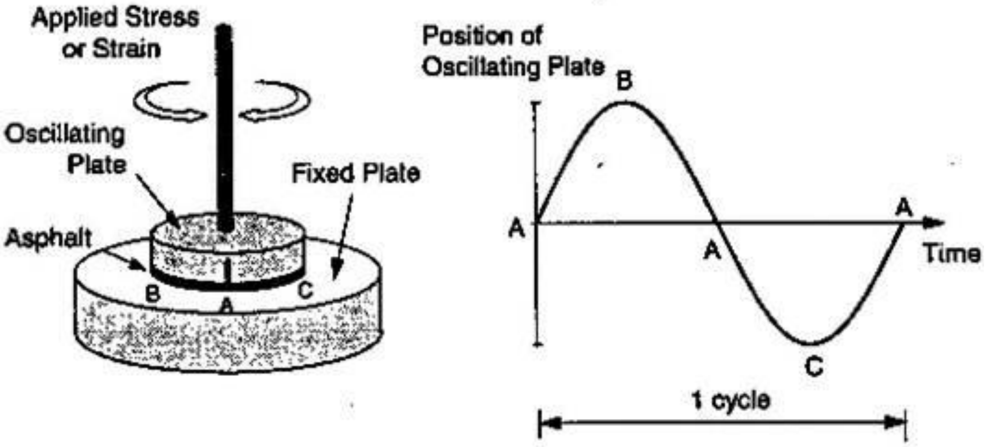

FIGURE 3 Dynamic Shear Rheometer Operation

The DSR is used to characterize both viscous and elastic behavior by measuring the complex shear modulus (G*) and phase angle (δ) of asphalt binders. G* is a measure of the total resistance of a material to deformation when exposed to repeated pulses of shear stress. It consists of two components: elastic (recoverable) and viscous (non-recoverable). δ is an indicator of the relative amounts of recoverable and non-recoverable deformation. The value of G* and δ for asphalt binders are highly dependent on the temperature and frequency of loading. At high temperatures, asphalt binders behave like a viscous fluid with no capacity for recovering or rebounding. In this case, the binder could be represented by the vertical axis (viscous component only) in Figure 3.5; there would be no elastic component of G^*_A or G^*_B, since the phase angle δ is 90°. Again at very low temperatures, AC binders behave like elastic solids that rebound from deformation completely. This condition is represented by the horizontal axis (elastic component only). In that case, there is no viscous component of G^*_A or G^*_B, since δ = 0°. Under normal pavement temperature and traffic loading, asphalt binders act with the characteristics of both viscous liquid and elastic solid. It may be noticed from Figure 3.5 that even if the values of complex shear modulus for asphalt A and B are same (i.e. $|G^*_A| = |G^*_B|$), the visco-elastic behavior may be very different due to different phase angle (δ) values. By measuring G* and δ, the DSR provides a more complete picture of the behavior of AC binders at pavement service temperatures.

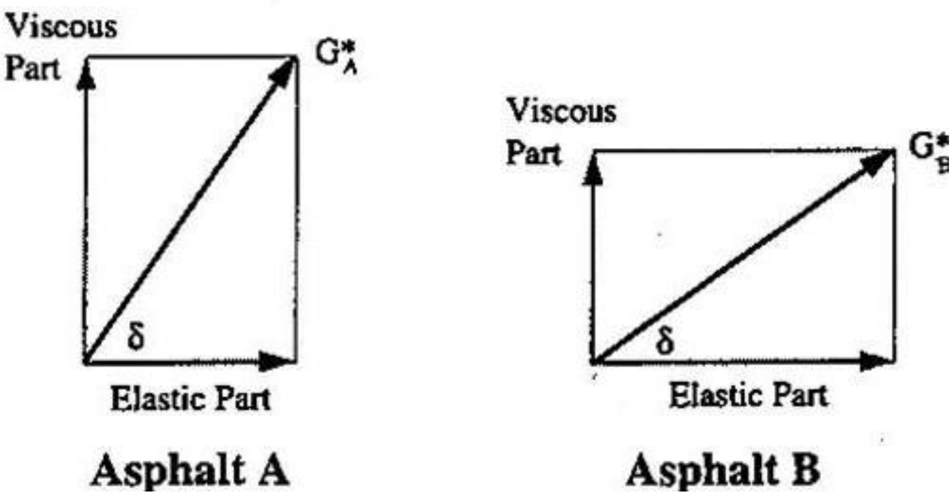

FIGURE 4 Determination of Asphalt Behavior by DSR

Test Apparatus

The Dynamic Shear Rheometer (DSR) System consists of test plates, environmental chamber, loading device, control and data acquisition system, specimen mold (optional), specimen trimmer and a calibrated temperature detector.

Test Method

Test specimens 1 mm thick by 25 mm in diameter or 2 mm thick by 8 mm in diameter are formed between parallel metal plates. During testing, one of the parallel plates is oscillated with respect to the other at pre-selected frequencies and rotational deformation amplitudes (or torque amplitudes). The required amplitude depends upon the value of the complex shear modulus of the asphalt binder being tested. These amplitudes are selected to ensure that measurements are within the region of linear behavior. The test specimen is maintained at the test temperature to within ± 0.1°C by positive heating and cooling of the upper and lower plates. Oscillatory loading frequencies using this standard can range from 1 to 100 rad/s using a sinusoidal wave form. Specification testing is performed at a test frequency of 10 radians per second, which is equal to approximately 1.59 Hz (cycles per second). The complex shear modulus and the phase angle are calculated automatically as part of the rheometer using proprietary computer software supplied by the equipment manufacturer. Original (i.e. tank) binders and RTFO aged binders are tested at strain values of about 10% to 12%. PAV-aged binders are tested at strain values of about 1%. In all cases, strain values must be small enough that the response of the binders (i.e. G* value) remains in the linear viscoelastic range. In this range, G* is virtually unaffected by changes in strain level.

<u>Significance and Use</u>

The DSR measures the rheological properties (complex shear modulus and phase angle) at intermediate to high temperatures experienced by the pavement in the geographical area for which the asphalt binder is intended. The DSR test provides stiffness behavior of asphalt binders over a wide range of temperatures. Two forms of G* and δ are used in the binder specification. Permanent deformation is governed by limiting the G*/sinδ at the test temperatures to values greater than 1.00 kPa for original binder and 2.20 kPa after RTFO aging. Fatigue cracking is governed by limiting G*sinδ of PAV aged material to values less than 5000 kPa at the test temperature.

BENDING BEAM RHEOMETER TEST

<u>Scope</u>

The Bending Beam Rheometer (BBR) test is used to evaluate binder properties accurately at low temperatures. It measures how much a binder deflects or creeps under a constant load at constant temperature. This temperature is related to a pavement's lowest service temperature. The test method uses beam theory to calculate the flexural creep stiffness or compliance of an asphalt binder under a creep load. This test is applicable to materials having creep stiffness values from 20 MPa to 1 GPa and can be used with asphalt binders having aging conditions of: Tank, RTFOT or PAV. The test apparatus is designed for testing within the temperature range from –36 ^{o}C to +22^{o}C. This test gives the Flexural Creep Stiffness, S(t) and m-values at different loading time and temperatures. Flexural Creep Stiffness is the ratio obtained by dividing the maximum bending stress in the beam by the maximum bending strain. The m-value is the absolute value of the slope of the logarithm of stiffness curve versus the logarithm of time.

<u>Background</u>

At low temperatures, asphalt binders are too stiff to reliably measure the properties using the parallel plate geometry of DSR. The BBR measures how much a binder deflects or creeps under a constant load at a constant temperature. The test is usually performed on binders that have been aged in the both rolling thin film oven (RTFO) and pressure aging vessel (PAV). The creep load simulates thermal stresses that gradually build up in a pavement when temperature drops. Creep stiffness is the resistance of the asphalt binder to creep loading and the m-value is the change in asphalt stiffness with time during loading. The desired value of creep stiffness is when the asphalt has been loaded for two hours at the minimum pavement temperature. However, using the concept of *time-temperature superposition*, SHRP researcher confirmed that by raising the test temperature 10^{o}C, equal creep stiffness could be obtained after only a 60 second loading. The obvious benefit is that a test result can be measured in a much shorter testing time.

Test Apparatus

The Bending Beam Rheometer (BBR) Test System, shown in Figure 3.6, includes loading frame, cell and LVDT, controlled temperature fluid bath, data acquisition system, temperature measuring equipment, test beam molds, stainless steel beams, standard masses, calibrated thermometers and thickness gauge.

Test Method

A test beam is placed in the controlled temperature fluid bath and loaded with a constant load for 240 seconds. The test load is 980 ± 50 mN. This load and the midpoint deflection of the beam are monitored versus time using a computerized data acquisition system. The maximum bending stress at the midpoint of the beam is calculated from the dimensions of the beam, the span length and the load applied to the beam for loading times of 8, 15, 30, 60, 120 and 240 seconds. The maximum bending strain in the beam is calculated for the same loading times from the dimensions of the beam and the deflection of the beam. The stiffness of the beam for the loading times specified above is calculated by dividing the maximum stress by the maximum strain.

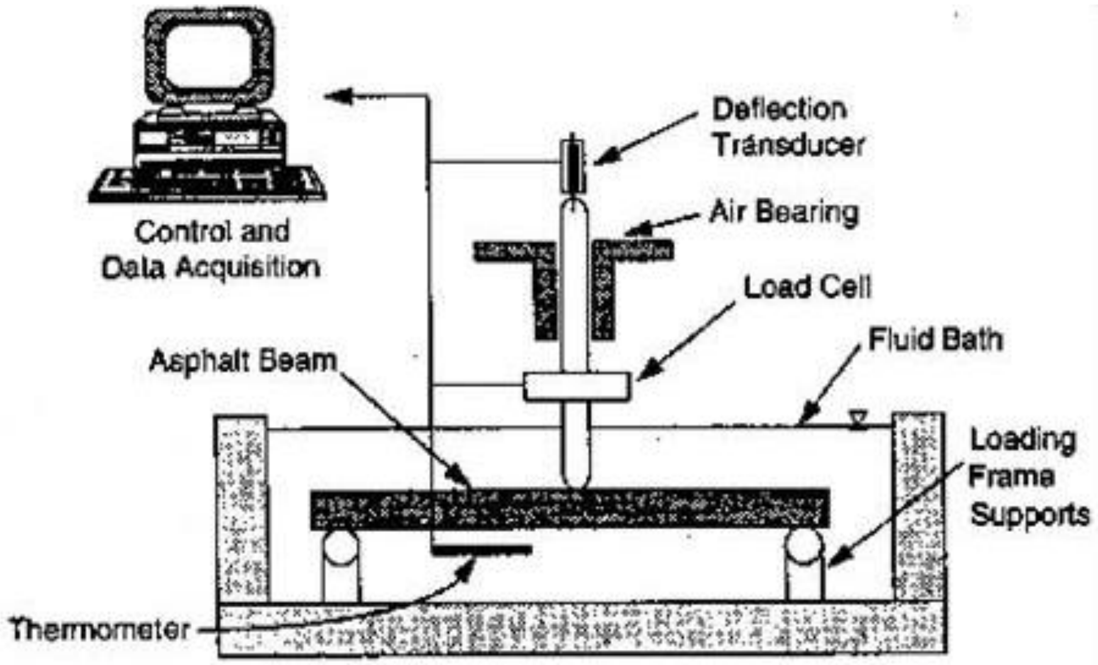

FIGURE 5 Schematic Diagram of BBR Test

Significance and Use

The test temperature is related to the lowest temperature experienced by the pavement in the geographical area for which the asphalt binder is intended. The flexural creep stiffness determined from this test describes the low temperature stress-strain-time response of asphalt binder at the test temperature within the linear viscoelastic response range.

The low temperature thermal cracking performance of paving mixtures is related to the creep stiffness and the m-value. These stiffness and m-values are used as performance-based specification criteria for asphalt binders.

In the PG (Performance Grade) grading system, the BBR test is used to establish the limiting temperature at 6°C shifts at which the stiffness modulus value is below 300 Pa and the slope m-value is below 0.3. For grading purposes, the binder is used in the RTFO plus PAV aged condition. The BBR may, however, be used to get the stiffness at the lowest pavement temperatures for binders in all stages (original, RTFO aged, RTFO + PAV aged) and used for comparison among the various binders tested or to evaluate influence of aging conditions on binder properties. Thus the BBR results may be used as a powerful tool for evaluation of binder properties at low temperature.

DIRECT TENSION TEST

Scope

The Direct Tension (DT) test is used to measure the ultimate low temperature tensile strength of an asphalt binder. The test is performed at low temperatures ranging from 0°C to –36°C, the temperature range within which asphalt exhibits brittle behavior. Furthermore, the test is performed in binders that have been aged both in the RTFO and PAV. Consequently, the test measures the performance characteristics of binders as if they had been exposed to hot mixing in a mixing facility and some in-service aging.

Background

Numerous studies of low temperature behavior of asphalt binders have shown that there is a strong relationship between stiffness of asphalt binders and the amount of elongation they undergo before breaking. Asphalts that undergo considerable stretching before failure are called “ductile”; those that break without much stretching are called “brittle”. It is important that an asphalt binder be capable of a minimal amount of elongation at specified low temperatures. Typically, stiffer binders are more brittle and softer binders are more ductile. Creep stiffness values, as measured by the BBR, are not adequate to completely characterize the capacity of asphalt binders to stretch before breaking. For example, a binder that exhibits high creep stiffness may also stretch farther before breaking. So according to the Superpave specifications, such a binder may be allowed to have a relatively high creep stiffness if it can show reasonably ductile behavior at low test temperature. This additional requirement is applicable to only to those binders having BBR creep stiffness between 300 and 600 MPa. If the creep stiffness is below 300 MPa, this additional requirement and direct tension testing does not apply.

Test Apparatus

The test apparatus include Universal Testing Machine, gripping system, elongation measuring system (usually a laser micrometer) and an environmental chamber (for maintaining specific low temperatures).

Test Method

Test specimens are formed in a silicone rubber mold. The dog-bone shaped mold allows fabrication of four specimens. These four specimens are used to produce one test result. Mold and specimen dimensions are shown in Figure. After the specimens are poured, trimmed and demolded, they must be tested within 60 ± 10 minutes. A tensile load is applied until the specimen fails. Average strain to failure of four specimens forms a single test result.

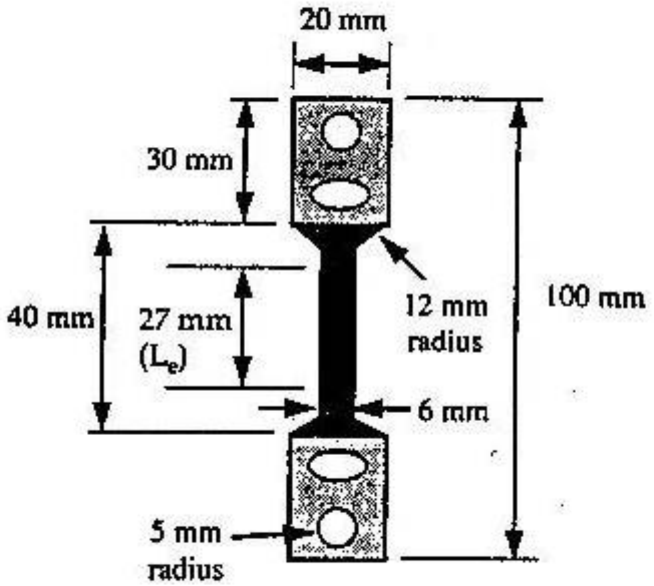

FIGURE 6 Direct Tension Specimen Dimensions

Significance and Use

The low temperature thermal cracking performance of paving mixtures is related to the creep stiffness and ductility of the binder. The creep stiffness alone, as measured by the BBR, is not adequate to completely characterize the capacity of asphalt binders to stretch before breaking. So according to the Superpave specifications, a binder may be allowed to have a relatively high creep stiffness if it can show reasonably ductile behavior at low-test temperatures. The Direct Tension test verifies such behavior.