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Transportation First Midterm Lab

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Chapter 4

AGGREGATE IMPACT VALUE TEST

4.1 INTRODUCTION

Aggregates play an important role in the design and construction of highway and air filed pavements. They are also major part of rigid (concrete) and flexible (asphalt) pavements.

Aggregate is a combination of sand, gravel, crushed stone, or other material of mineral composition. Aggregate may be classified as natural or manufactured natural aggregates are taken from natural deposits without change in their nature during production, with the exception of crushing, sizing, grading or washing. Manufactured aggregates include blast furnace slag, clay, slate and lightweight aggregates. Further, the aggregates could be classified as fine and coarse. According to ASTM C125, fine aggregate is defined as aggregate passing no-4 (4.75 mm) sieve and retained on no. 200 (75 Micron m) sieve.

Fig. 4.2 Fine Aggregate

Figure 4.1 Coarse Aggregate

Coarse aggregate is defined as aggregate retained on no. 4 (4.75 Micron m) sieve.

Aggregates used in road construction should be strong enough to resist crushing under traffic wheel loads. If the aggregates are weak, the stability of the pavement structure is likely to be adversely affected.

Toughness is the property of a material to resist impact. Due to traffic loads, the road stones are subjected to the pounding action or impact and there is possibility of stones breaking into smaller pieces. The road aggregates should therefore be tough enough to resist fracture under impact.

In this test, a test specimen is compacted, in a standardized manner, into an open steel cup. The specimen is then subjected to a number of standard impacts from a dropping weight. This action breaks the aggregate to a degree which is dependent on the impact resistance of the material. This degree is assessed by sieving the impacted specimen and is taken as are aggregate impact value (AIV).

4.2 OBJECTIVE

To determine the aggregate impact value of the given aggregate sample.

4.3 APPARATUS

i. Impact testing machine, the machine consists of a metal base with a plane lower surface supported well on a firm floor. A detachable cylindrical cup, a metal hammer capable of sliding freely between vertical guides, and fall concentric over the cup. There is an arrangement for raising the hammer and allowing it to fall freely between vertical guides from a height of 38 cm in the test sample cup. A key is provided for supporting the hammer while fastening or removing the cup (Fig. 4.1).

ii. A cylindrical measure.

iii. Tamping rod.

iv. BS sieve size 14 mm, 10 mm and 2.36 mm.

v. Balance, oven, rubber mallet, metal tray and brush, etc.

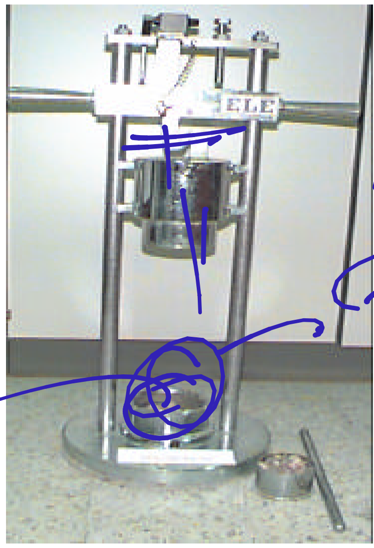

Figure 4.1 Aggregate Impact Testing Machine

4.4 PROCEDURE

1. The test sample consists of the aggregates passing 14 mm and retained of 10 mm sieve. Wash the sample and dry at 100° to 110°C for four hours and cool to room temperature.

2. Fill the cylindrical measure by the aggregate sample to in three equal layers, each layer being given 25 tampings. Struck off the samples aggregate by tamping rod weigh and record the mass of the sample (M1).

3. Place the impact testing machine with its bottom plate flat on the floor so that hammer guides are vertical, fix the cup firmly in its position on the base of the machine and transfer the entire sample in the cup and compact it 25 times.

4. Raise the hammer and allow it to fall freely on the aggregates. The sample is subjected to a total of 15 such blows, each being delivered at an interval of not less than one second.

5. Remove the crushed aggregate from the cup and sieve from 2.36 mm sieve. The fraction passing the sieve is weighed (M2). The fraction retained on the sieve is also weighed (M3). If M2 + M3 differs from M1 by more than 1 g discard the results and repeat the test.

4.5 CALCULATIONS

The aggregate impact value is expressed as the percentage of the fines formed in terms of the total weight of the sample

$$\text{Aggregate Impact Value (AIV)} = \frac{100\,M_2}{M_1}$$

Where:
M1 = Mass of the test specimen
M2 = Mass of the test specimen passing 2.36 mm test sieve

REFERENCES

British Standard Methods of four determination of aggregate impact value (AIV). B.S. 812: Part 112: 1990.
Harold N. Atkins, Highway Materials, Soils and Concretes, 3rd Edition, Prentice Hall Inc
Kenneth N. Derucher and George P. Korfiatis, Materials for civil d and highway engineers , Prentice Hall, NJ, 2nd edition, 1988.
Harold N. Attkins, Highway materials, soils, and concretes, 3rd edition, Prentice Hall, 1990.
Freddy L. Roberts, Prithivi S. Khandal et. al Hot Mix Asphalt Materials, Mixtures, Design and construction NAPA Foundation Maryland 199.
Garber and Hoel, Traffic and Highway Engineering, 1990.

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OBSERVATION SHEET

Aggregate Impact Test

S. #	Details	Trial Number 1	Trial Number 2	Average
1.	Total weight of aggregate sample filling the cylindrical measure = M_1 g			
3.	Weight of aggregate retained on 2.36 mm sieve after the test = M3 g			
2.	Weight of aggregate passing 2.36 mm sieve after the test = M_2 g = M1-M3			
4.	Aggregate impact value = percent fines = $100 \frac{M_2}{M_1}$ %			

Data Analysis and Interpretation:

Experimental data used to determine the AIV are presented in Table 1 below.

Table1: Aggregate Impact Value test data

Details	Data
Total weight of aggregate sample filling the cylindrical measure = M1 g	386.7 g
Weight of aggregate retained on 2.36 mm sieve after the test = M3 g	341.1 g
Weight of aggregate passing 2.36 mm sieve after the test = M2 g = M1-M3	45.6 g
Aggregate impact value = percent fines = 100(M2/M1) %	11.792 %

Aggregate impact value (AIV) found to be 11.792%.

The aggregate impact value was 11.792% that considered to be strong and satisfactory for road surfacing.

Appendix:

M2=M1-M3 = 386.7-341.1 = 45.6 g

Aggregate impact value = percent fines = 100(M2/M1) % = 100*(45.6/386.7) = 11.792%

Acceptable Range of Values for Tests on Aggregates

Crushing Value

Not more than 30% - For surface layers
Not more than 45% - For other layers

Aggregate Impact Value

Less than 10% - Exceptionally strong
10% - 20% - Strong
10% - 30% - Satisfactory for road surfacing

Los Angeles Abrasion Value

Less than 25% - For base course
Less than 30% - General use

Shape test

Flakiness Index - Max. 15%
Elongation Index - Max. 15%

Figure 3: Acceptable range of values for tests on aggregate

AGGREGATE CRUSHING VALUE TEST

5.1 INTRODUCTION

The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied compressive loads. In this test an aggregate specimen is compacted in a standardized manner into a steel cylinder fitted with a freely moving plunger. The specimen is then subjected to a standard loading applied through the plunger. This action crushes the aggregate to a degree which is dependent on the crushing resistance of the material. This degree is assessed by a sieving test on the crushed aggregate and is taken as a measure of the aggregate crushing value (ACV).

5.2 OBJECTIVE

To determine the aggregate crushing value (ACV) of the given aggregate sample.

5.3 APPARATUS

i. Steel cylinder with open ends; square base plate, plunger of piston diameter 15 cm.

ii. Cylindrical measure.

iii. Steel tamping rod

iv. Balance.

v. Compression testing machine capable of applying 400 kN at the rate of 40 kN/min.

vi. Test sieves 14.0, 10.0 and 2.36 mm size.

vii. Metal tray, brush, etc.

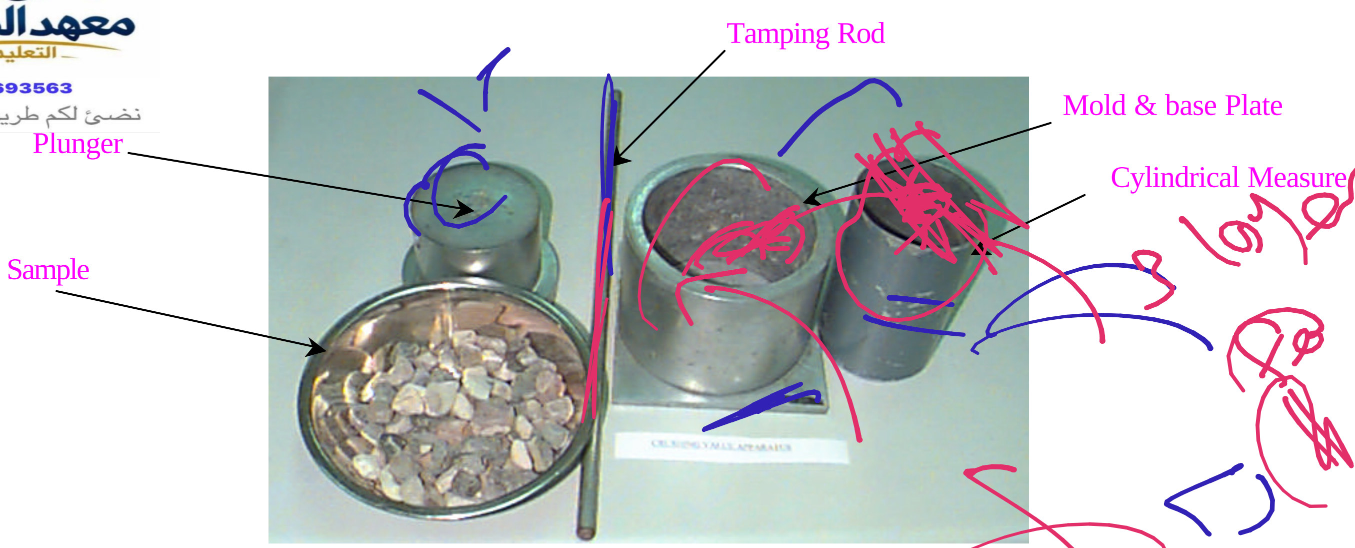

Fig. 5.1 Crushing Value Apparatus

5.4 PROCEDURE

1. The aggregate passing 14 mm and retained on 10 mm BS sieve is selected for standard test. The aggregate is washed, heated at 100°C to 110°C for 4 hours and then cooled to room temperature before test.

2. The cylindrical measures is filled by the test sample of aggregate in three layers, each layer being tamped by tamping rod. After the third layer, level the cylinder by tamping rod. Weight the sample (M1g).

3. The cylinder of the test apparatus is placed in position on the base plate and add the test specimen in three layers of approximately equal depth, each layer being subjected to 25 strokes by tamping rod. Carefully level the surface and insert the plunger so that it rests horizontally.

4. Place the cylinder between the platens of testing machine and apply the load of 400 kN in 10 min.

5. Release the load and remove the crushed aggregate and sieve through 2.36 mm BS sieve and find the mass of the material passing the sieve.

5.5 CALCULATIONS AND RESULTS

Mass of test specimen = M1 g

Mass of material passing 2.36 mm sieve = M2 g

$$\text{Aggregate Crushing Value (ACV)} = \frac{M_2}{M_1} \times 100$$

Report the average ACV

REFERENCES

British Standard Methods for determination of aggregate crushing value BS 812, Part 110, 1990.
Kenneth N. Derucher and George P. Korfiatis, Materials for civil and highway engineers, Prentice Hall, NJ, 2nd edition, 1988.
Harold N. Attkins, Highway materials, soils, and concretes, 3rd edition, Prentice Hall, 1990.
Freddy L. Roberts, Prithivi S. Khandal et. al Hot Mix Asphalt Materials, Mixtures, Design and construction NAPA Foundation Maryland 1991
Asphalt Institute Amnual Series 2 (MS-2) Mix design methods for Asphalt Concrete 1988

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OBSERVATION SHEET

Aggregate Crushing Value Test

S. #	Details	Trial Number		Average
		1	2	
1.	Total weight of aggregate sample filling the cylindrical measure = M_1 g			
3.	Weight of aggregate retained on 2.36 mm sieve after the test = M3 g			
2.	Weight of aggregate passing 2.36 mm sieve after the test = M_2 g = M1-M3			
4.	Aggregate impact value = percent fines = $100 \frac{M_2}{M_1}$ %			

Nomenclature

ACV: Aggregate crushing value

BS: sieve size (mm)

M1: Mass of the test specimen (g)

M2: Mass of the test specimen passing 2.36 mm test sieve (g)

M3: Mass of the test specimen retained on 2.36 mm test sieve (g)

T: temperature degree (°C)

%: percentage

Data Analysis and Interpretation:

Table 1 below presents the data collected during the aggregate crushing value test performed in the laboratory.

Table 1: Data of aggregate crushing value test

Details	Data
Total weight of aggregate sample filling the cylindrical measure = M1g	3089 g
Weight of aggregate retained on 2.36 mm sieve after the test = M3g	2741.9 g
Weight of aggregate passing 2.36 mm sieve after the test = M2g= M1-M3	347.1 g
Aggregate impact value = percent fines = 100 M2/M1 %	11.24%

The aggregate impact value was 11.24% which is acceptable for both surface and other layers.

11.24% < 30% for surface layers
11.24% < 45% for other layers

Appendix:

M2= M1-M3 = 3089-2741.9=347.1 g

Percent fines = 100M2/M1 % =100 *(347.1/3089) =11.24%

Highway Materials Lab.

Acceptable Range of Values for Tests on Aggregates

Crushing Value

Not more than 30% - For surface layers
Not more than 45% - For other layers

Aggregate Impact Value

Less than 10% - Exceptionally strong
10% - 20% - Strong
10% - 30% - Satisfactory for road surfacing

Los Angeles Abrasion Value

Less than 25% - For base course
Less than 30% - General use

Shape test

Flakiness Index - Max. 15%
Elongation Index - Max. 15%

Figure 2: Acceptable range of values for tests on aggregate.

Chapter 6

ABRASION VALUE TEST

6.1 INTRODUCTION

Due to the movements of traffic, the road aggregates are subjected to wearing action. Resistance to wear or hardness is an essential property of road aggregates, especially when used in wearing course. Therefore the aggregates should be hard enough to resist abrasion due to traffic. Abrasion test on aggregates are generally carried out by any one of the following methods:

1. Los Angeles abrasion test
2. Deval Abrasion test
3. Dorry Abrasion test

The Los Angeles Abrasion test is more common and is applicable in Kuwait.

The Los Angeles test is a measure of degradation of mineral aggregates of standard grading resulting from a combination of actions including abrasion, attrition, impact and grinding in a rotating steel drum containing, a specified number of steel spheres, the number depending upon the grading of test sample. As the drum rotates, a shelf plate picks up the sample and steel spheres carrying them around until they are dropped to the opposite side of the drum, creating an impact crushing effect. The contents then roll with in the drum with an abrading and grinding action until the shelf plate impacts and cycle is separated. After the prescribed number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss.

6.2 OBJECTIVE

To determine the Los Angeles abrasion value of the given aggregate sample.

6.3 APPARATUS

1. Los Angeles machine: consists of a hollow steel cylinder, closed at both ends, having inside diameter 70 cm and inside length 50 cm, mounted on slab shafts about which it rotates on a horizontal axis (Figure 6.1).

2. Abrasive charge: Consists of cast iron spheres approximately 4.7 cm in diameter and 390 to 445 g in weight. The number of spheres used depends in sample grading (Table 6.1).

3. Sieves, balance, etc.

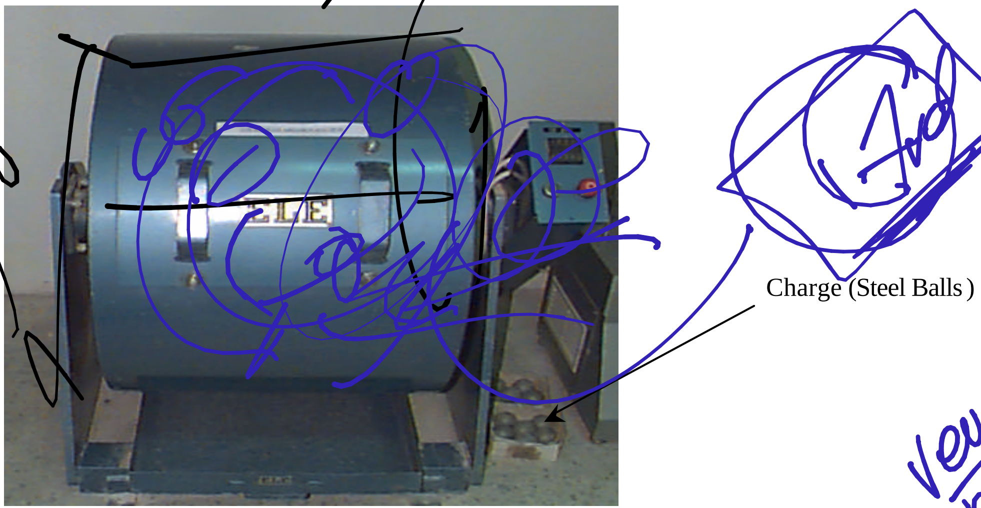

Fig. 6.1 Los Angeles Machine

6.4 PROCEDURE

1. Wash the test sample conforming to any of the sample grading (Table 6.1) and dry at 105-110°C to constant weight. Take the weight of the sample in gm (W1).
2. Place the sample in the cylinder along with the specified change. Fix the cover of the machine and rotate it at a speed of 30 to 33 rpm for 500 revolutions.
3. Discharge the material from the machine and make a preliminary separation of the sample on a sieve courses than 1.70 mm. Sieve the finer portion in a 1.70 mm sieve.
4. Wash the material coarser than 1.70 mm and over dry at 105-110°C to constant weight weigh in gm (W2).

6.5 CALCULATIONS

Original weight of the sample	=	W1 gm.
Weight of aggregate retained on 1.70 mm sieve of the test	=	W2 gm.
Los Angeles abrasion value	=	$\frac{W_1 - W_2}{W_1} * 100$

The result of the Los Angeles Abrasion value is expressed as a percentage wear and the average value of two tests may be adopted.

REFERENCES

ASTM – C131-90. *Standard Test Method for resistance to Degradation of small-size coarse aggregate by abrasion and impact in Los Angeles Machine.*

Harold N. Atkins, *Highway Materials, Soil & Concretes, Prentice Hall Inc. 1987.*

AASHTO – T96-87.

Web page., www.mastrad.com/psvdoc.htm

Table 6.1 Grading of Test Samples

Sieve Size (Square Openings)		Weight of Indicated Sizes, g			
Passing	Retained on	Grading			
		A	B	C	D
37.5 mm (1½ in)	25.0 mm (1 in)	1 250 ± 25	--	--	--
25.0 mm (1 in)	19.0 mm (¾ in)	1 250 ± 25	--	--	--
19.0 mm (¾ in)	12.5 mm (½ in)	1 250 ± 10	2 500 ± 10	--	--
12.5 mm (½ in)	9.5 mm (3/8 in)	1 250 ± 10	2 500 ± 10	--	--
9.5 mm (3/8 in)	6.3 mm (¼ in)	--	--	2 500 ± 10	--
6.3 mm (¼ in)	4.75 mm (No.4)	--	--	2 500 ± 10	--
4.75 mm (No.4)	2.36 mm (No.8)	--	--	--	5 000 ± 10
Total		5 000 ± 25	5 000 ± 10	5 000 ± 10	5 000 ± 10
No. of Spheres		12	11	8	6
Wt. of Charge (g)		5 000	4584	3330	2500

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DATA SHEET

Los Angeles Abrasion Test

i) Type aggregate =
ii) Grading =
iii) # of spheres used =
iv) Weight of charge =
v) # of revolution =

	Test	Number	Average Value
	1	2	
1. Weight of specimen = W_1 g			
2. Weight of specimen after abrasion test, coarser than 1.70 mm IS sieve = W_2 g			
3. Percentage wear = $\frac{(W_1 - W_2)}{W_1} * 100$			

Nomenclature

- L: Length (cm)
- Percentage %
- Revelation (rev)
- T: Temperature (°C)
- W1: Weight of specimen (g)
- W2: Weight of specimen after abrasion test, coarser than 1.70 mm IS sieve (g)

Data Analysis and Interpretation:

- Type aggregate = Gravel
- Grading = B
- # of spheres used = 11
- Weight of charge = 4584g
- # of revolution = 500rev

Table 1 shows the outcome of an abrasion test used to assess aggregate abrasion value. It records the specimen's initial weight, the weight retained after abrasion, and the calculated percentage wear. In essence, the table provides a straightforward measure of how much material was lost during the test, reflecting the resistance of the aggregate to wear.

Table1: Los Angeles abrasion data

	Value
1. Weight of specimen = W1g	5000 g
2. Weight of specimen after abrasion test, coarser than 1.70 mm IS sieve = W2 g	4384.3 g
3.percentage wear = [W1-W2)/W1] *100	12.314%

Table 1 shows the data of the Los angles abrasion test. The percentage wear was 12.314% which is accepted for both base course and general use.

Appendix:

Sample Calculation:

Percentage wear = [(W1-W2)/W1] *100= [(5000-4384.3)/5000] *100=12.314%

Table 2: Grading of Test Sample

Sieve Size (Square Openings)		Weight of Indicated Sizes, g			
Passing	Retained on	Grading			
		A	B	C	D
37.5 mm (1½ in)	25.0 mm (1 in)	1 250 ± 25	--	--	--
25.0 mm (1 in)	19.0 mm (¾ in)	1 250 ± 25	--	--	--
19.0 mm (¾ in)	12.5 mm (½ in)	1 250 ± 10	2 500 ± 10	--	--
12.5 mm (½ in)	9.5 mm (3/8 in)	1 250 ± 10	2 500 ± 10	--	--
9.5 mm (3/8 in)	6.3 mm (¼ in)	--	--	2 500 ± 10	--
6.3 mm (¼ in)	4.75 mm (No.4)	--	--	2 500 ± 10	--
4.75 mm (No.4)	2.36 mm (No.8)	--	--	--	5 000 ± 10
Total		5 000 ± 25	5 000 ± 10	5 000 ± 10	5 000 ± 10
No. of Spheres		12	11	8	6
Wt. of Charge (g)		5 000	4584	3330	2500

Highway Materials Lab.

Acceptable Range of Values for Tests on Aggregates

2 *Crushing Value*

Not more than 30% - For surface layers
Not more than 45% - For other layers

1 *Aggregate Impact Value*

Less than 10% - Exceptionally strong
10% - 20% - Strong
10% - 30% - Satisfactory for road surfacing

Los Angeles Abrasion Value

Less than 25% - For base course
Less than 30% - General use

Shape test

Flakiness Index - Max. 15%
Elongation Index - Max. 15%

Figure 2: Acceptable range of values for test on aggregate

Chapter 7

SHAPE TEST

7.1 INTRODUCTION

The particle shape of aggregates is determined by the percentages of flaky and elongated particles. Flaky and elongated particles are considered undesirable as they cause weakness of the pavement. Rounded aggregates are preferred in cement concrete pavements as the workability of concrete improves. A regular shape of particles are desirable for granular base course due to increased stability desired from better interlocking. When the shape of aggregates deviates more from the spherical shape, as in the case of angular, flaky and elongated aggregate, the void content increases and hence the grain size distribution of the aggregates has to be suitably altered in order to obtain minimum voids in the dry mix on the maximum density.

7.2 OBJECTIVE

To determine the flakiness and elongation indices of the given aggregate sample.

7.3 FLAKINESS INDEX

Aggregate particles are classified as flaky when they have a thickness (smallest dimension) of less than 0.6 of their mean sieve size. The flakiness index of an aggregate sample is found by separating the flaky particles and expressing their mass as a percentage of the mass of the sample tested. This test is not applicable to aggregate passing 6.30 mm sieve and retained as 63.0 mm sieve.

7.3.1 Apparatus

Metal thickness gauge (Fig. 7.1)
Test sieves, balance, trays, etc.

Fig. 7.1 Shape Test Apparatus

7.3.2 Procedure

1. The sieve sample with sieves mentioned in Table 7.1. Weigh each of the individual size fractions (w_1, w_2, w_3, …) retained on these sieves, other than the 63.0 mm sieve and store them in separate trays marked with their size.

2. Gauge each fraction from the respective slots in the thickness gauge weigh pieces which pass through the slots (x_1, x_2, x_3, …. etc.).

7.3.3 Calculations and Results

$$\text{Flakiness index} = \frac{(x_1 + x_2 + x_3 \ldots)}{(w_1 + w_2 + w_3 + \ldots)} \times 100$$

Where x_1, x_2, … etc. are the weight of the fractions passing from the thickness gauge. w_1, w_2, …, etc. are the weight of the original sample retained as the corresponding sieves.

7.4 ELONGATION INDEX

Aggregate particles are classified as elongated when they have a length (greatest dimension) of more than 1.8 of their mean sieve size, the elongation index is found by separating the elongated particles and expressing their mass as a percentage of the mass of sample tested. The test is not applicable to material passing 6.30 mm sieve or retained on 50 mm sieve.

7.4.1 Apparatus

Metal length gauge (Fig. 7.1). Test sieves, balance, trays, etc.

7.4.2 Procedure

1. Sieve the sample with sieves mentioned in Table (7.2) weight each of the individual size fractions (w_1, w_2, w_3, … etc.) retained on these sieves other than the 50.0 mm sieve.

2. Gauge each fraction as follows, select the length gauge appropriate to the single fraction under test and gauge each particle separately by hand. Elongated particles are those whose greatest dimension prevents them from passing through the gauge. Weigh each fraction which doesn't pass through the gauge (y_1, y_2, … etc.).

7.4.3 Calculation and Results

$$\text{Elongation index} = \frac{(y_1 + y_2 + y_3 \ldots)}{(w_1 + w_2 + w_3 + \ldots)} \times 100$$

where: y_1, y_2, y_3, … weight of the fractions not passing through the length gauge w_1, w_2, w_3, … are the weight of the original sample on the corresponding sieve.

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OBSERVATION SHEET

Aggregate Shape Test

Size of aggregates		Weight of the fraction consisting of at least 200 pieces, g	Weight of aggregates in each fraction passing thick-ness gauge, g	Weight of aggregates in each fraction retained on length gauge, g
Passing through IS sieve, mm	Retained on IS sieve, mm			
(1)	(2)	(3)	(4)	(6)
63	50	$W_1 = \ldots\ldots$	$x_1 = \ldots\ldots$	$y_1 = \ldots\ldots$
50	37.5	$W_2 = \ldots\ldots$	$x_2 = \ldots\ldots$	$y_2 = \ldots\ldots$
37.5	28	$W_3 = \ldots\ldots$	$x_3 = \ldots\ldots$	$y_3 = \ldots\ldots$
28	20	$W_4 = \ldots\ldots$	$x_4 = \ldots\ldots$	$y_4 = \ldots\ldots$
20	14	$W_5 = \ldots\ldots$	$x_5 = \ldots\ldots$	$y_5 = \ldots\ldots$
14	10	$W_6 = \ldots\ldots$	$x_6 = \ldots\ldots$	$y_6 = \ldots\ldots$
10	6.3	$W_7 = \ldots\ldots$	$x_7 = \ldots\ldots$	$y_7 = \ldots\ldots$
Total				

Flakiness index (FI) $= \dfrac{(x_1 + x_2 + x_3 \ldots)}{(W_1 + W_2 + W_3 + \ldots)} \times 100\% = \dfrac{100\,w}{W}\%$

Elongation index (EI) $= \dfrac{(y_1 + y_2 + y_3 \ldots)}{(W_1 + W_2 + W_3 + \ldots)} \times 100\% = \dfrac{100\,x}{W}\%$

Table 7.1. Data for Determination of Flakiness Index

Aggregate size fraction BS test sieve nominal aperture size		Width of slot in thickness Gauge or special sieve[1]	Minimum mass for subdivision
100 % passing	100 % retained		
mm	mm	mm	kg
63.0	50.0	33.9 ± 0.3	50
50.0	37.5	26.3 ± 0.3	35
37.5	28.0	19.7 ± 0.3	15
28.0	20.0	14.4 ± 0.15	5
20.0	14.0	10.2 ± 0.15	2
14.0	10.0	7.2 ± 0.1	1
10.0	6.30	4.9 ± 0.1	0.5

[1] This dimension is equal to 0.6 times the mean test sieve size.

Table 7.2. Data for Determination of Elongation Index

Aggregate size fraction Test sieve		Gap between Pins of length Gauge[2]	Minimum mass for subdivision
100 % passing	100 % retained		
mm	mm	mm	kg
50.0	37.5	78.7 ± 0.3	35
37.5	28.0	59.0 ± 0.3	15
28.0	20.0	43.2 ± 0.3	5
20.0	14.0	30.6 ± 0.3	2
14.0	10.0	21.6 ± 0.2	1
10.0	6.30	14.7 ± 0.2	0.5

[2] This dimension is equal to 1.8 times the mean test sieve size.

REFERENCES

British Standards Methods of determination of particle shape BS 812, Part 105, 1989.

Kenneth N. Derucher and George P. Korfiatis, Materials for civil and highway engineers, Prentice Hall, NJ, 2nd edition, 1988.

Harold N. Attkins, Highway materials, soils, and concretes, 3rd edition, Prentice Hall, 1990.

Nomenclature

- EI: Elongation Index
- FI: Flakiness Index
- L: Length (mm)
- Percentage %
- W: Weight of the fraction consisting of at least 200 pieces (g)
- x: Weight of aggregate in each fraction passing through the thickness gauge (g)
- y: Weight of aggregate in each fraction retained on the length gauge (g)

Data Analysis and Interpretation:

Table 3 below presents the results of shape testing for coarse aggregates. It outlines sieve sizes, fraction weights, and the portions passing or retained on gauges. In essence, the table provides a concise overview of how aggregate particles of different sizes behave in shape tests, highlighting their distribution and suitability for construction use.

Table 3: Aggregate shape test data

Size of aggregate		Weight of the fraction consisting of at least 200 pieces, g	Weight of aggregate in each fraction passing thick-ness gauge, g	Weight of aggregate in each fraction retained on length gauge, g
Passing through IS sieve, mm	Retained on IS sieve, mm			
(1)	(2)	(3)	(4)	(5)
50	37.5	W2=965.4	X2=204.6	Y2=541.2
37.5	28	W3=467.6	X3=43.3	Y3=107.3
28	20	W4=197.4	X4=50	Y4=27
20	14	W5=97.1	X5=14.6	Y5=0
14	10	W6=38.1	X6=9.7	Y6=0
10	6.3	W7=23.1	X7=3.9	Y7=2.4
Total		1788.7	326.1	677.9

Flakiness index (FI) = 18.231%
Elongation index (EI) = 37.899%

Table 3 shows the data of aggregate shape test. The flakiness index was 18.231% and the elongation index was 37.899%, so the sample is rejected for both flakiness index and elongation index.

Appendix:

Sample Calculation:

Flakiness index (FI) = (total x / total W) *100%= (326.1/1788.7) *100=18.231%

Elongation index (EI) = (total y / total W) *100%= (677.9/1788.7) *100=37.899%

Highway Materials Lab.

Acceptable Range of Values for Tests on Aggregates

Crushing Value

Not more than 30% - For surface layers
Not more than 45% - For other layers

Aggregate Impact Value

Less than 10% - Exceptionally strong
10% - 20% - Strong
10% - 30% - Satisfactory for road surfacing

Los Angeles Abrasion Value

Less than 25% - For base course
Less than 30% - General use

Shape test

Flakiness Index - Max. 15%
Elongation Index - Max. 15%

Figure 2:Acceptable range of values for tests on aggregate

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5

1.1 INTRODUCTION

Traffic volume studies are conducted to collect data on the number of vehicles and/or pedestrians that pass a point on a highway facility during a specified time period. This time period varies from as a little as 15 min. to as much as a year, depending on the purpose of the survey. The data collected may also be put in such class like directional movement occupancy rates and vehicle classification. The following traffic volume characteristics may be collected from Traffic volume studies.

a) Average Annual Daily traffic. (AADT)_ is the average of 24-hr counts collected every day in the year. AADT may be useful in estimation of highway user revenues, computation of accident rate, established of volume trends and for improvement and maintenance programs.

b) Average Daily Traffic (AADT) is the average of 24-hour counts collected over a number of days greater than, but less than a year ADT may be used for planning of highway activities, measurement of current demand and evaluation of existing traffic flow.

c) Peak hour volume (PHV) is the maximum number of vehicles that pass a point on a highway during a period of 60 consecutive minutes. PHVs are used for functional classification on highways, geometric design, traffic operations and management.

d) Vehicle miles of Travel (VMT)_ is a measure of travel along a section of road. It is the product of the traffic volume and the length of roadway in miles or kilometers to which the volume is applicable. VMTs are used mainly as a base for maintenance and improvement decisions.

1.2 OBJECTIVES

1. To determine the peak hour volume and composition (Vehicle mix) at the given location (mid-block) of a given road/street.
2. To determine turning movement volume at a given intersection.

1.3 METHODS OF VOLUME COUNT

a) Manual Method: This method consists in a person recording each vehicle by making tally marks on the field data sheet.

b) Automatic methods: This method involves the laying of surface detectors (such as pneumatic road tubes) or surface detectors (such as magnetic or electric contact devices) on the road. These detect the passing vehicle and transmit the information to a recorder, which is connected to the detector at the side of the road. Pneumatic road tubes are employed by counters like those from PEEK Inc. (Figure 1.1, Figure 1.2), and magnetic detectors are used by Hi-star NC-97 from Nu-Metrics Figure (1.2), turning movements study at an intersection is conducted using Jamar Technologies Traffic Counter

Fig. 1.1 PEEK Model 241 Counter

Figure 1.2 ADR 3000 Counters from PEEK

Figure 1.3 Numetrics Count Card

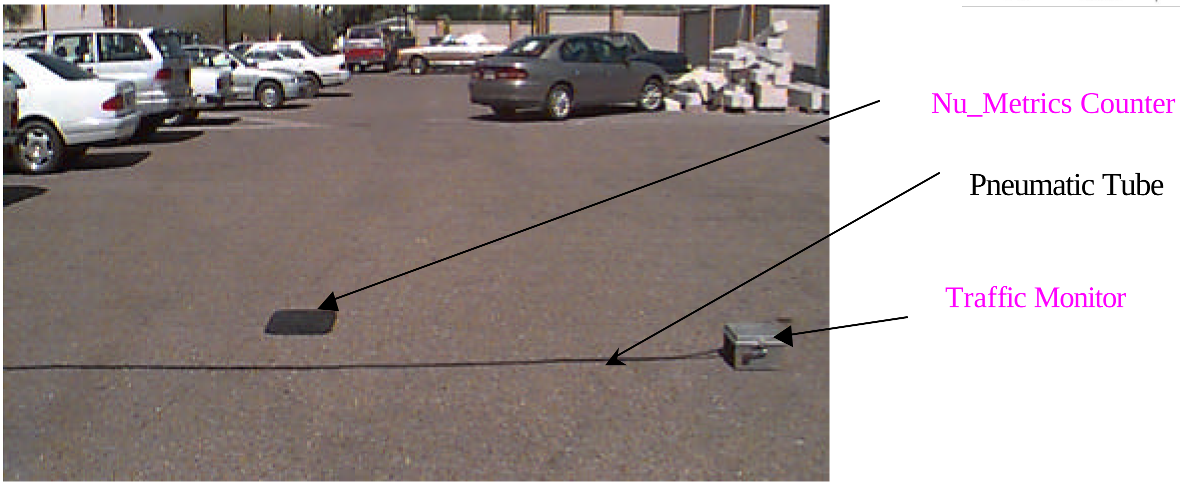


Figure 1.4 Tube and Count Card Systems

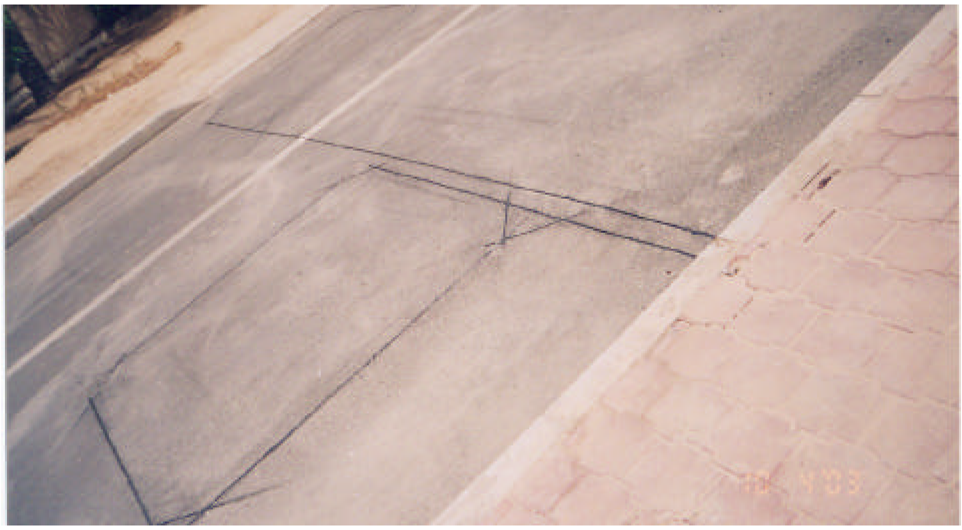


Figure 1.5 Traffic Detection Loop

Figure 1.6 Intersection Counter

1.4 EQUIPMENT

For manual method the following equipment are needed

1. Stop Watch
2. Pencils, erasers,
3. Blank Data Sheets
4. Chip board
5. Mechanical counters
6. Turning Movement Counters

1.5 PROCEDURE OF MANUAL TRAFFIC COUNT

a) Mid-Block Traffic Count:

1. Prepare data sheets
2. Organize the study teams and assign type of data collected to each member of team
3. Each member should station himself/herself at the study site in a convenient but SAFE location.
4. Start counting the assigned type of traffic simultaneously using mechanical counters and/or by directly inputting in the data sheets.
5. Stop the count at the end of 15 minute period and assemble the data in a single data sheet for each team.

b) Intersection Traffic Count:

1. Prepare data sheets
2. Organize the study teams and assign type of data collected to each member of team
3. Each member should station himself/herself at the study site in a convenient but SAFE location.
4. Start counting the assigned type of traffic simultaneously using mechanical counters and/or by directly inputting in the data sheets.
5. Stop the count at the end of 15 minute period and assemble the data in a single data sheet for each team.

Data Presentation

a) Mid-Block Traffic Count:

i. Report the peak hour volume in vehicles/hour and PCE/hour present it graphically.
ii. Report the composition of traffic and represent it graphically.
iii. Report the Directional and Lane-wise distribution of Traffic graphically.

b) Intersection Traffic Count:

i. Present a graphic summary of vehicle turning movements.
ii. Present intersection flow diagram.

CE 366 Transportation Engineering Laboratory

Field Data Sheet for Mid-Block Traffic Volume Count

Count Station :
Road Classification:
Direction of Traffic:

Time:
Period:

Lane No.	Cars, Jeeps	Buses	Trucks	Rec. Vehicles	Half Lorry & Vannets	Others

TABULAR SUMMARY OF VEHICLE COUNTS

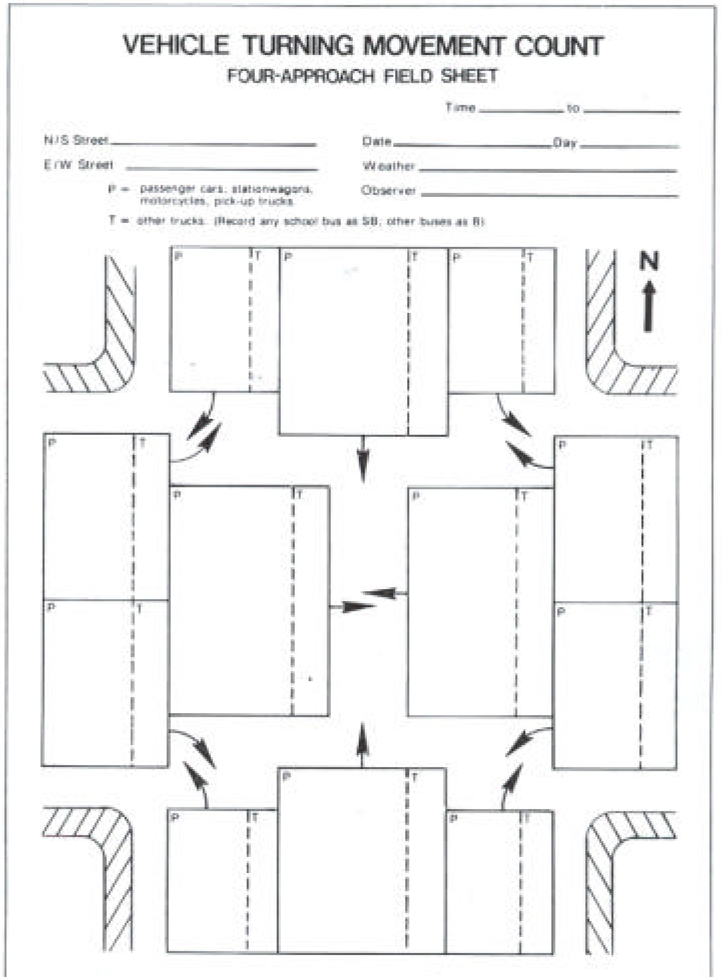
Observer ____________ Date ________ Day ________ City ____________

INTERSECTION OF ____________ AND ____________

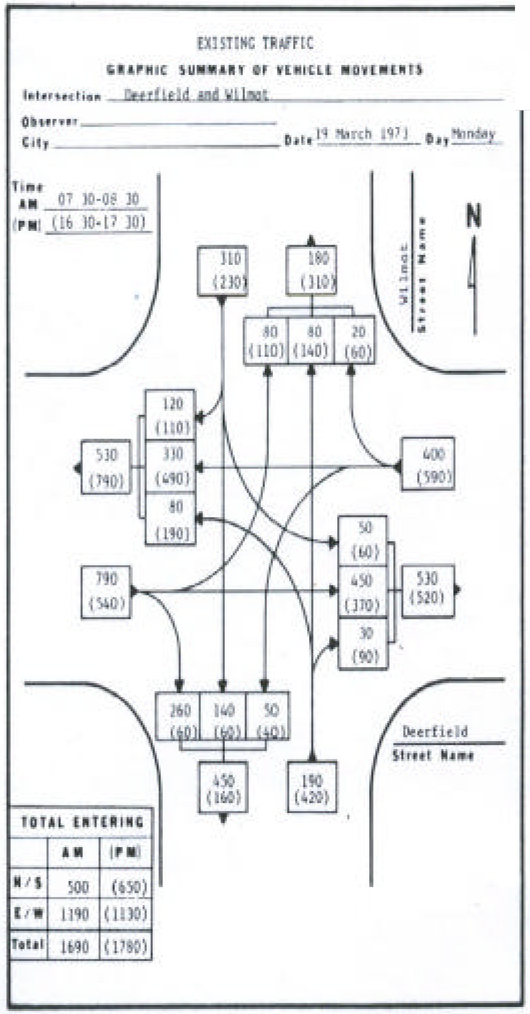
R = Right turn
S = Straight
L = Left turn

TIME BEGINS	from NORTH				from SOUTH				TOTAL North South	from EAST				from WEST				TOTAL East West	TOTAL ALL
	R	S	L	Total	R	S	L	Total		R	S	L	Total	R	S	L	Total		

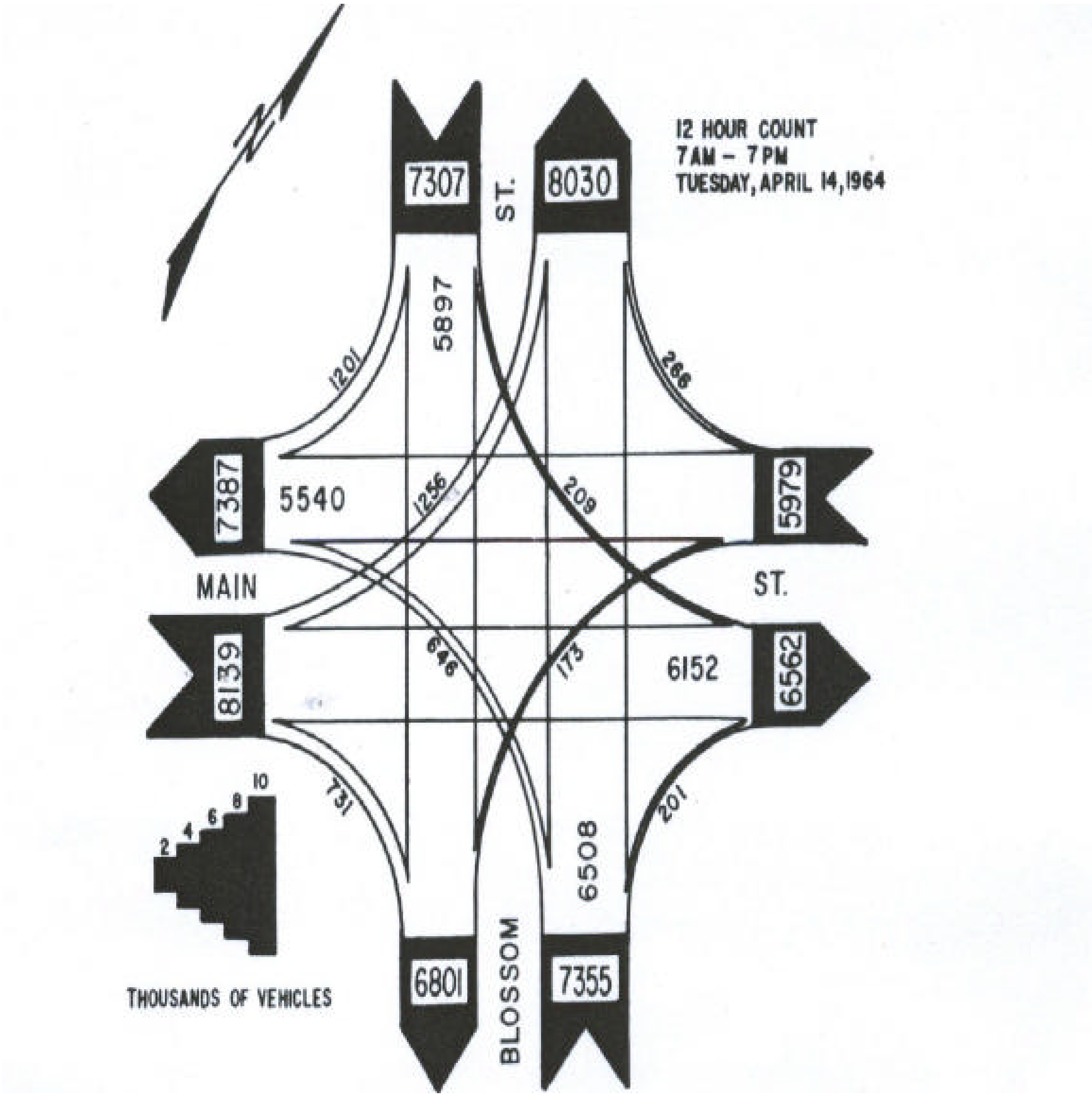
Example Filed Summary Form for Intersection Turning Movement Count



Intersection Filed Tally Sheet



Graphic Summary of Vehicle Movements



Example Intersection Flow Diagram

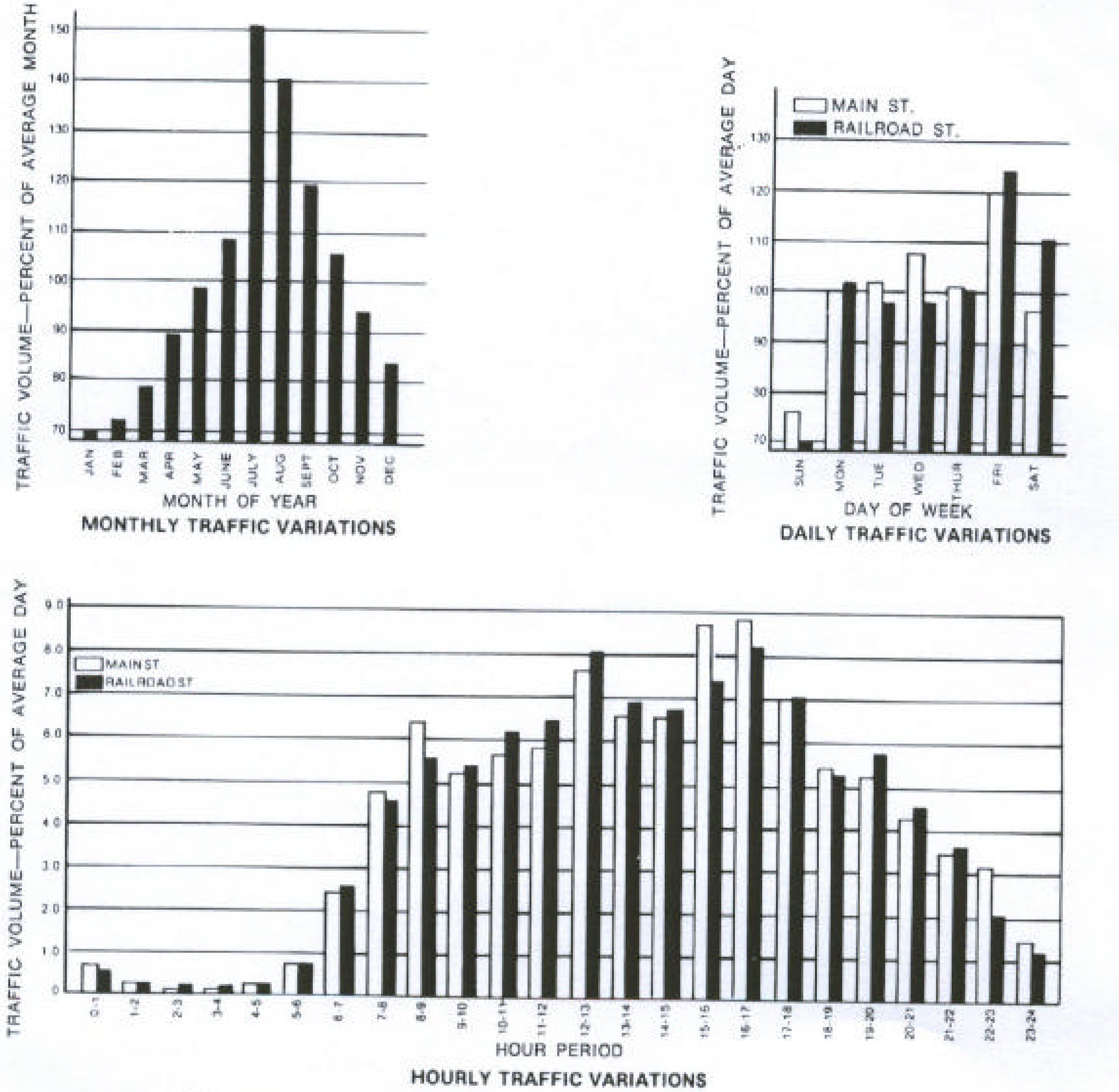


Figure 2-10 Bar charts of monthly, daily, and hourly traffic volumes.
Source: Box and Oppenlander, 1976, p. 190.

Traffic Volume Variation - Example Charts

Nomenclature

- AADT: Average annual daily traffic
- ADT: Average daily traffic
- PHV: Peak hour volume
- PCE: Passenger car equivalent
- VMT: Vehicle miles of travel
- Veh: Vehicle
- NB: North Bound
- N: North
- SB: South Bound
- S: South
- V: Volume (PCE/hr)
- PCE/hr: Passenger car equivalent
- Hr: Hour
- min: Minutes
- %: Percentage

Data Analysis and Interpretation:

Road: Riyadh Road
Count Station No.:1
Road Classification: Highway

Location: Near College of Eng.&Petr.
Time: 8 AM
Period: 15 min

Table 1 below shows a mid-block traffic volume count conducted on Riyadh Road, a highway near the College of Engineering and Petroleum, at 8 AM over a 15-minute interval. It categorizes vehicle flow by direction (North and South), lane number, and vehicle type Cars/Jeeps, Buses, and Trucks measured in vehicles per hour. The data provides a structured overview of traffic composition across six lanes, supporting analysis of directional flow and vehicle mix for transportation planning and operational assessments.

Table1: Field data sheet for mid-block traffic volume count

Direction	Lane #	Cars,Jeeps	Buses	Trucks
		Veh/hr	Veh/hr	Veh/hr
North	1	375	2	2
	2	212	8	9
	3	88	7	20
Total		675	17	31
South	4	100	4	25
	5	97	27	28
	6	93	7	85
Total		290	38	138

1. Total volume:

Total volume = 1189 veh/hr
Total volume = 1582 PCE/hr

These values for 15 min not for 1 hr

2. Directional movement:

veh/hr:
%North=60.807%
%South=39.193%

3. Vehicle composition:

NB:
%cars: 93.361%

%Buses: 2.351%
%Trucks: 4.288%

SB:
%cars: 62.232%
%Buses: 8.1545%
%Trucks: 29.614%

Total:
%cars: 81.161%
%Buses: 4.626%
%Trucks: 14.214%

4. % of Lanes:

% Lane 1: 31.88%
% Lane 2: 19.26%
% Lane 3: 9.672%
% Lane 4: 10.85%
% Lane 5: 12.78%
% Lane 6: 15.56%

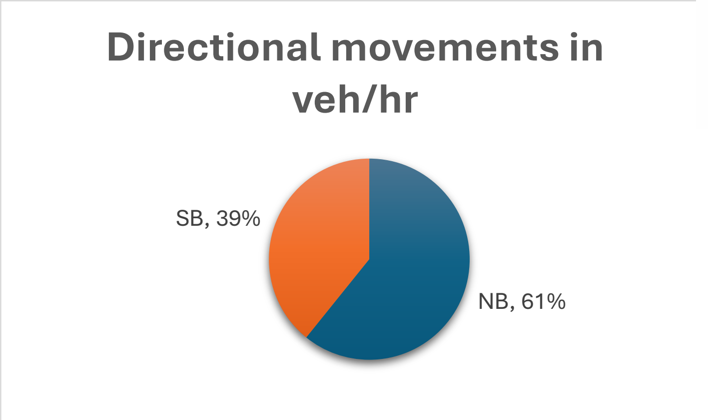


Figure 2:irectional movements in veh/hr

Figure 2 illustrates the directional distribution of vehicle movements per hour on Riyadh Road, showing that 61% of the traffic flows northbound (NB) while 39% moves southbound (SB). This indicates a heavier traffic load in the northbound direction during the observed period.

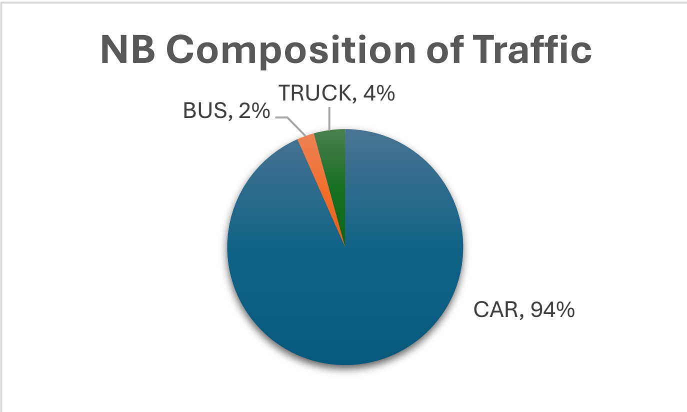


Figure 3:NB Vehicle composition

The third figure displays the composition of northbound traffic on Riyadh Road, highlighting the dominant presence of cars, which account for 94% of the total vehicle flow. Trucks and buses represent only 4% and 2%, respectively. This indicates that private vehicles are the primary contributors to northbound traffic during the observed period.

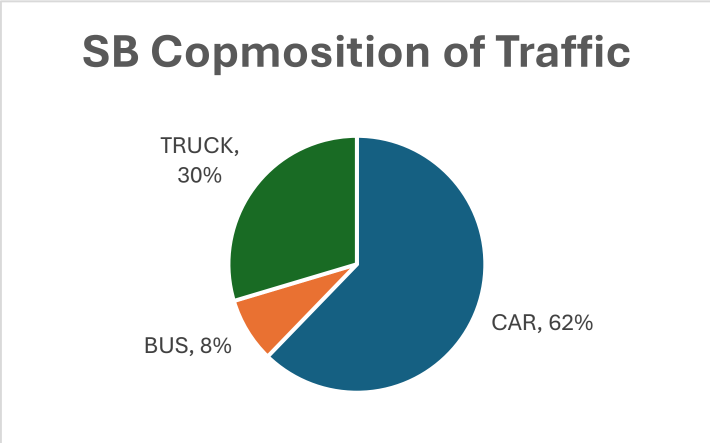


Figure 4:SB Vehicle composition

The fourth figure illustrates the composition of southbound traffic, revealing a more diverse vehicle mix. Cars constitute 62% of the traffic, while trucks make up a substantial 30%, and buses account for 8%. Compared to the northbound direction, the southbound flow shows a significantly higher proportion of heavy vehicles, suggesting different usage patterns or logistical demands.

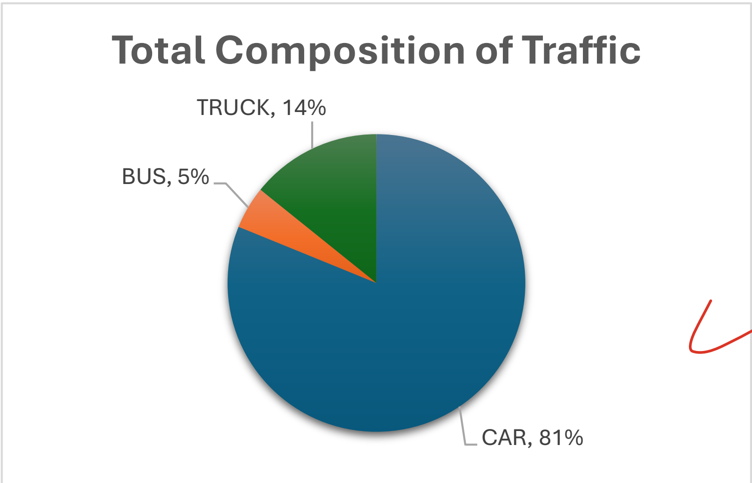


Figure 5:Total Composition of Traffic

Figure 5 presents the overall composition of traffic on Riyadh Road, showing that cars dominate the flow with 81% of the total volume, followed by trucks at 14% and buses at 5%. This distribution reflects a strong reliance on private vehicles, with relatively lower proportions of heavy and public transport vehicles.

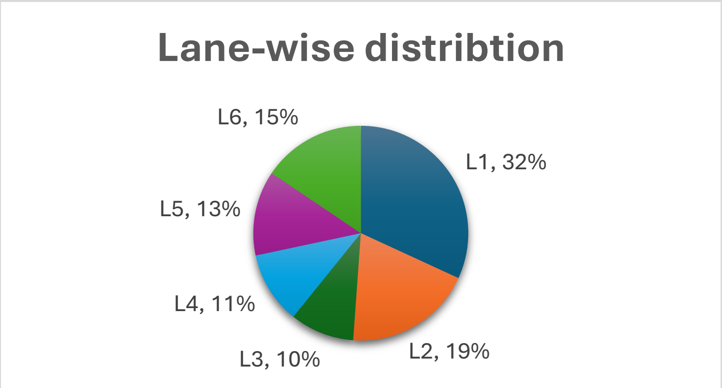


Figure 6:Lane-wise distribtion

Figure 6 above illustrates lane-wise traffic distribution across six lanes. Lane 1 carries the highest share at 32%, while the remaining lanes range between 10% and 19%. This suggests uneven lane utilization, possibly influenced by road geometry, vehicle type preferences, or directional flow patterns.

Roess, R. P., Prassas, E. S., & McShane, W. R. (2010). Traffic Engineering (4th ed.). Pearson.

Transportation Research Board (TRB). (2016). Highway Capacity Manual (6th ed.). National Academies Press.

Ali, M. (October 2004). Transportation Engineering Laboratory Manual.

Appendix:

Sample Calculation:

Total volume in veh/hr = 675+17+31+290+38+138 = 1189 veh/hr
Total volume in PCE/hr = 675+34+93+290+76+414 = 1582 PCE/hr

veh/hr:
%North = ((675+17+31)/1189) *100= 60.81%

%South = ((290+38+138)/1189) *100=39.19%

NB Composition of Traffic:
%cars:(675/1189) *100 = 93.361%
%Buses:(17/1189) *100=2.351%
%Trucks: (31/1189) *100=4.288%

SB Composition of Traffic:
%cars:(290/1189) *100=62.23%
%Buses:(38/1189) *100=8.155%
%Trucks: (138/1189) *100=29.61%

Total Composition of Traffic:
%cars: ((675+290)/1189) *100=81.16%
%Buses: ((17+38)/1189) *100=4.626%
%Trucks: ((31+138)/1189) *100=14.21%

Lane-wise Distribution:
% Lane 1 = (375+2+2)/1189*100 = 31.88%
% Lane 2 = (212+8+9)/1189*100 = 19.26%
% Lane 3 = (88+7+20)/1189*100 = 9.672%
% Lane 4 = (100+4+25)/1189*100 = 10.85%
% Lane 5 = (97+27+28)/1189*100 = 12.78%
% Lane 6 = (93+7+85)/1189*100 = 15.56%

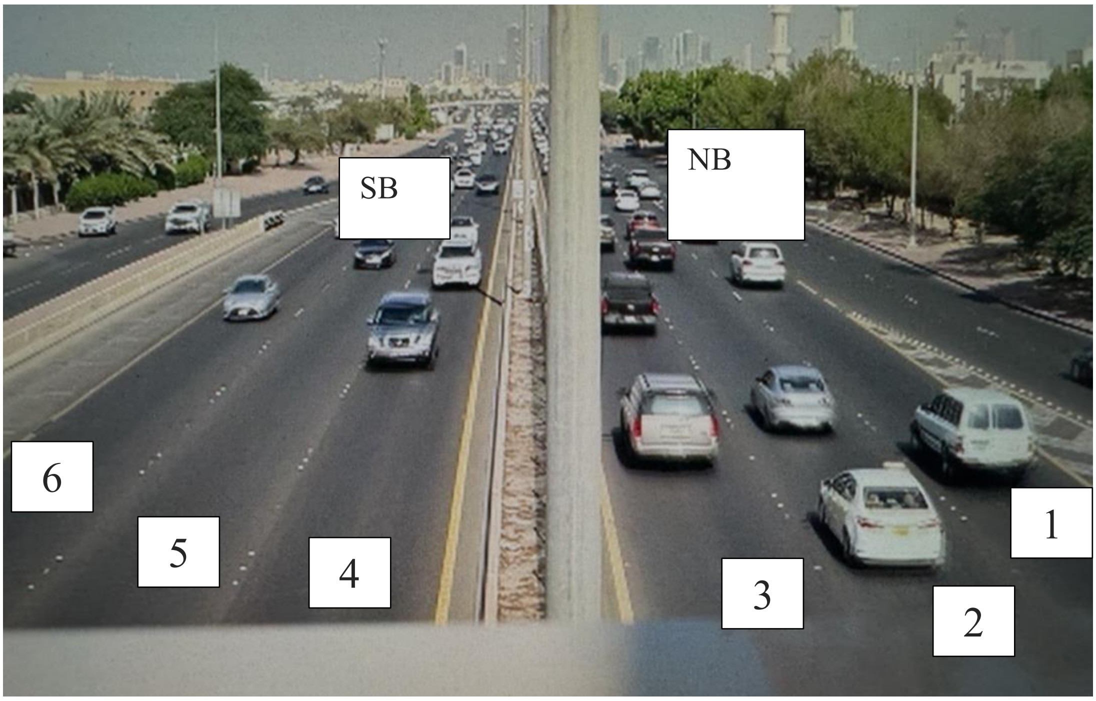


Figure 7: Road Lane

2.1 INTRODUCTION

Spot speed studies are conducted to estimate the distribution of speeds of vehicles in a stream of traffic at a particular location on a highway. The speed of a vehicle is defined as the rate of movement of the vehicle, expressed in miles per hour or kilometers per hour. A spot speed study is carried out by recording the speeds of a sample of vehicles at a specified location. Speed characteristics determined from a spot speed may be used to establish speed zones, establish passing and no-passing zones, design geometric elements, analyze accident data, evaluate the improvements, evaluate the speed control measures and to determine speed trends.

2.2 OBJECTIVE:

To conduct spot studies and analyse the data for a given mid-block section of road/street.

2.3 METHODS OF CONDUCTING SPOT SPEED STUDIES

The methods used for conducting spot speed studies can generally be divided into two main categories : manual and automatic. Automatic devices can be grouped into three main categories (i) Those that use road detectors, (ii) Those that use Doppler principle meters and (iii) those that use the principles of electronics.

Road Detectors : Road detectors can be used to collect volume data and speed at the same time. Pneumatic road tubes are laid across the lane in which data are to be collected. Two tubes at a specified spacing are laid on the road. When a moving vehicle passes over the tube, an air impulse is transmitted through the tube to the counter, shortly afterward a second impulse is recorded when the front wheels pass over the second tube. The time elapsed between the two impulses and the distance between the tunes are used to compute the speed of the vehicle.

An Inductive Loop is a rectangular wire loop buried under the roadway surface. It usually serves as the detector of a resonant circuit. It operates on the principle that a disturbance in the electrical field is created when a motor vehicle passes across it. This causes a change in the potential that is amplified, resulting in an impulse being sent to the counter.

Figure 2.1 Peek Traffic Monitors Model 241

Doppler Principle Meters: Doppler meters work on the principle that when a signal is transmitted onto a moving vehicle, the change in frequency between the transmitted signal and that of the reflected signal is measured by the equipment, then converted to speed in km/hr. An example in this category is a Radar speed meter. Care must be taken to reduce the angle`` between the direction of moving vehicle and the line joining the vehicle and the speed meter. The value of the speed recorded depends on that angle. If the angle is not zero, an error related to the consine of that angle is introduced, resulting in a lower speed.

Electronic - Principle Detectors : In this method, the presence of vehicles is detected through electronic means and information on these vehicles is obtained from which traffic characteristics such as speed, volume, ques, and headways are computed. An example of this method is Autoscope which uses video image processing, or machine-vision system. This system consists of an electronic camera overlooking a large section of the roadway and a microprocessor. The electronic camera receives the images from the road and the microprocessor determines the vehicle's presence or passage. The information is than used to determine the traffic characteristics in real time.

Figure 2.2 Radar Speed Meters

Figure 2.3 Measurement of spot speed using RADAR speed meter

2.4 EQUIPMENT

For radar method of the following equipment are needed

1. Stop Watch
2. Pencils, erasers,
3. Blank Data Sheets
4. Clip board
5. Speed Radars

2.5 PROCEDURE

1. Prepare data sheets.
2. Organize the study teams.
3. Each member should station himself/herself at the study site in a convenient but SAFE location.
4. Start targeting the traffic using radars and inputting the speeds displayed in the data sheets.
5. Stop the study at the end of 15 minute period, you should collect about 100 vehicle speeds in this duration.

2.6 DATA PRESENTATION AND ANALYSIS

The spot speed data collected is organized into a frequency distribution table. From the frequency distribution prepare frequency distribution, and cumulative frequency distribution graphs are prepared.

Following speed characteristics are also to be presented:

Average speed : The arithmetic mean of all observed vehicle speeds. It is given as

$$\bar{u} = \frac{\sum f_i u_i}{\sum f_i}$$

where,

$\bar{u}$ = arithmetic mean

f_i = number of observations in each speed group

U_I = mid value of the i^{th} speed group

Median Speed : This is the speed at the middle value in a series of spot speeds that are arranged in ascending order.

Modal Speed : This is the speed value which occurs most frequently in a sample of spot speeds. Determined from the cumulative distribution of speed.

Percentile Speeds : 85^{th} and 97^{th} percentile speeds are determined from the cumulative speed distribution curve.

Pace : This is the internal (usually 10 km/hr) which has the highest number of observations.

Standard deviation of speeds : It is a measure of speed of the individual speeds.

$$S = \sqrt{\frac{\Sigma f_i (u_i - \bar{u})^2}{N - 1}}$$

where,

S	=	standard deviation
u_i	=	mid value of the speed class
$\bar{u}$	=	average speed
f_i	=	class frequency
N	=	Σf_i

CE 366 Transportation Engineering Laboratory

Field Data Sheet for Speed Studies (Radar)

Name of Enumerator : ………………………………..
Date and Day : ………………………………..
Direction of Traffic : ………………………………..

Count Station : ……………………….
Road Classification : ……………………….
Lane No. : ……………………….

S. No.	Speed	S. No.	Speed	S. No.	Speed	S. No.	Speed	S. No.	Speed	S. No.	Speed	S. No.	Speed	S. No.	Speed	S. No.	Speed	S. No.	Speed
1		11		21		31		41		51		61		71		81		91	
2		12		22		32		42		52		62		72		82		92	
3		13		23		33		43		53		63		73		83		93	
4		14		24		34		44		54		64		74		84		94	
5		15		25		35		45		55		65		75		85		95	
6		16		26		36		46		56		66		76		86		96	
7		17		27		37		47		57		67		77		87		97	
8		18		28		38		48		58		68		78		88		98	
9		19		29		39		49		59		69		79		89		99	
10		20		30		40		50		60		70		80		90		100	

CE 366 Transportation Engineering Laboratory

Spot Speed Frequency Distribution Table

Speed Class	Class Mid Value	Class Frequency f_i	$f_i\ u_i$	Percentage of Class Frequency % f_i	Cumulative Percentage f_i	$f_i \left(u_i - \bar{u}\right)^2$

TABLE 3-5
Speed Data Obtained on a Rural Highway

Car No.	Speed (mph)	Car No.	Speed (mph)	Car No.	Speed (mph)	Car No.	Speed (mph)
1	35.1	23	46.1	45	47.8	67	56.0
2	44.0	24	54.2	46	47.1	68	49.1
3	45.8	25	52.3	47	34.8	69	49.2
4	44.3	26	57.3	48	52.4	70	56.4
5	36.3	27	46.8	49	49.1	71	48.5
6	54.0	28	57.8	50	37.1	72	45.4
7	42.1	29	36.8	51	65.0	73	48.6
8	50.1	30	55.8	52	49.5	74	52.0
9	51.8	31	43.3	53	52.2	75	49.8
10	50.8	32	55.3	54	48.4	76	63.4
11	38.3	33	39.0	55	42.8	77	60.1
12	44.6	34	53.7	56	49.5	78	48.8
13	45.2	35	40.8	57	48.6	79	52.1
14	41.1	36	54.5	58	41.2	80	48.7
15	55.1	37	51.6	59	48.0	81	61.8
16	50.2	38	51.7	60	58.0	82	56.6
17	54.3	39	50.3	61	49.0	83	48.2
18	45.4	40	59.8	62	41.8	84	62.1
19	55.2	41	40.3	63	48.3	85	53.3
20	45.7	42	55.1	64	45.9	86	53.4
21	54.1	43	45.0	65	44.7		
22	54.0	44	48.3	66	49.5		

Source: Garber and Hoel, 1988.

TABLE 3-6
Frequency Distribution Table for Set of Speed Data

Speed Class (mph)	Class Midvalue, u_i	Class Frequency (Number of Observations in Class), f_i	$f_i u_i$	Percentage of Observations in Class	Cumulative Percentage of All Observations	$f(u_i - \bar{u})^2$
34–35.9	35.0	2	70	2.3	2.30	420.5
36–37.9	37.0	3	111	3.5	5.80	468.75
38–39.9	39.0	2	78	2.3	8.10	220.50
40–41.9	41.0	5	205	5.8	13.90	361.25
42–43.9	43.0	3	129	3.5	17.40	126.75
44–45.9	45.0	11	495	12.8	30.20	222.75
46–47.9	47.0	4	188	4.7	34.90	25.00
48–49.9	49.0	18	882	21.0	55.90	9.0
50–51.9	51.0	7	357	8.1	64.0	15.75
52–53.9	53.0	8	424	9.3	73.3	98.00
54–55.9	55.0	11	605	12.8	86.1	332.75
56–57.9	57.0	5	285	5.8	91.9	281.25
58–59.9	59.0	2	118	2.3	94.2	180.50
60–61.9	61.0	2	122	2.3	96.5	264.50
62–63.9	63.0	2	126	2.3	98.8	364.50
64–65.9	65.0	1	65	1.2	100.0	240.25
		86	4260			3632.00

Source: Garber and Hoel, 1988.

Example Speed Data Tables

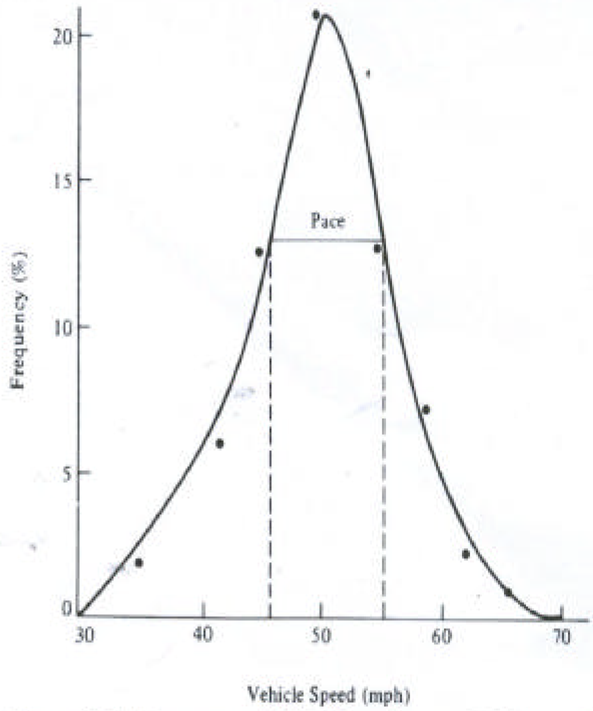


Figure 3-7 Frequency distribution. *Source:* Garber and Hoel, 1988.

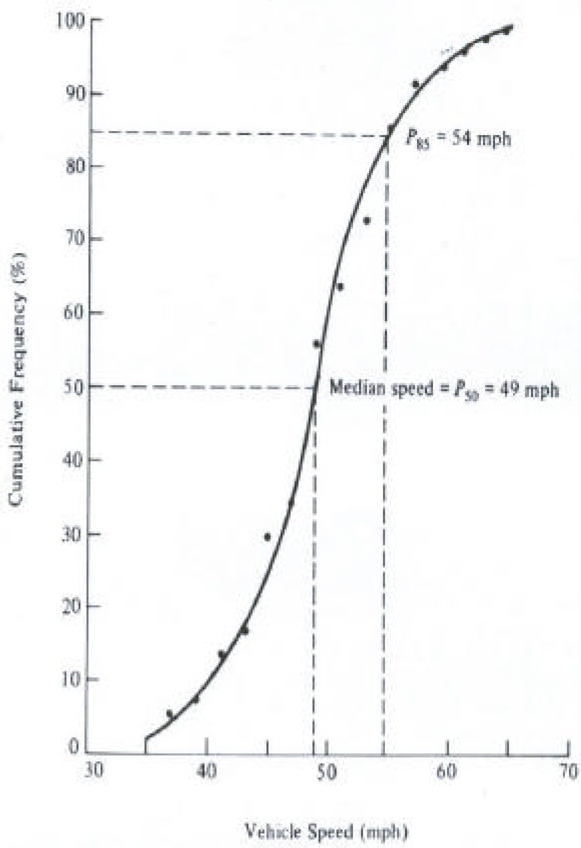


Figure 3-8 Cumulative distribution. *Source:* Garber and Hoel, 1988.

Example Speed Graphs

Nomenclature

- fi: Number of observations in each speed group (Class frequency)
- hr: Hour
- min: Minutes
- N: Sample size
- S: Standard deviation
- u: Average speed
- ui: Mid value of the i-th speed group (Mid value of the speed class)
- $\bar{u}$: Arithmetic mean
- %: Percentage

Data Analysis and Interpretation:

Table 1 represents the speed distribution in km/hr in Riyadh street exit ramp to 4th RR as shown below and it was used to determine Table 2 data and to draw the two graphs.

Table 1: Field Data for Speed

Speed Distribution:

70	89	72	57	92	76	45	50	79	99
57	41	63	71	42	64	78	71	67	78
68	81	60	86	67	71	34	88	59	66
83	56	66	79	78	73	58	68	43	75
62	48	79	28	68	88	47	63	68	109
71	44	61	67	74	67	87	57	69	37
51	93	51	85	24	74	78	74	87	91
78	30	76	72	95	84	61	32	105	62
76	76	62	64	73	39	73	72	70	86
65	77	52	61	69	73	48	55	71	63

The calculations in Table 2 were done to determine ui, frequency and its percentage also the cumulative fi to finally draw the speed distribution curve and speed cumulative distribution.

Table 2:Spot Speed Frequancy Distibution

Speed Class	ui	fi	fi*ui	%fi	%fi com.	fi(ui-ū)^2
24≤x≤31.9	27.95	3	83.85	3	3	4606.1576
31.9<x≤39.8	35.85	4	143.4	4	7	3914.7546
39.8<x≤47.7	43.75	6	262.5	6	13	3280.8687
47.7<x≤55.6	51.65	7	361.55	7	20	1678.2798
55.6<x≤63.5	59.55	16	952.8	16	36	920.2729
63.5<x≤71.4	67.45	22	1483.9	22	58	2.196832
71.4<x≤79.3	75.35	24	1808.4	24	82	1620.0637
79.3<x≤87.2	83.25	8	666	8	90	2077.8036
87.2<x≤95.1	91.15	7	638.05	7	97	4037.3778
95.1<x≤103	99.05	1	99.05	1	98	1018.6311
103<x≤110.9	106.95	2	213.9	2	100	3170.6277
Total		100	6713.4	100		26327.034

ū(km/hr) = 67.134

S = 16.307

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The frequency distribution graph as shown in figure 2 shows a bell-shaped curve of vehicle speeds, with the x-axis representing speed (10–120 km/hr) and the y-axis showing percentage frequency. The peak occurs at the modal speed of 74 km/hr, meaning most vehicles were observed at this speed. The highlighted pace range of 79–69 km/hr captures most vehicles, indicating the typical speed band for traffic flow. This distribution reflects a relatively uniform pattern, where most drivers travel close to the central speed, making it useful for evaluating roadway performance and setting speed regulations.

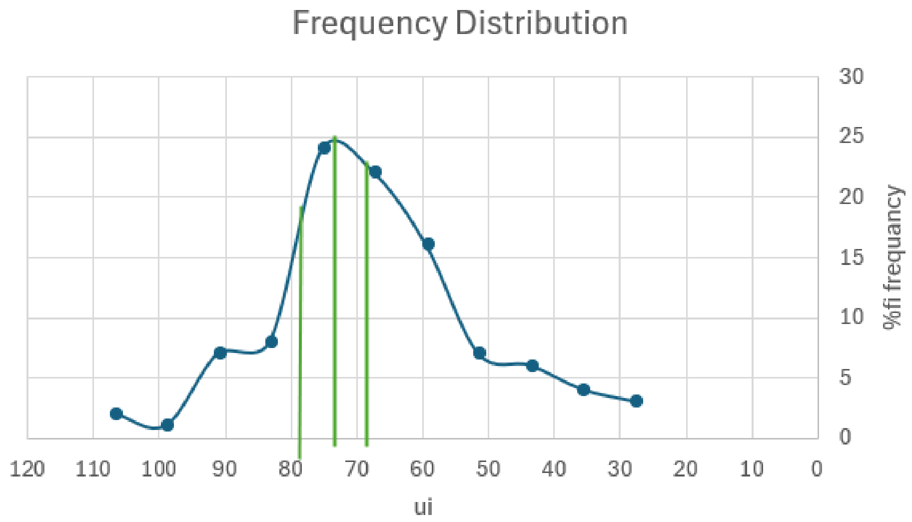

Figure 2:Frequency Distribution

Modal Speed = 74 km/hr
Pace = 79-69 km/hr

The cumulative distribution graph as shown in figure 3 shows the percentage of vehicles traveling at or below a given speed, with the curve steadily rising from 0 to 100%. The median speed is 64 km/hr, meaning half of the vehicles travel slower and half faster. The 85th percentile speed is 78 km/hr, often used as the limit speed for setting speed regulations, while the 97th percentile speed is 90 km/hr, considered the design speed for roadway planning. This distribution highlights how vehicle speeds are spread across the traffic stream and provides key benchmarks for traffic engineering decisions.

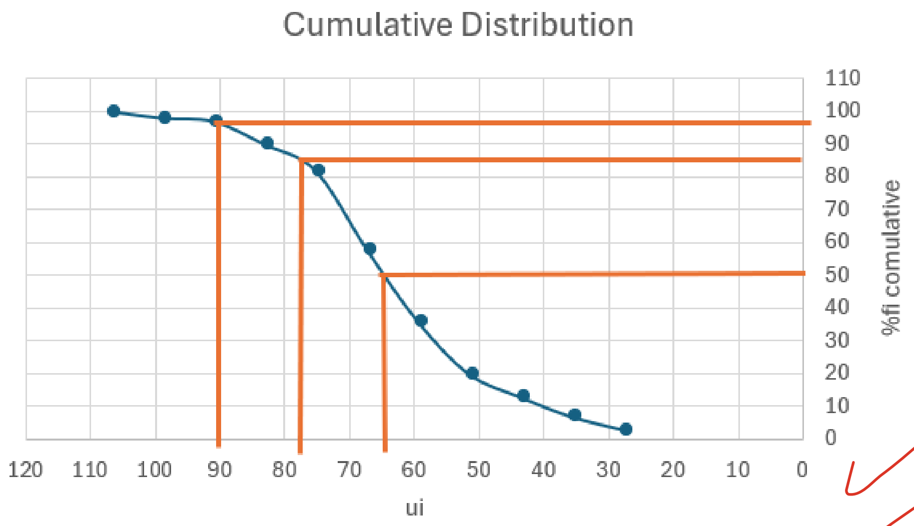

Figure 3:Cumulative Distribution

Median speed at 50% = 64 km/hr
Limit speed at 85% = 78 km/hr
Design speed at 97% = 90 km/hr

Appendix:

Sample Calculations:

N = 100

Maximum = 109 km/hr

Minimum = 24 km/hr

Range = Maximum – Minimum = 109-24 = 85

Class Length = Range / N = 85/10 = 8.5

Round to 8 - 0.1 = 7.9

$\bar{u} = (\Sigma f_i u_i) / (\Sigma f_i) = 6713.4/100 = 67.134$ km/hr

$S = \sqrt{[\Sigma fi (ui - u)^2 / (N - 1)]} = 16.307$