ATT-58/96 DENSITY TEST, Control Strip Method

1.0 SCOPE

This test procedure covers the method in determining the apparent maximum density of granular base course materials with approved compaction equipment utilizing a nuclear moisture-density gauge for density determination.

2.0 EQUIPMENT

nuclear moisture-density gauge: Troxler 2401 or 3401 or CPN MC-1

reference standard	carrying case
calibration tables	charge cord
operating instructions	gauge log book

Data Sheets: Control Strip Rolling Pattern, MAT 6-45
Control Strip Rolling Pattern Graph, MAT 6-46
Test Section Density, MAT 6-47

3.0 PROCEDURE

3.1 General

A "Control Strip" is a typical 400 m section of a lift of granular base course under construction, where specified compaction equipment and methods are used to establish a maximum density called the "Control Density". To determine the Control Density, nuclear moisture and density readings are taken during the compaction passes until a maximum dry density is reached, thus establishing a "Rolling Pattern".

A "Pass" is defined as one complete coverage of a Control Strip with all the specified compaction equipment. The increment in the number of passes at which the road is testing is referred to as a "Series of Passes". The number of passes per series is dependent upon the compaction equipment and is recommended by the Senior Materials Technologist in agreement with the Project Manager and Contractor's representative. Each site of a Control strip is usually tested after every second pass.

The Rolling Pattern established for the Control Strip can be used as a guide for the compaction of the following Test Sections, if the same equipment is used. A "Test Section" is any section of a lift of granular base course under construction not exceeding 400 m in length, where its average dry density will be compared to the Control Density obtained on the same lift and thickness, of the same designation and class of aggregate from the same source. The average dry density of a Test Section is the Test Section Density. Each lift of the granular base course shall not exceed the specified maximum compacted thickness.

The Control Moisture Content is the percent moisture at which the Control Strip must be kept during construction and is recommended by the Project Manager.

The compaction equipment specification applies only when the Control Strip density is determined. In subsequent base course construction, the contractor may choose his own combination of compaction equipment as long as the lift thickness, finished grade and density specifications are met.

3.2 Equipment Preparation

1. Immediately upon the arrival of the gauge on the job and before each control strip or test section, determine if the gauge is functioning properly by performing the "Checkout Procedure" as directed in ATT-11, DENSITY TEST, In-Place Nuclear Method. This procedure comprises of:

    a) "Circuitry Check". This is used to identify problems with the electronics. This test is not routinely performed with Troxler 3401 gauges.

    b) Moisture and Density Standard Counts. These counts are used to determine the "Percent Drift" caused by component aging and drift within the instrument.

2. The gauge must be placed outside for at least 30 minutes before testing begins for the day. Air temperature affects the gauge when the gauge is taken from a warm temperature to a cool temperature.

3.3 Site Preparation

Proper site preparation is the most important step in the nuclear density test. Inconsistent and incorrect results are caused by surface voids. Surface voids should be reduced to a minimum as follows:

1. The surface of the granular base course shall be kept wet until testing is completed because the surface water acts as a void filler. However water should not be added in such quantities that it seeps into the underlying subgrade.

2. The surface to be tested must be smooth and flat. This is best achieved immediately after the compaction equipment has been removed from the test site. The gauge should never "rock" on an irregular surface. In order to achieve the same surface condition, native fines of approximately the same moisture content must be used to fill the surface voids.

3.4 Control Strip

As portions of the lift are being spread, the aggregate should be compacted so that, when the entire lift has been laid, the specified compaction equipment completed a minimum of 4 passes over all area.

Once the aggregate for the lift has been completely spread, the measurements for the Control Density commence. Compaction and density measurements

continue until a maximum dry density is achieved, and this will be the Control Density for subsequent granular base course construction for the same lift and the same material. A Control Strip and its corresponding Control Density is required:

1. For each lift.

2. For a change in designation or class or source of aggregate.

3. Whenever there is a significant change in the gradation of the aggregate from the same pit.

4. Whenever a different nuclear moisture-density gauge is used.

3.5 Backscatter Testing

The Control Strip test method has been developed specifically for aggregates. With aggregates, backscatter testing is effective and is the recommended mode. Direct transmission testing on larger sized aggregates is inaccurate because the pounding of the drill rod used to create the hole for the probe distorts the surface, resulting in poor gauge seating.

Direct transmission testing on some -20 000 Fm aggregates is effective and may be implemented. Refer to Section 3.6, Direct Transmission Testing to determine if this mode may be used on a project.

3.5.1 Rolling Pattern

1. Once the standard counts have been taken, select 5 evenly spaced test sites within the "Control Strip". The test sites should be representative, have minimum segregation, have no ravelling and their surfaces must be moist.

2. Record opposite the corresponding site number, the station (column "C") and location (column "D") of each site, as shown in Figure 1(MAT 6-45).

3. After the material for the lift has been completely spread, allow one series of passes (usually two passes) of the compaction equipment, then proceed to the test site.

4. Mark the site by placing a flagged nail at least 0.3 m in front of the proposed site or spray painting the site.

5. Prepare the test site as directed in test method ATT-11, Section 3.6.3.

6. Place the gauge on the prepared site. Do not set the gauge on the nail as it may affect the reading.

7. Take two moisture and two backscatter density measurements as directed in test method ATT-11.

8. Record the readings for the Pass No. opposite the corresponding site number as Density Count (column "E") and Moisture Count (column "F").

9. Proceed to the other 4 test sites and repeat steps 4 to 8 of this Section.

10. Calculate the average of the ten density and ten moisture readings for that pass.

11. Determine the Density Count Ration (line "G") using the formula:

$$Density\ Count\ Ratio = \frac{Average\ Backscatter\ Density\ Count}{Density\ Standard\ Count}$$

12. Use the Backscatter Density Calibration Table and the Density Count Ratio (line "G") to obtain the Wet Density (line "H").

13. Determine the Moisture Count Ratio (line "I") using the formula:

$$Moisture\ Count\ Ratio = \frac{Average\ Moisture\ Count}{Moisture\ Standard\ Count}$$

14. Use the Moisture Calibration Table and the Moisture Count Ratio (line"I") to obtain the Moisture in kg/m^3 (line "J").

15. Calculate the Dry Density in kg/m^3 (line "K") as follows:

$$Dry\ Density\ (kg/m^3) = Wet\ Density\ (kg/m^3) - Moisture\ (kg/m^3)$$

16. Calculate the Moisture Content in percent (line "L") using the formula:

$$Moisture\ Content\ (\%) = \frac{Moisture\ in\ kg/m^3}{Dry\ Density\ in\ kg/m^3} \times 100$$

17. After each "series of passes" (pass #2, 4, 6, etc.) of the compaction equipment, repeat steps 5 to 16 of this Section.

NOTE: Site preparation may not be required after a few series of passes. All readings must be taken at the exact same locations with the gauge sitting in the same position as the first set of readings.

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MAT 6-45/96

CONTROL STRIP ROLLING PATTERN

PROJECT	DATE *96.01.02*	DISTRICT *12*
FROM *E. of Camrose*		TO *Jct of Hwy 26*
PIT NAME *Driedmeat Hill*		LOCATION *W 1/2 17-45-19-4*
PROJECT MANAGER *N. Tillman*		CONTRACTOR *Leduc Construction*

CONTROL STRIP NUMBER *1*	AGGREGATE TOPSIZE *20 000* µm	LIFT *1*
FROM STATION *10 + 800*	TO STATION *11 + 200*	LIFT THICKNESS *100* mm
GAUGE TYPE *Troxler 2401*	GAUGE NUMBER *1379*	MODE *Backscatter*

COMPACTION EQUIPMENT

NO. OF VIBRATORY STEEL ROLLERS	OTHER(S)
NO. OF WOBBLY TIRED ROLLERS *2*	
NO. OF PNEUMATIC TIRED ROLLERS	

STANDARD COUNTS

A DENSITY STANDARD COUNT	*263*	
B MOISTURE STANDARD COUNT	*1378*	

SITE NO.	STATION C	LOCATIO D
1	*10 + 835*	*2.5 m rt*
2	*10 + 914*	*centerline*
3	*11 + 980*	*1.0 m rt*
4	*10 + 038*	*2.5 m lt*
5	*11 + 186*	*1.0 m rt*

PASS NO.	SITE NO.	DENSITY COUNT E		MOISTURE COUNT F	
2	1	*394*	*396*	*589*	*593*
	2	*392*	*394*	*595*	*595*
	3	*377*	*383*	*538*	*542*
	4	*382*	*386*	*547*	*549*
	5	*380*	*380*	*570*	*571*
	AVE	*386.4*		*568.9*	

CALCULATIONS			
G DENSITY COUNT RATIO	E AVE. / A		*1.469*
H WET DENSITY	(BY TABLES)	kg/m^3	*2044*
I MOISTURE COUNT RATIO	F AVE. / B		*0.413*
J MOISTURE	(BY TABLES)	kg/m^3	*136*
K DRY DENSITY	H - J	kg/m^3	*1908*
L MOISTURE CONTENT	100 J / K	kg/m^3	*7.1*

PASS NO.	SITE NO.	DENSITY COUNT E		MOISTURE COUNT F	
4	1	*356*	*360*	*606*	*606*
	2	*372*	*376*	*545*	*535*
	3	*349*	*351*	*551*	*561*
	4	*363*	*361*	*605*	*601*
	5	*345*	*347*	*632*	*640*
	AVE	*358.0*		*589.2*	

CALCULATIONS			
G DENSITY COUNT RATIO	E AVE. / A		*1.361*
H WET DENSITY	(BY TABLES)	kg/m^3	*2201*
I MOISTURE COUNT RATIO	F AVE. / B		*0.428*
J MOISTURE	(BY TABLES)	kg/m^3	*142*
K DRY DENSITY	H - J	kg/m^3	*2059*
L MOISTURE CONTENT	100 J / K	kg/m^3	*6.9*

PASS NO.	SITE NO.	DENSITY COUNT E		MOISTURE COUNT F	
6	1	*336*	*336*	*640*	*644*
	2	*347*	*345*	*545*	*551*
	3	*358*	*358*	*570*	*586*
	4	*347*	*345*	*658*	*646*
	5	*355*	*357*	*550*	*554*
	AVE	*348.4*		*594.4*	

CALCULATIONS			
G DENSITY COUNT RATIO	E AVE. / A		*1.325*
H WET DENSITY	(BY TABLES)	kg/m^3	*2259*
I MOISTURE COUNT RATIO	F AVE. / B		*0.431*
J MOISTURE	(BY TABLES)	kg/m^3	*144*
K DRY DENSITY	H - J	kg/m^3	*2115*
L MOISTURE CONTENT	100 J / K	kg/m^3	*6.9*

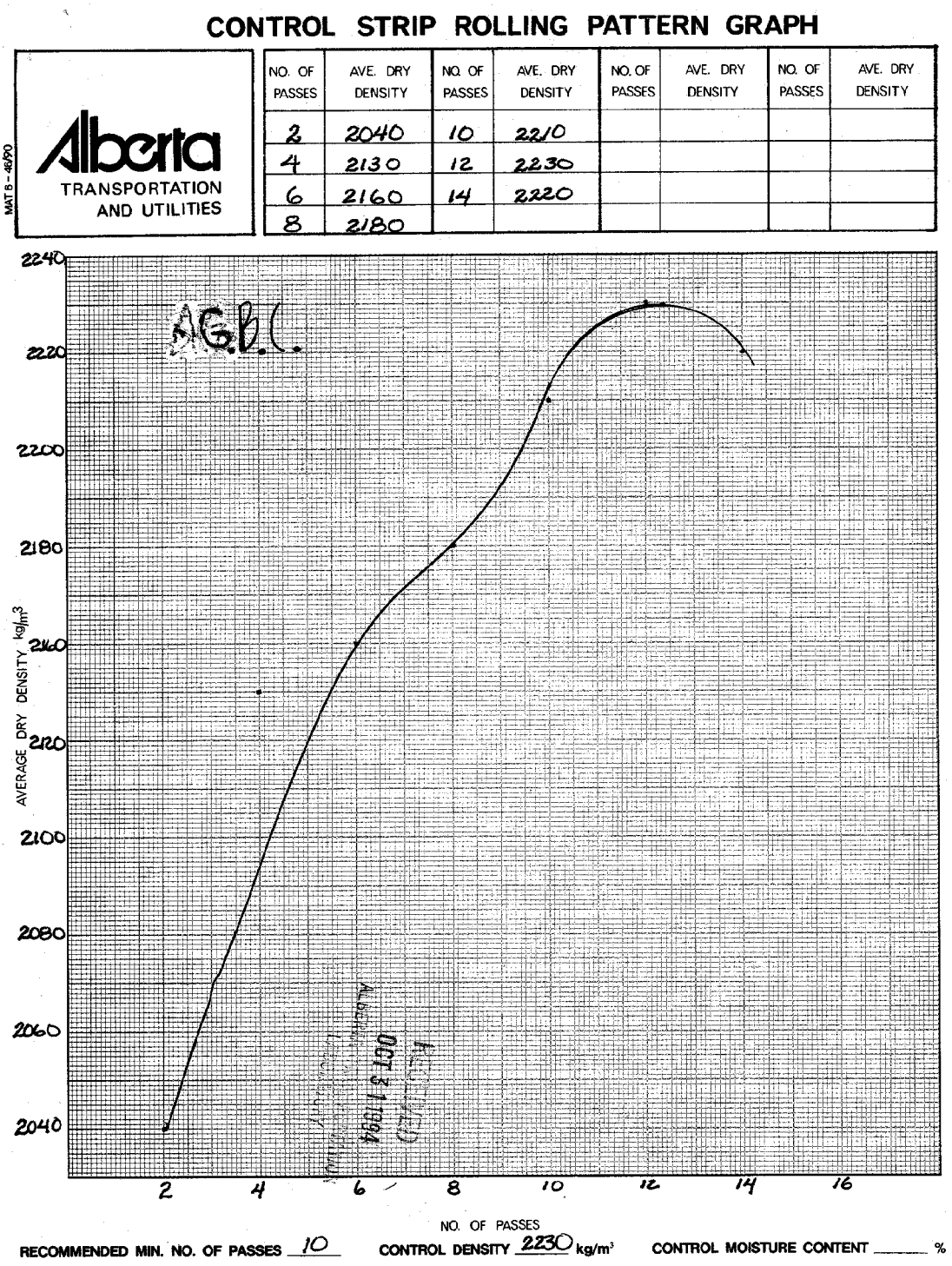
PASS NO.	SITE NO.	DENSITY COUNT E		MOISTURE COUNT F	
8	1	*333*	*331*	*642*	*641*
	2	*346*	*346*	*564*	*576*
	3	*341*	*339*	*563*	*565*
	4	*341*	*343*	*600*	*604*
	5	*357*	*355*	*647*	*645*
	AVE.	*343.2*		*604.7*	

CALCULATIONS			
G DENSITY COUNT RATIO	E AVE. / A		*1.305*
H WET DENSITY	(BY TABLES)	kg/m^3	*2289*
I MOISTURE COUNT RATIO	F AVE. / B		*0.439*
J MOISTURE	(BY TABLES)	kg/m^3	*148*
K DRY DENSITY	H - J	kg/m^3	*2141*
L MOISTURE CONTENT	100 J / K	kg/m^3	*6.9*

Allowable day to day drift on standard counts: 1% for density and 2% for moisture (as determined by the log book data)
REMARKS

MATERIALS TECHNOLOGIST *K. Leroy*

FIGURE 1


CONTROL STRIP ROLLING PATTERN GRAPH
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TRANSPORTATION AND UTILITIES
MAT 8 – 46/90
NO. OF PASSES
AVE. DRY DENSITY
NO. OF PASSES
AVE. DRY DENSITY
NO. OF PASSES
AVE. DRY DENSITY
NO. OF PASSES
AVE. DRY DENSITY
2 2040
4 2130
6 2160
8 2180
10 2210
12 2230
14 2220
G.B.C.
2240
2220
2200
2180
2160
2120
2100
2080
2060
2040
AVERAGE DRY DENSITY kg/m3
2 4 6 8 10 12 14 16
NO. OF PASSES
RECOMMENDED MIN. NO. OF PASSES 10
CONTROL DENSITY 2230 kg/m3
CONTROL MOISTURE CONTENT _____ %

Figure 2

18. The Rolling Pattern is complete when after the completion of three consecutive series of passes, the average dry density between each series of passes:

    a) Increases by less than 10 kg/m^3,

    b) Continually decreases, or

    c) Remains constant.

3.5.2 Control Density

Since compaction actually begins as soon as the material for the lift is spread and testing does not start until the entire lift is spread, the Rolling Pattern test does not indicate the true number of passes required to achieve maximum density; it only identifies the point at which maximum density should be reached if all conditions remain constant, i.e., road moisture, compaction equipment, gradation, etc.

1. Plot the Dry Density obtained in each series of passes on the vertical ordinate, versus the Number of Passes on the horizontal ordinate, as shown in Figure 2 (MAT 6-46).

2. Connect the points with smooth flowing curves.

3. From the peak of the curve, pick off the minimum number of passes required to obtain the maximum dry density. Record on the bottom of the data sheet the recommended Minimum No. of Passes, the Control Density and the Control Moisture Content.

3.5.3 Test Section

After a contractor has compacted a section of granular base course and is satisfied that the section is ready for testing, walk the section and identify visually failed areas.

3.5.3.1 Visually Failed Areas

Visually failed areas are areas of completed granular base course that appear segregated, too wet or too dry, rutted, distorted, loose or rough. Visually failed areas must be tested and the test results must be used to confirm the failure:

a) Before determining the random test sites to obtain the test section density, and

b) Prior to placing subsequent lifts of base course (even if the test section had been previously passed).

The procedure is as follows:

1. Visually inspect the test section for obviously failed areas.

2. Take a density and a moisture standard count as directed in ATT-11.

3. Test each visually failed area as described in Section 3.5.3.2, steps 3 to 5.

4. Calculate the dry density and moisture content of each site as directed in steps 11 to 16 or Section 3.5.1.

5. Determine the percent compaction of each site by repeating steps 8 and 9 of Section 3.5.3.2.

6. Report the test results and visual appearance of the failed areas in the Daily Report to Contractor and on the Weekly Compaction Report form.

7. Visually failed areas are tested to provide documentation in the event a dispute occurs. The Contractor should repair and/or restore to specified condition each visually failed area, as directed by the project manager.

8. Proceed with the Test Section Density, Section 3.5.3.2.

3.5.3.2 Test Section Density

After a stretch of road is checked for visually failed areas, determine the test section within the section to be tested as follows:

1. Determine the beginning and ending station of the section to be tested.

   Note: Normally the maximum length of section shall be 1000 metres, however if the Contractor can maintain a larger area and the area appears to be representative throughtout, this length may be increased. Lengths up to 1500 metres can be tested with only one randomly choosen 400 metre test section within the section. lengths over 1500 metres and less then 2000 metres shall be split into two sections.

2. Calculate the length of the section to be tested as follows:

   = Ending Station of Section - Beginning Station of Section

3. Determine a length random number for test section using:

   a) one of the supplied Random Number Tables

   b) the random number generator of a calculator.

4. Calculate the Distance from Beginning Station of the Section using the formula:

   = Length of Section x Length Random Number

5. Calculate the Midpoint, Ending or Beginning of the Test Section as follows:

Distance from Beginning Station of Segment + Beginning Station of Segment

6. If the station is less than 200 metres from the ending station of the section , then record the station on the Test Section Density data sheet as the To Station and determine the From Station as follows:

To Station - 400 metres

7. If the station is less than 200 metres from the beginning station of the section , then record the station on the Test Section Density data sheet as the From Station and determine the To Station as follows:

From Station + 400 metres

8. If the station is not with 200 metres from the beginning or ending station of the section, then determine the From Station and To Station and record the stations on the Test Section Density data sheet as follows:

From Station = Station - 200 metres

To Station = Station + 200 metres

9. Use test method ATT-56, RANDOM TEST SITE LOCATIONS, Part I, Granular Base Course, to randomly choose ten (10) test sites within the Test Section.

NOTE: If the Contractor is working in an area shorter than 400 m in length such as an approach or an intersection, a modified test section may be established and less than 10 test sites may be tested. However a minimum of 5 test sites must be used to obtain a representative result.

10. Record the station (line "C") and location (line "D") of each test site, as shown in Figure 3 (MAT 6-47).

11. Prepare test site 1, then take two backscatter density readings and two moisture readings as directed in test method ATT-11. Record as density Readings in lines "E_1" and "E_2" and Moisture Readings in lines "F_1" and "F_2".

NOTE: All four readings must be taken with the gauge sitting in the same position.

12 Calculate the average density and the average moisture readings for the site and record as Average Density Count (line "E") and Average Moisture Count (line "F").

13. Repeat steps 4 and 5 for each of the remaining nine test sites.

14. Calculate the dry density and moisture content of each site as directed in steps 11 to 16 of Section 3.5.1.

15. Obtain from the Control Strip Rolling pattern Graph (MAT 6-46) the Control Density obtained in the same lift and the same material. Record the corresponding Control Density in Line "N".

16. Determine the percent compaction of each site (line "M") using the formula:

$$Site\ \%\ Compaction\ ' \frac{Dry\ Density\ (line\ "K")}{Control\ Density\ (line\ "N")}\ x\ 100$$

17. Determine the average Site % Compaction (line "M") and record it in the "Average" column.

18. Determine the average dry density (line "K") and the average moisture content (line "L") of the Test Section and record them in the "Average" column.

19. Check the average dry density (line "K", Average column) using the formula:

$$Average\ Dry\ Density\ '\ Average\ Wet\ Density\ \&\ Average\ Moisture$$

The two figures should be equal. If not, check for calculation errors.

20. Transpose the average dry density to the Test Section Density line (line "U").

21. Calculate the percent compaction of the Test Section (line "P") using the formula:

$$Test\ Section\ \%\ Compaction\ ' \frac{Test\ Section\ Density}{Control\ Density}\ x\ 100$$

NOTE: The Test Section % Compaction (line "P") should be equal to the Average Site % Compaction. If not, check for calculation errors.

22. Compare the results to the specifications which state that the Test Section % Compaction (line "P") shall be at least 98% and each Site % Compaction (line "M") shall be at least 95% of the applicable Control Density.

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MAT 6-47/96

TEST SECTION DENSITY

PROJECT *HW*	DATE *96.01.02*	DISTRICT *16*
FROM *WILDHAY RIVER*	TO *ALTA RESOURCES RWY*	
PIT NAME *TWELVE MILE CREEK*	LOCATION *SW 10-53-27-5*	
PROJECT MANAGER *E. ANDERSON*	CONTRACTOR *CAMP 200*	

CONTROL STRIP NUMBER *1*	AGGREGATE TOPSIZE *20 000* µm	LIFT *1*
FROM STATION *10 + 800*	TO STATION *11 + 200*	LIFT THICKNESS 150
GAUGE TYPE *TROXLER 2401*	GAUGE NUMBER *1379*	MODE *BACKSCATTER*

COMPACTION EQUIPMENT

NO. OF VIBRATORY STEEL ROLLERS *2*	OTHER(S)
NO. OF WOBBLY TIRED ROLLERS *2*	
NO. OF PNEUMATIC TIRED ROLLERS	

STANDARD COUNTS

A	DENSITY	*262*
B	MOISTURE	*1376*

	SITE NO.	1	2	3	4	5	6	7	8	9	10	AVERAGE
C	STATION	*1+8411*	*1+880*	*1+805*	*1+980*	*1+028*	*1+056*	*1+068*	*1+108*	*1+136*	*1+161*	
D	LOCATION	*C. LINE*	*3.2 LT*	*4.0 RT*	*1.4 RT*	*0.3 LT*	*1.6 LT*	*5.0 RT*	*4.0 LT*	*4.0 RT*	*C. LINE*	
E_1	DENSITY READINGS	*345*	*359*	*344*	*335*	*333*	*336*	*347*	*340*	*349*	*338*	
E_2		*352*	*346*	*341*	*333*	*334*	*331*	*347*	*336*	*353*	*333*	
E	AVE. DENSITY COUNT	*349*	*352*	*342*	*334*	*334*	*334*	*347*	*338*	*351*	*336*	*342*
F_1	MOISTURE READINGS	*573*	*559*	*566*	*573*	*555*	*571*	*574*	*541*	*497*	*565*	
F_2		*572*	*560*	*552*	*559*	*547*	*577*	*598*	*568*	*497*	*576*	
F	AVE. MOISTURE COUNT	*573*	*560*	*559*	*566*	*551*	*574*	*586*	*555*	*497*	*571*	*559*

CALCULATIONS

G	DENSITY COUNT RATIO E / A	*1.332*	*1.334*	*1.305*	*1.275*	*1.275*	*1.275*	*1.324*	*1.290*	*1.340*	*1.282*	
H	WET DENSITY (BY TABLES) kg/m^3	*2251*	*2227*	*2291*	*2339*	*2339*	*2339*	*2259*	*2315*	*2235*	*2323*	*2292*
I	MOISTURE COUNT RATIO F / B	*0.416*	*0.407*	*0.406*	*0.411*	*0.400*	*0.417*	*0.426*	*0.403*	*0.361*	*0.415*	
J	MOISTURE (BY TABLES) kg/m^3	*136*	*132*	*132*	*136*	*128*	*136*	*140*	*132*	*112*	*136*	*132*
K	DRY DENSITY H - J kg/m^3	*2115*	*2095*	*2159*	*2203*	*2211*	*2203*	*2119*	*2183*	*2123*	*2187*	*2160*
L	MOISTURE CONTENT 100 J / K %	*6.4*	*6.3*	*6.1*	*6.2*	*5.8*	*6.2*	*6.6*	*6.1*	*5.3*	*6.2*	*6.1*

M	SITE PERCENT COMPACTION 100 K / N %	*98.8*	*97.9*	*100.8*	*102.9*	*98.1*	*102.9*	*103.6*	*102.0*	*99.2*	*102.1*	*100.9*

N	CONTROL DENSITY kg/m^3	*2141*	REMARKS
O	TEST SECTION DENSITY AVERAGE OF K kg/m^3	*2160*	
P	TEST SECTION PERCENT COMPACTION 100 O / N %	*100.9*	MATERIALS TECHNOLOGIST

FIGURE 3

23. If the test section does not average at least 98 % of the control density then the Contractor must compact the entire section to the satisfaction of the Engineer. Then a new test section is determined and tested by repeating steps 3 to 22, of Section 3.5.3.2 Test Section Density.

24. Each site that is not 95 % of the control, on test sections that average at least 98 % of the control density, shall have there surrounding area compacted to the satisfaction of the Engineer and retested until they are at least 95 % of the control density.

3.6 Direct Transmission Testing

Testing in the direct transmission mode may be used when the following conditions are met:

a) The topsize of the aggregate is 20 000 Fm or less.

b) The pounding of the drill rod causes no disruption of material.

c) The depth and alignment of the hole does not cause the gauge to tilt from the plane of the prepared area when the probe is inserted into the hole.

d) The lift exceeds 75 mm.

NOTE: Use the backscatter mode for -20 000 Fm aggregate if the lift thickness is less than 75 mm.

The procedure for direct transmission testing is similar to the backscatter method described in Section 3.5. The following points apply to direct transmission testing:

a) When a Troxler 2401 gauge is used, take the moisture readings before the access hole is drilled.

b) Record the density mode as DT and the depth test.

c) Use the average direct transmission density count to calculate the density count ratio.

d) Use the direct transmission calibration table for the tested depth to determine the site wet density.