Transportation test procedures

ATT-58 / 2023 – Density Test, Control Strip Method

Alberta

Contents

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 Dry Density and Moisture Content determinations.

2.0 EQUIPMENT

nuclear moisture-density gauge	reference standard block
operator's manual	transport case
calibration tables	AC/DC charging cords
nuclear gauge logbook	Source Certificate
scraper plate, drill rod, & extraction tool	flagging nail

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

3.0 PROCEDURE

3.1 General

A "Control Strip" is defined as a lift of granular base course constructed using the equipment and method of compaction as described in the "Standard Specifications for Highway Construction." Typically, a 400 m section of granular base course is used for this Control Strip.

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 is 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. 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 any following Test Sections if the same compaction equipment is being 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 Strip Moisture Content shall be adjusted to the Optimum Moisture Content during the mixing and spreading of the aggregate.

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

Water trucks with spray bars are used, as required, to uniformly spray water across the aggregate surface, and thoroughly mixed in by the motor grader while it is being spread, to enable that the maximum compaction will be reached.

Water shall not be added in such quantities that it seeps into the underlying subgrade.

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

3.2 Equipment Preparation

1. Immediately upon the arrival of the nuclear 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.

    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, to acclimatize, 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 crucial step in the nuclear density test. Inconsistent and incorrect results are caused by surface voids. Surface voids can 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 has completed a minimum of 4 passes over the entire area.

Once the aggregate for the lift has been completely spread, the measurements for the Control Density will 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 new Control Strip and its corresponding Control Density is required:

- For each different lift.
- For a change in designation or class or source of aggregate.
- Whenever there is a significant change in the gradation

of the aggregate from the same pit.

- 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 would give inaccurate results 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 µm 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 Nuclear Gage Standard Counts have been taken, record them in “A.” & “B.” on the Control Strip Rolling Pattern form.

2. 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.

3. Record opposite the corresponding site number, the Station and Location in columns C & D of each site, such as shown in Figure 1.

4. 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. Ensure that all compaction equipment is stopped when you are taking nuclear gage readings, as vibrations from the passing equipment will affect the gage readings.

5. Mark the site by placing a flagged nail at least 0.3 m in front of the proposed site, and by spray painting a square on the site where the gage should sit. Stake whiskers (see pic) are an alternative marking choice to a nail with some plastic flagging tape attached. Virtually indestructible, these coloured whiskers spring back up when run over by the compaction equipment.

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

7. Place the gauge on the prepared site. **DO NOT** set the gauge on the nail as it may affect the readings. **All readings must be taken at the exact same locations with the gauge sitting in the same orientation as the first set of readings.**

8. Take two readings with the nuclear gage. After each reading the gage display will show the “DD” (Dry Density) and “M” (Moisture). Record these measurements, as directed in test method ATT-11.

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

10. Proceed to the other four (4) test sites and repeat steps 4 to 9 of this Section.

11. Calculate the Average of the ten Dry Density and ten Moisture Content readings for that pass.

12. After each "series of passes" (pass #2, 4, 6, 8, 10 etc.) of the compaction equipment, repeat steps 5 to 10 of this Section.

13. The Rolling Pattern is complete when after the completion of three consecutive series of passes, the average dry density between each series of passes:
    - Increases by less than 10 kg/m3,

- Continually decreases, or
- Remains constant.

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MAT 6-45A/22

CONTROL STRIP ROLLING PATTERN (GBC)

ATT-58 / 22 DENSITY TEST, Control Strip Method

CONTRACT NO. :	77711	DATE:	1-Jan-2014
FROM:	Any Road	PIT NAME:	Koala Pit
TO:	End of Road	PIT LOCATION:	SW 10-053-27-W5
TECHNOLOGIST:	N. Tillman	CONTRACTOR:	Moves Lotsa Dirt

CONTROL STRIP INFORMATION						STANDARD COUNTS	
CONTROL STRIP NO.	1	LIFT	1	LIFT THICKNESS	150mm	Troxler Model 3430	Serial # 37666
FROM STATION	0+000			TO STATION	0+400	DENSITY COUNT	MOISTURE COUNT
						A. 1985	B. 679

COMPACTION EQUIPMENT			C.	D.	AGG.	CONTROL STRIP	
NO. OF VIBRATORY STEEL ROLLERS	2	SITE NO.	STATION	LOCATION	TOP SIZE	MAXIMUM DRY DENSITY	MOISTURE CONTENT
NO. OF WOBBLY TIRED ROLLERS	2	1	0+070	4.0m Rt	µm	2144	5.4
NUMBER OF PNEUMATIC TIRED ROLLERS		2	0+140	2.0m Rt	20 000		
OTHER:		3	0+210	cl		RECOMMENDED MINIMUM NO. of PASSES	
OTHER:		4	0+280	2.0m Lt		10	
OTHER:		5	0+350	4.0m Lt			

PASS NO.	DRY DENSITY / MOISTURE MEASUREMENTS										AVERAGE	
	SITE NO. 1		SITE NO. 2		SITE NO. 3		SITE NO. 4		SITE NO. 5			
	E.	F.	E.	F.	E.	F.	E.	F.	E.	F.	G.	H.
	DRY DENSITY	MOISTURE CONTENT	DRY DENSITY	MOISTURE CONTENT	DRY DENSITY	MOISTURE CONTENT	DRY DENSITY	MOISTURE CONTENT	DRY DENSITY	MOISTURE CONTENT	DRY DENSITY	MOISTURE CONTENT
2	2055	3.7	2020	4.1	2020	4.4	2025	4.6	2030	4.2	2030	4.2
	2060	3.7	2015	3.9	2015	4.2	2025	4.1	2035	4.8		
4	2080	3.7	2068	4.1	2049	4.4	2038	4.6	2050	4.2	2066	4.2
	2107	3.7	2065	3.9	2067	4.2	2071	4.1	2060	4.8		
6	2108	4.4	2099	4.2	2113	4.6	2062	4.7	2137	4.8	2099	4.6
	2109	4.8	2095	4.5	2072	4.5	2074	4.2	2119	4.9		
8	2105	4.6	2130	5.2	2145	4.9	2097	5.4	2157	4.6	2130	5.0
	2120	4.6	2134	4.8	2135	5.4	2106	5.5	2166	4.8		
10	2135	5.5	2146	5.6	2148	5.8	2135	5.4	2144	4.8	2144	5.4
	2140	5.4	2140	5.8	2132	5.6	2162	5.5	2156	4.7		
12	2139	5.4	2127	5.8	2130	5.7	2140	4.8	2137	5.0	2136	5.4
	2138	5.3	2136	5.8	2133	6.0	2135	5.1	2145	4.9		
14	2129	5.4	2117	5.8	2120	5.7	2130	4.8	2127	5.0	2126	5.4
	2128	5.3	2126	5.8	2123	6.0	2125	5.1	2135	4.9		
16												

FIGURE 1

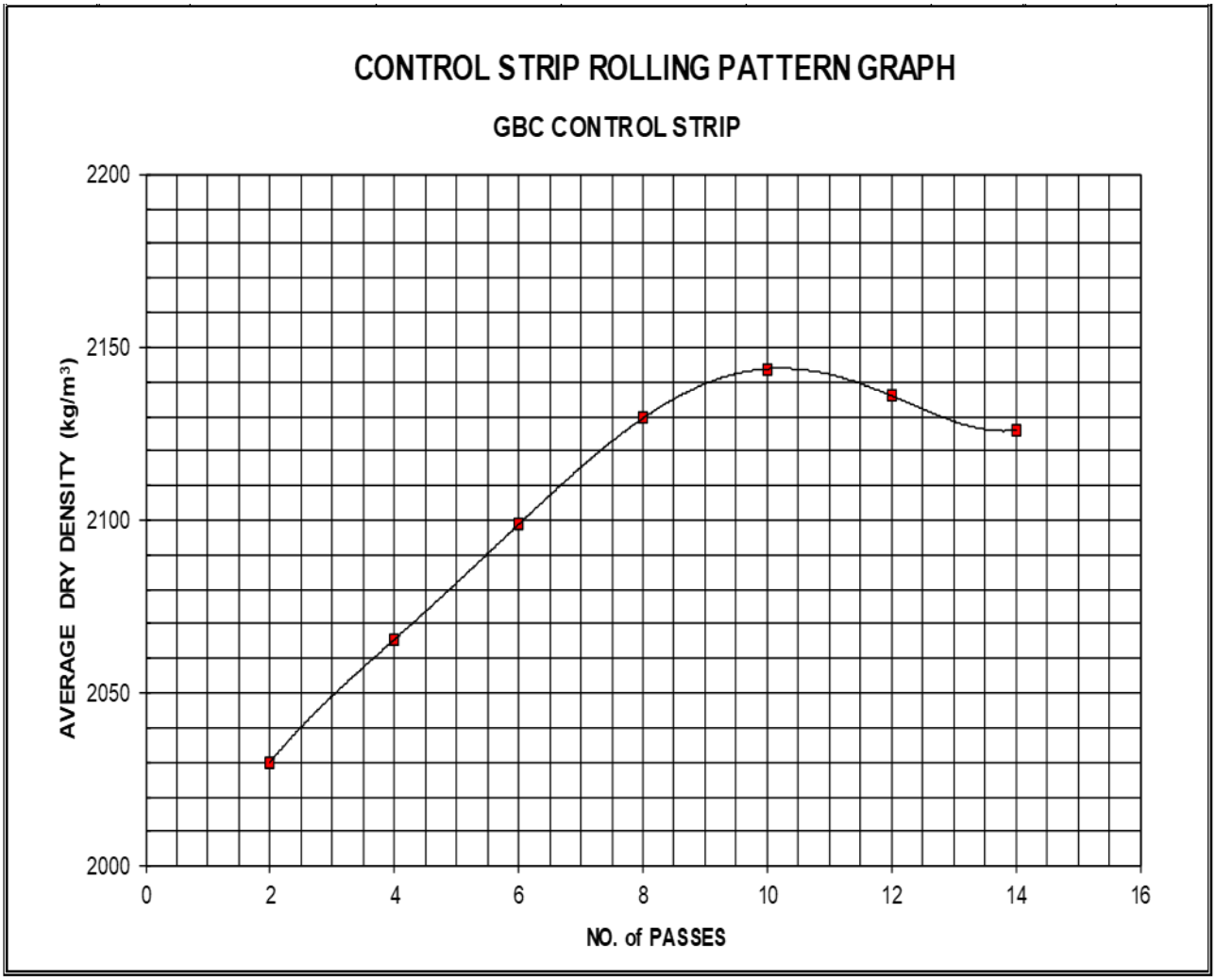

FIGURE 2

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 “No. of Passes” on the horizontal ordinate, as shown in Figure 2.

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 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 any 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 Dry Density and a Moisture Content reading 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 % Compaction of each site by repeating steps 8 & 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 throughout, this length may be increased.

   Lengths up to 1500 metres can be **tested with only one randomly chosen 400 metre test section** within the section.

   Lengths > 1500 metres and < 2000 metres **shall be split into two sections**.

2. Calculate the length of the section to be tested as follows (see Figure 3):
   = Ending Station of Section - Beginning Station of Section

Example: =11+500 – 10+500 = 1000m

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 computer or calculator.

4. Calculate the Distance from Beginning Station of the Section using the formula:
   = Length of Section x Length Random Number
   Example: = 1000m x Length Random # of 0.3 = 300m

5. Calculate the Midpoint, Ending or Beginning of the Test Section as follows:
   Distance from Beginning Station of Segment + Beginning Station of Segment
   Example: 300 + 10+500 = 10+800

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 within 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, NON-BIASED RANDOM TEST SITE LOCATIONS, Part I, Granular Base Course, to randomly choose ten (10) test sites within the Test Section.
   See Figure 3, Random Test Sites.

   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 assessed. However, a minimum of 5 test sites must be used to obtain a representative result.

10. Record the Station and Location of each calculated test site, as shown in the Test Section Density spreadsheet (see FIGURE 4, such as MAT 6-47).

11. Prepare test “Site No. 1”, then take one set of backscatter readings.
    Record the Dry Density (G1) and Moisture Content (H1) readings.

    Without moving the gage, take another set of backscatter readings on Site 1, then record the Dry Density (G2) and Moisture Content (H2) readings

    NOTE: Both sets of readings must be taken with the gauge sitting in the exact same position and orientation.

12. Calculate the “Average Dry Density” and the “Average Moisture Content” readings for both Site No. 1 readings, and record as “Average Dry Density (G3)” and “Average Moisture Content (H3)”.

13. Repeat steps 11 and 12 for each of the remaining nine test sites.

14. Determine the “Avg Dry Density” and “Avg Moisture Content” for Sites 1-10, and record them in columns G3 and H3.

17. Obtain from the Control Strip Rolling Pattern Graph (MAT 6-46), the Control Strip Maximum Dry Density and the Moisture Content, obtained for the same lift and the same material. Record the corresponding Control Strip Max Dry Density and Moisture Content in Line "C" & “D” of the Test Section Density form.

18. Determine the “SITE % COMPACTION” for each Site 1-10 using the following formula and record each one in column “I”.

$$\textit{Site No. \% Compaction} = \frac{\textit{Site Dry Density } (kg/m^3)}{\textit{Control Dry Density } (kg/m^3)} \times 100\%$$

19. Calculate the % Compaction of the Test Section using the formula:

J = ((G4 / C) x 100)

Test Section % Compaction = (Test Section Density / Control Density) x 100

20. Compare the results to the specifications which state that:
    - the Test Section % Compaction (line "J") shall be at least 98%, and
    - No single % Compaction (line "I") shall be less than 95% of the applicable Control Density.

21. 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 20, of Section 3.5.3.2 Test Section Density.

22. **Each site that is < 95% of the Control Strip**, on test sections that average at least 98% of the Control Density, shall have their surrounding area compacted to the satisfaction of the Engineer, then re-tested until they are at least 95% of the control density.

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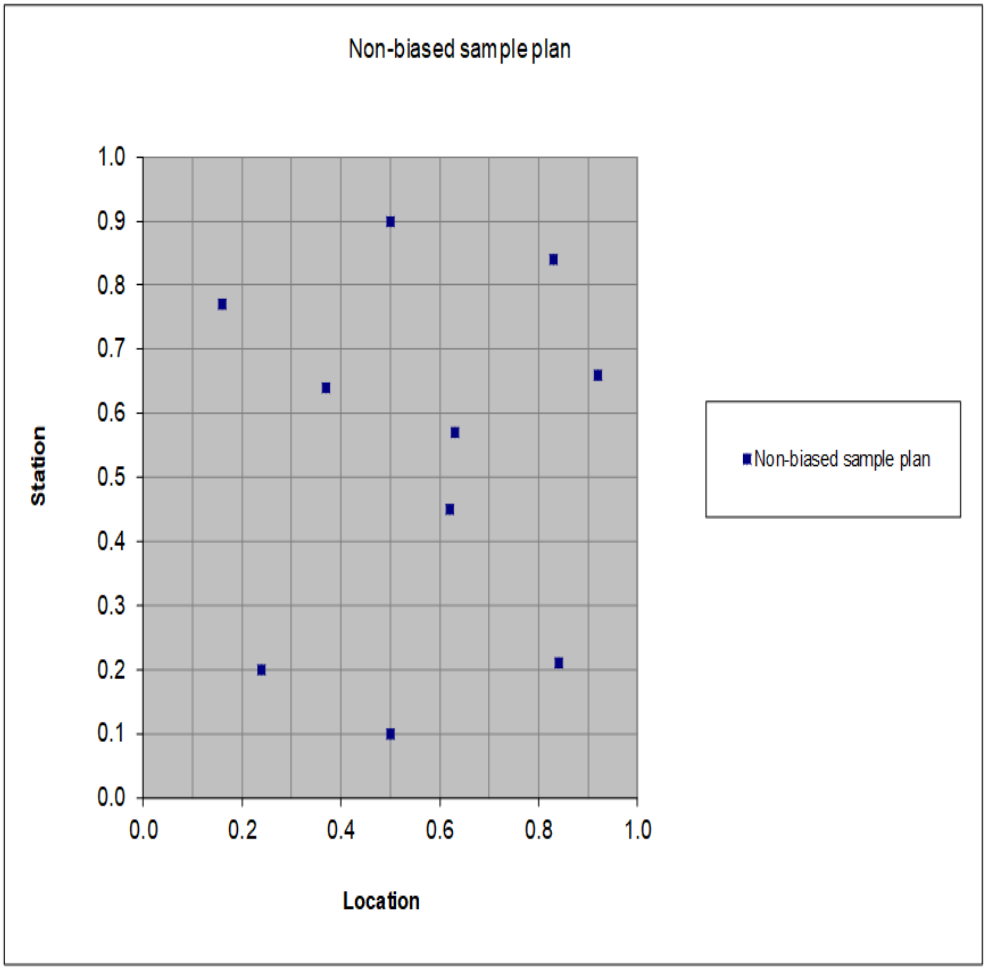
NON-BIASED RANDOM TEST SITES
ATT-56 Part I, RANDOM TEST SITE LOCATIONS, GBC

	PROJECT			**HWY 70:08**		**GBC**			**Lift 1 - 60mm**			
A.	RANDOM TABLE NO.			3								
B.	LENGTH OF AREA		m	400								
C.	WIDTH OF AREA		m	13								
D.	BEGINNING STATION			10+800								
E.	TABLE SITE NUMBER			1	2	3	4	5	6	7	8	9	10
F.	LENGTH (RANDOM NUMBER)			0.45	0.77	0.10	0.66	0.20	0.21	0.84	0.64	0.90	0.57
G.	DISTANCE FROM BEGINNING STA.	B x F	m	180	308	40	264	80	84	336	256	360	228
H.	WIDTH (RANDOM NUMBER)			0.62	0.16	0.50	0.92	0.24	0.84	0.83	0.37	0.50	0.63
I.	DISTANCE FROM LEFT EDGE	C x H	m	8.1	2.1	6.5	12.0	3.1	10.9	10.8	4.8	6.5	8.2
J.	STATION			**10+980**	**11+108**	**10+840**	**11+064**	**10+880**	**10+884**	**11+136**	**11+056**	**11+160**	**11+028**
K.	LOCATION		m	**1.6**	**-4.4**	**cl**	**5.5**	**-3.4**	**4.4**	**4.3**	**-1.7**	**cl**	**1.7**
L.	SITE NUMBER			4	8	1	7	2	3	9	6	10	5

C: \ My Documents \ FORMS AT 2011 \ GBC 2010 \ GBC RANDOMS - 10spots - 2014

FIGURE 3



Completed GBC Section from

10+500 to 11+500

TOTAL = 1000 m

Random # 0.3

Start testing at

1000m x 0.3

300 m from the start

x-axis	0.62	0.16	0.50	0.92	0.24	0.84	0.83	0.37	0.50	0.63
y-axis	0.45	0.77	0.10	0.66	0.20	0.21	0.84	0.64	0.90	0.57

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MAT 6-47/22

TEST SECTION DENSITY
(GBC)
ATT-58, DENSITY, Control Strip Method

CONTRACT NO.:	77711	DATE:	1-Jan-2014
PROJECT:	big ciTY	PIT NAME:	Koala Pit
FROM:	Any Road	PIT LOCATION:	SW 10-053-27-W5
TO:	End of Road		
PROJECT MANAGER:	E. Anderson	CONTRACTOR:	Moves Lotsa Dirt

TEST SECTION INFORMATION								TEST SECTION NUMBER
CONTROL STRIP NO.	1	LIFT	1	LIFT THICKNESS	150	AGG. TOPSIZE	20 000µm	
FROM STATION	10+800			TO STATION	11+200			1

COMPACTION EQUIPMENT		STANDARD COUNTS		CONTROL STRIP DENSITY AND MOISTURE	
NUMBER OF VIBRATORY STEEL ROLLERS	2	Troxler Model 3430	Serial # 37666		
NUMBER OF WOBBLY TIRED	6	DENSITY STD COUNT	MOISTURE STD COUNT	C.	D.
NUMBER OF PNEUMATIC TIRED		A. 1985	B. 679	MAX DRY DENSITY	MOISTURE CONTENT
OTHER:		MODE	BACKSCATTER	2174	5.6

SITE NO.	STATION	LOCATION	DRY DENSITY / MOISTURE MEASUREMENTS						
			DRY DENSITY		AVG DRY DENSITY	MOISTURE CONTENT		AVG MOIST. CONT.	SITE % COMPACTION
	E.	F.	G_1	G_2	G_3	H_1	H_2	H_3	I
1	10+840	cl	2193	2190	2192	4.8	4.8	4.8	100.8%
2	10+880	3.4m Lt	2162	2182	2172	4.8	4.5	4.7	99.9%
3	10+884	4.4m Rt	2161	2171	2166	4.5	4.4	4.5	99.6%
4	10+980	1.6m Rt	2150	2155	2153	4.2	4.3	4.3	99.0%
5	11+028	1.7m Rt	2175	2182	2179	5.5	5.4	5.5	100.2%
6	11+056	1.7m Lt	2192	2183	2188	5.6	5.5	5.6	100.6%
7	11+064	5.5m Rt	2171	2181	2176	5.6	5.4	5.5	100.1%
8	11+108	4.4m Lt	2200	2186	2193	5.3	5.4	5.4	100.9%
9	11+136	4.3m Rt	2205	2190	2198	5.1	5.3	5.2	101.1%
10	11+160	cl	2060	2050	2055	6.4	6.2	6.3	94.5%
			TEST SECTION DENSITY AVG		2167 G_4	TEST SECTION MOISTURE AVG		5.2 H_4	$(G_5 / C) \times 100$ (Dry Density / Control)
					TEST SECTION % COMPACTION	J.	$(G_4 / C) \times 100$		99.7%

NO. OF TESTS BELOW 95%	1

COMMENTS :

Test Section % Compaction shall be at least 98% of the applicable Control Density, with no single test less than 95%.

As specified for Control Strip construction, the surface of the granular base course shall be kept moist until testing is completed.

ENTER DATA INTO SHADED AREAS

TECHNOLOGIST: T. Square

FIGURE 4

3.5 Backscatter Testing

Testing in the Direct Transmission Mode may be used when the following conditions are met:

a) The top size of the aggregate is 20,000 µm 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 thickness exceeds 75 mm.

NOTE: Use Backscatter mode on -20,000 µm aggregate if the lift thickness < 75 mm.

The procedure for direct transmission testing is similar to the backscatter method described in Section 3.5. Record the "Density Mode" as "DT" and record the test depth.

4.0 HINTS AND PRECAUTIONS

1. Excessive amounts of moisture should be avoided, to prevent pumping of fines to the surface, or washing away of fines.

2. The finished granular base course should exhibit a smooth, even, and uniformly compacted surface.

3. Moisture content of aggregate is vital to proper compaction. Moisture acts as a lubricant, allowing the particles to slide together. The maximum density for most aggregates is at a certain moisture content for a given compactive effort.

   Too little moisture means inadequate compaction, as the particles cannot move past each other to achieve maximum density.

   Too much moisture leaves water-filled voids and subsequently weakens the load-bearing ability.

4. Ensure that all compaction equipment is stopped while you are taking nuclear gage readings, as vibrations from the passing equipment will affect the gage readings.

5. To obtain accurate results, the nuclear gage must be seated flush against the compacted layer of aggregate. Level an area to place the gage, either with a shovel or the scraper plate. If significant voids remain in the area where the gage is to be placed, the voids should be filled with small amounts of fines common to the site, and lightly tamped in place with the scraper plate and excess material removed.

6. Nuclear Gage Calibrations: The source decays at a rate of 2.2% per year and the electronics have a minor amount of drift from aging parts. **Therefore, gages are calibrated at least yearly** under controlled conditions using blocks of known density and moisture contents.