SUBGRADE TESTING REPORT-25April2016

CITY OF FORT WORTH STREETS-18 YEARS OLD OR OLDER

ROADBOND EN1 w 3% CEMENT VS 6% CEMENT

PREPARED FOR STEVE MERRITT, ROADBOND SERVICE COMPANY

Background

The City of Fort Worth was experiencing extensive block cracking in the early 1990s on streets being recycled with 6% cement. The subgrades for the most part were a mined road base of material from the Village Creek area south of I-20 and consisted of "river run" gravel in a clay of moderate plasticity. Attempts to limit block cracking by lowering the cement percentage to 3% were successful, but resulted in a significant loss of strength. The garbage trucks were especially hard on these streets. Engineering staff had been impressed by the success of Roadbond EN1 on Tarrant County, Precinct #4 projects and elected to experiment on several streets. A one block section of Floyd Dr. just off Camp Bowie Blvd was completed in **1996** with 3% Roadbond EN1 and 3% cement. The remainder of Floyd Dr. to Woodstock Drive was recycled with 6% cement. The results in terms of reduction in block cracking were quite favorable so a section of W. Lowden St. behind Paschal High School was completed in **1997** with Roadbond EN1 and 3% cement as the street required reconstruction due to the installation of a very large box culvert for drainage. The remainder of W. Lowden between Forest Park and McCart was recycled with 6% cement. The 3700 block of Earl St. was recycled by City of Fort Worth work crews using a reported 6% cement in **1998** whereas the 3800 block was done with Roadbond EN1 with 3% cement. The extensive block cracking on the cement stabilized section suggests that the percentage of cement was substantially above the 6% level.

The Roadbond Service Company obtained permission from the City of Fort Worth to conduct testing on the referenced subgrades in order to determine long term performance of their product vis a vis 6% cement.

Testing Procedure

The commonly accepted measure of both subgrade strength and base course strength is the **CBR** (California Bearing Ratio). It was developed by the California Department of Transportation in the 1930s to measure the strength of subgrade soils. It is the CBR value that determines how thick the pavement must be. It is a percentage comparison of the bearing capacity of a material compared to that of a well graded crushed stone. A well graded crushed stone would have a CBR value of 100. The CBR value in a base course material will be influenced by the quality of the stone and the degree of compaction. Although the test itself is

simple, it is also time consuming and requires special equipment which is expensive and unwieldy. The U.S. Army Corp of Engineers (Waterways & Experiment Station) has developed a relatively simple and quick method of determining CBR values using a Dynamic Cone Penetrometer (DCP). That device uses a hammer (10.1 lb. or 17.6 lb. depending on the material being tested) dropping a distance of 22.6 inches onto a steel rod connected to a .79 inch diameter cone with a 60 degree angle. The number of blows is recorded against the penetration of the cone and input into a correlation program developed by the Corp of Engineers. The 17.6 lb. hammer was used for all testing in this report. One limitation of this device in base course material is that occasionally the point of the cone will lodge on a large piece of aggregate and not allow representative penetration. This error was experienced on Floyd Dr.Hole #3 (RBw3%cement) and Floyd Dr Hole #1 (6% cement), Earl St. Hole #3 (6% cement), and W. Lowden Hole#2(RB w 3% cement). The correlation value for "all other soils" was used for all CBR values in this report. Most of the binder material on the streets tested would classify as CH clay. The CBR values listed in this report may therefore be **understated** by approximately 20%.

The asphalt surface was penetrated by a one-inch drill and penetration into the base course material was verified by the change in resistance noted by the drill operator and the change in color of the drill residue. The Kessler Dual Mass Dynamic Cone Penetrometer was seated with one or two blows and a starting reading was taken. Vertical alignment was determined with a bubble level. Blows of the hammer were then applied in series of 5, 10, 15, or 20 until a minimum penetration of 25 mm had been achieved. The total number of blows was recorded against the total penetration in millimeters for entry into the correlation template. See photo attached.

Test Results-Floyd Drive

Floyd Drive had been resurfaced with slurry seal since 1996. The average CBR value of the two test holes with RB w 3% cement was 357 (340,375). The average value of the three holes in the 6% section of Floyd Dr. was 152 (45,358,52). The wide variation in readings suggest that the cement may not have been evenly distributed.

Test Results-W. Lowden Street

The pavement surface behind Pascal High School was in good condition and had minor crack sealing. The one test hole with Roadbond EN1 and 3% cement had a value of 767. The other test hole readings were discarded for reasons outlined above. The average value of the two test holes on the 6% cement section between Forest Park and McCart was 29. The pavement surface had failed completely and was marked by severe alligator cracking. Alligator cracking is

symptomatic of base failure. Pot holes were already forming. This section of paving requires immediate attention. See photos attached.

Test Results –Earl St.

The pavement surface in the 3800 block was in generally good condition in the section where Roadbond EN1 was used with 3% cement. The average value of the 3 test holes was 204 (138,245,228). The average value of the two test holes in the 3700 block was 211(315,107). The pavement surface showed extensive block cracking which suggested that the cement percentage applied by City of Fort Worth crews was substantially above 6%. The two readings vary widely. The cracks had been properly sealed and, though unsightly, there was no evidence of impending pavement failure. See photo attached from 2004.

Conclusions

This testing of material in place from 18 to 20 years shows that Roadbond EN1 used with 3% cement equals or exceeds the performance of the 6% cement subgrades and is permanent. The reduced block cracking of the Roadbond EN1/cement sections has saved the City of Fort Worth substantial maintenance funds over the years and will prolong the life of the streets. The resurfacing interval on the Roadbond EN1 treated streets should be extended as a result of the reduced block cracking. Performance of Roadbond EN1 in other cities suggest that it may be possible to eliminate the need for cement in the base material with high plasticity indexes in the binder clay. Roadbond Service Company should look for situations where this might be verified as it has the potential for cutting the costs in half.

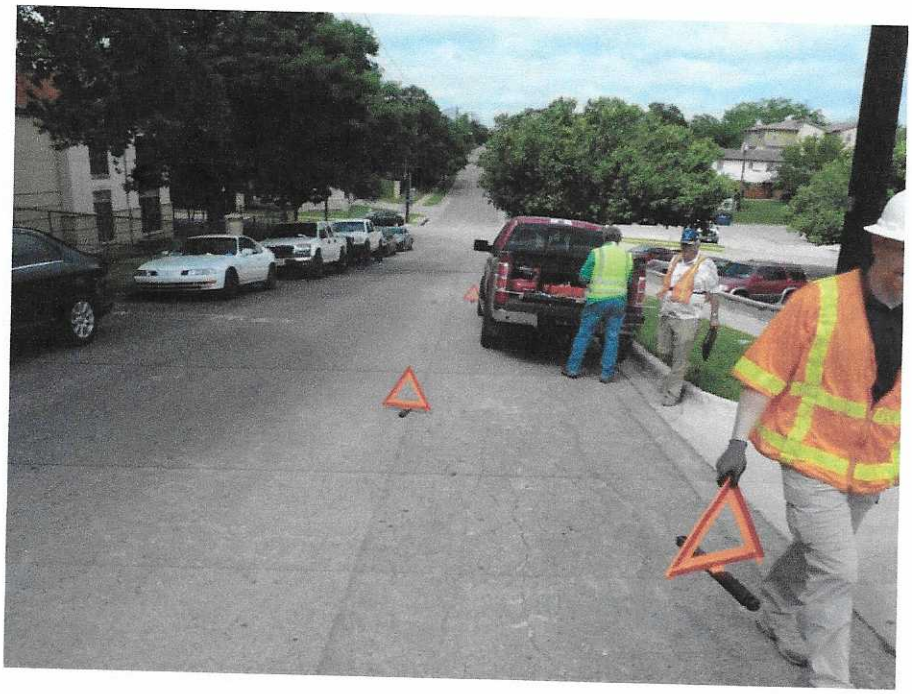
The engineer warrants that the findings, recommendations, specifications, or professional advice contained herein have been made in accordance with generally accepted professional engineering practices in the local area. No other warranties are implied or expressed. This report may not be copied, except in the entirety, without expressed written permission from Roadbond Service Company.

James Roy Anderson

James Roy Anderson, P.E.

Technical Representative

Roadbond Service Company



W. Lowden St. between Forest Park & McCart (note alligator cracking)

Potholes are beginning to form in the Center of the street

3700 Blk of Earl St. Note extensive block cracking in 6%? Cement section.

Picture from 2004

Preparing to take readings at location on Floyd Road

DCP TEST DATA

File Name:

Project: *FLOYD ST.-HOLE #1*
Location:

Date: 25-Apr-16
Soil Type(s): Recycled street w Roadbond EN 1

Hammer
○ 10.1 lbs.
◉ 17.6 lbs.
○ Both hammers used

Soil Type
○ CH
○ CL
◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
55	48	1
		1
		1
		1
		1
		1
		1
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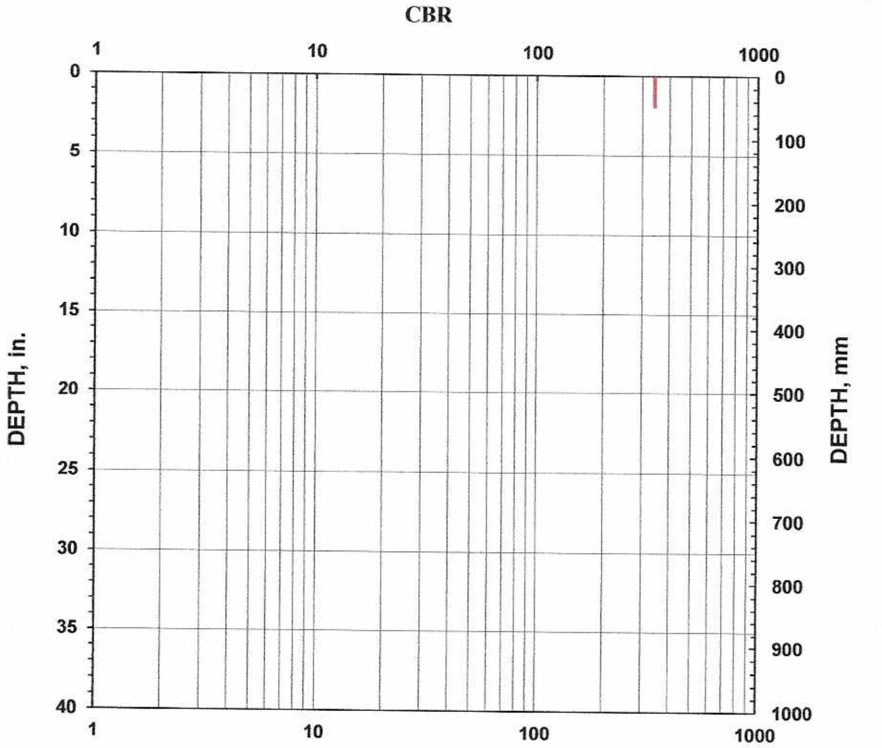

Average CBR 340.

DCP TEST DATA

File Name:

Project: *FLOYD ST.-Hole #2*

Location:

Date: 25-Apr-16

Soil Type(s): Recycled street w Roadbond EN 1

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
30	24	1
		1
		1
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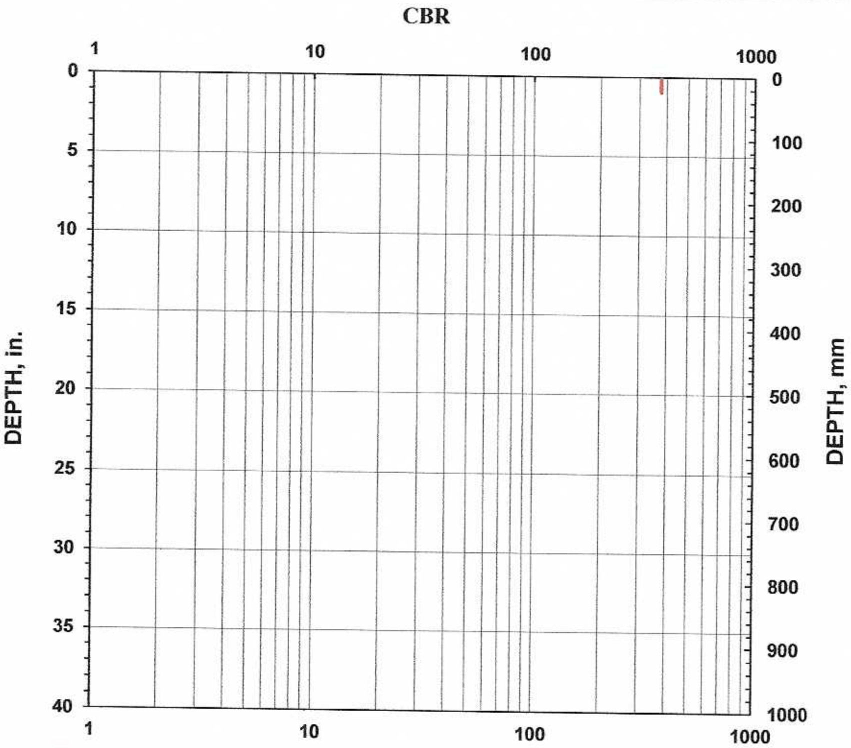

Average CBR 375.

DCP TEST DATA

File Name:

Project: *Floyd Dr.-Hole #2 w 6% Cement*
Location:

Date: 25-Apr-16
Soil Type(s): Recycled street w 6% Cement

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
11	58	1
		1
		1
		1
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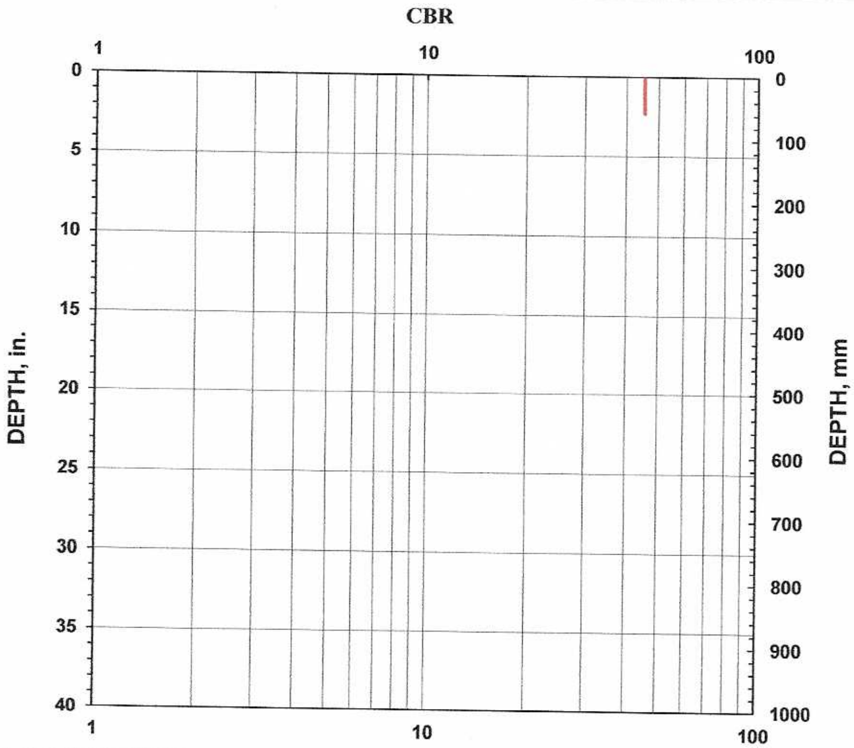

Average CBR 45

DCP TEST DATA

File Name:

Project: *FLOYD ST-HOLE #3*
Location: 3800 FLOYD ST

Date: 25-Apr-16
Soil Type(s): 6% CEMENT

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
30	25	1
		1
		1
		1
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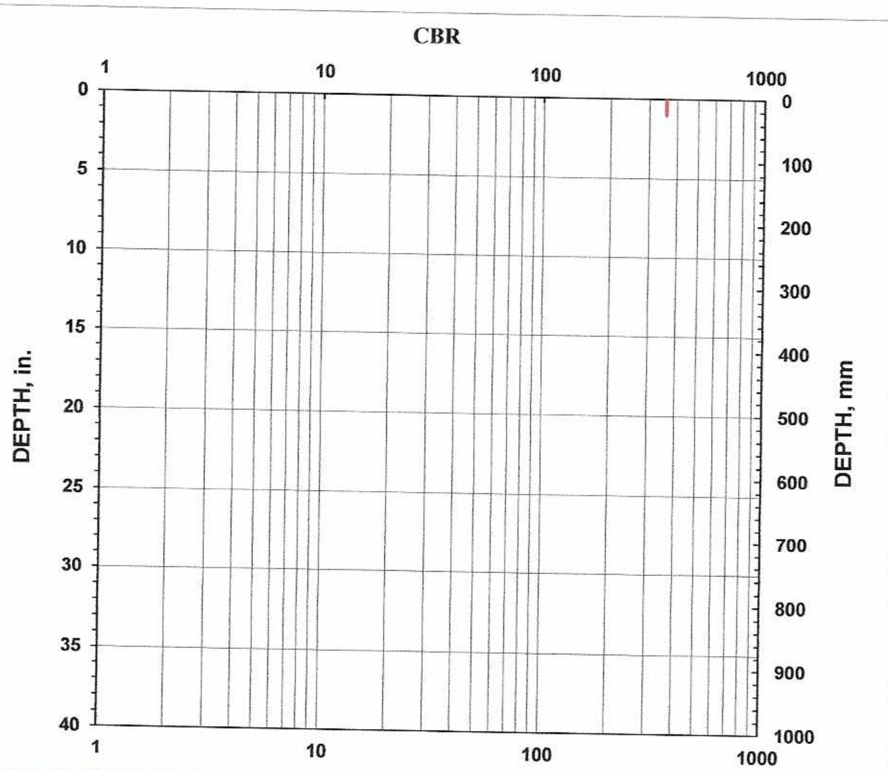

Average CBR 358

DCP TEST DATA

File Name:

Project: *Floyd Dr.-Hole #4 w 6% Cement*
Location:

Date: 25-Apr-16
Soil Type(s): Recycled street w 6% Cement

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
10	47	1
		1
		1
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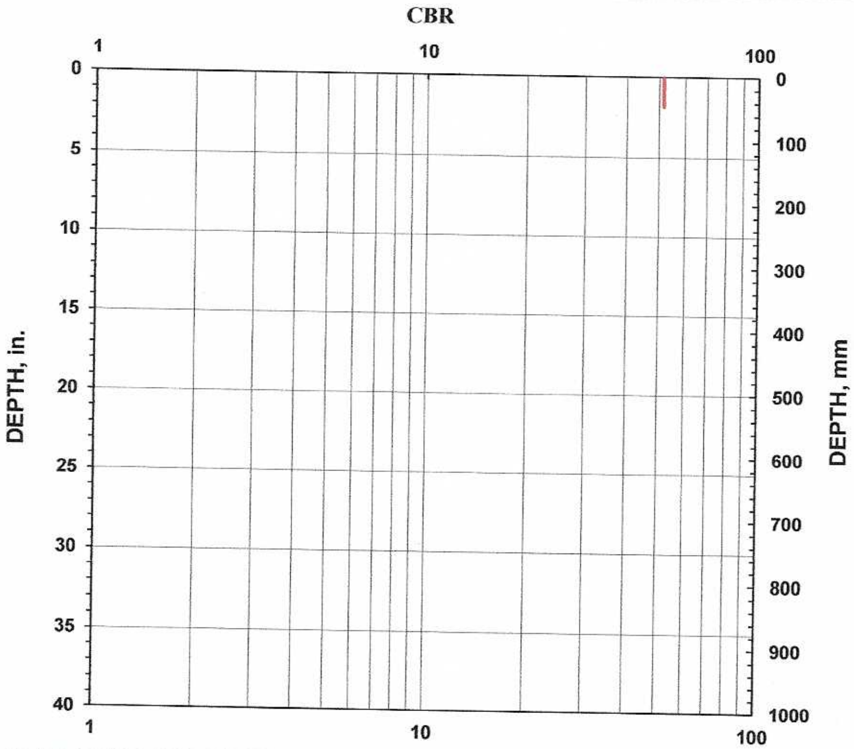

Average CBR 52

DCP TEST DATA

File Name:

Project: *EARL ST.-HOLE #1-RB & 3% CEMENT*
Location: 3803 Earl St.

Date: 25-Apr-16
Soil Type(s): RB w 3% Cement

Hammer
○ 10.1 lbs.
◉ 17.6 lbs.
○ Both hammers used

Soil Type
○ CH
○ CL
◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
20	39	1
		1
		1
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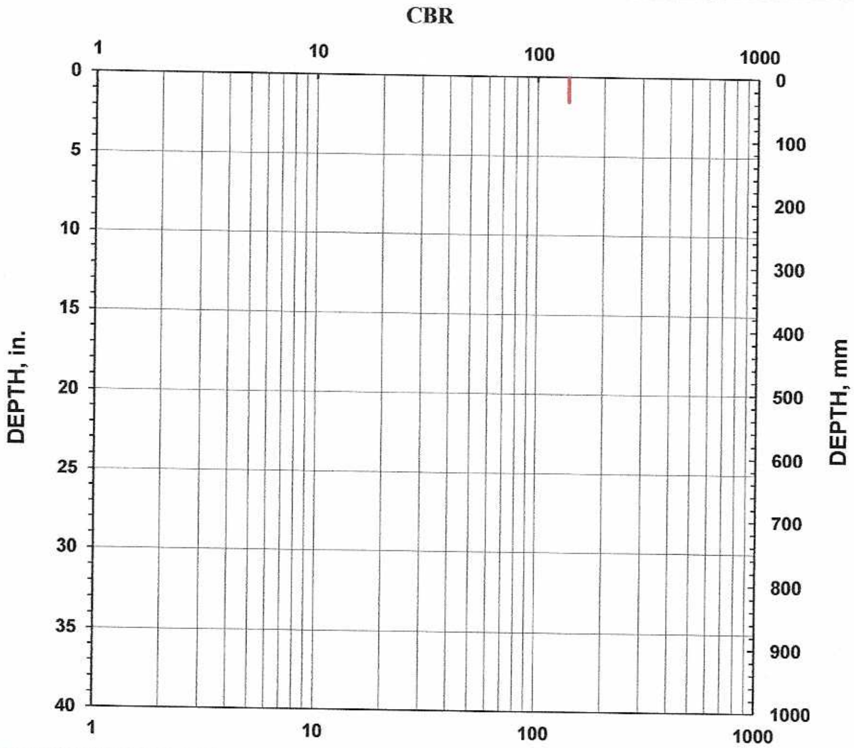

Average CBR 138

DCP TEST DATA

File Name:

Project: *EARL ST.-HOLE #2-RB & 3% CEMENT*
Location: 3809 EARL ST.
Date: 25-Apr-16
Soil Type(s): RB w 3% Cement

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
30	35	1
		1
		1
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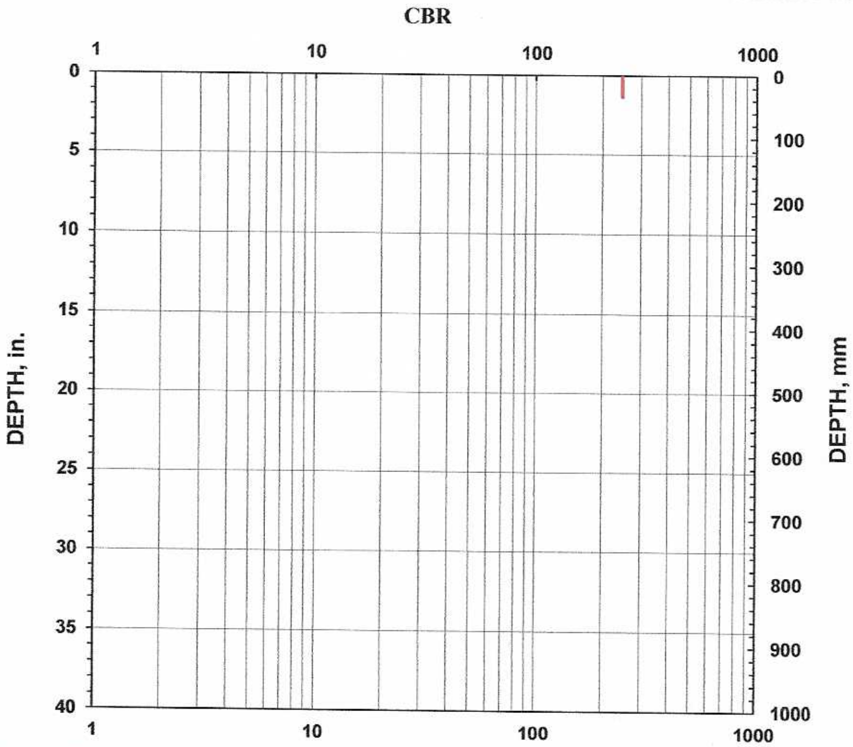

Average CBR 245

DCP TEST DATA

File Name:

Project: *EARL ST.-HOLE #3-RB & 3% CEMENT* **Date:** 25-Apr-16
Location: 3749 EARL ST. **Soil Type(s):** RB w 3% Cement

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
20	25	1
		1
		1
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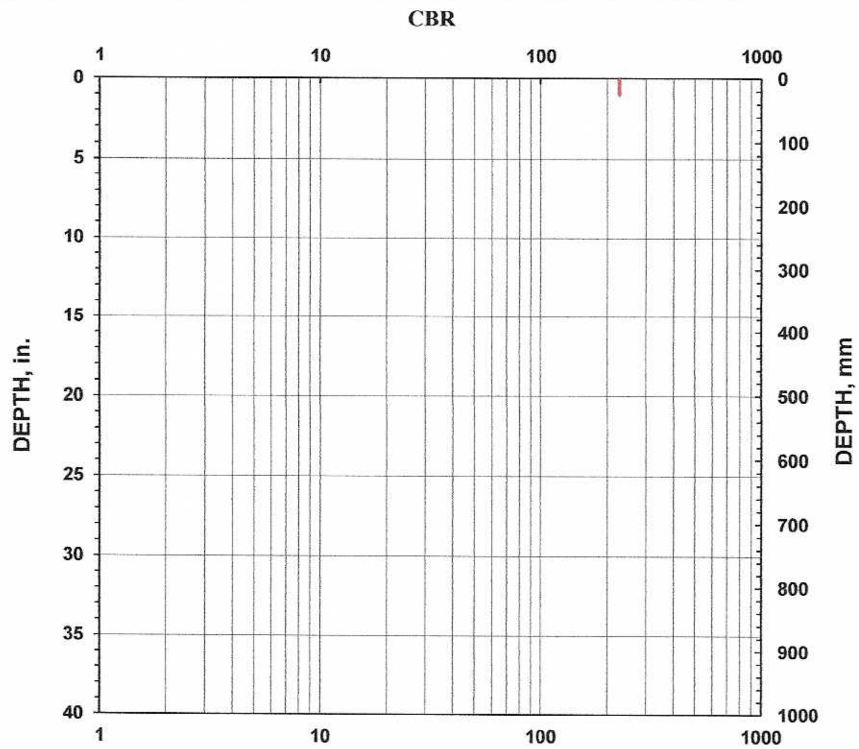

Average CBR 228

DCP TEST DATA

File Name:

Project: *W. Lowden St. -Hole #1*
Location:

Date: 25-Apr-16
Soil Type(s): Recycled street w Roadbond EN 1

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
45	19	1
		1
		1
		1
		1
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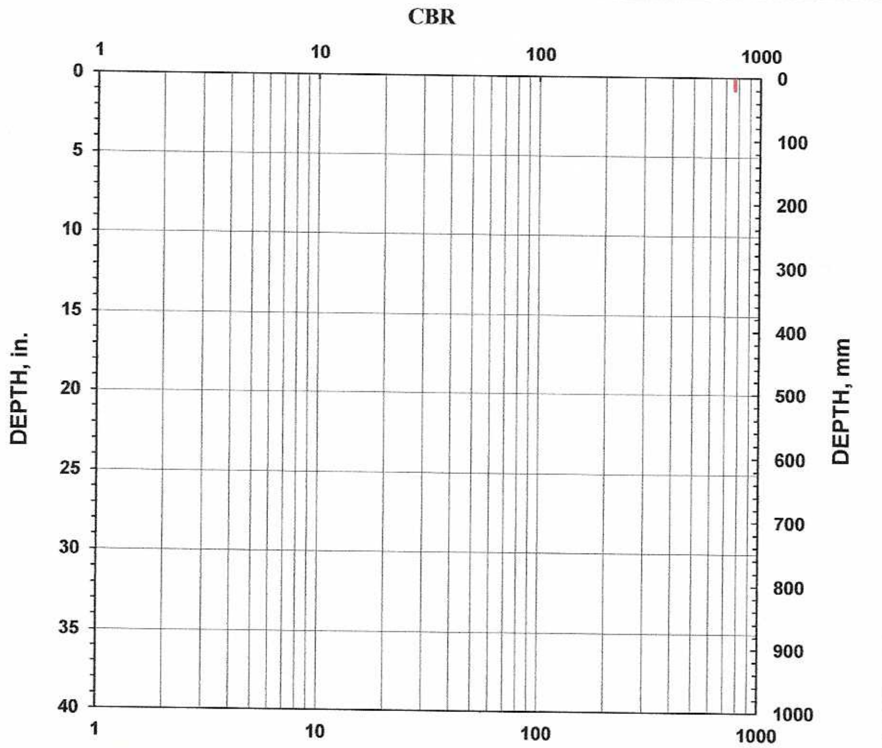

Average CBR 767 7

DCP TEST DATA

File Name:

Project: *W. Lowden-Hole #1*
Location:

Date: 25-Apr-16
Soil Type(s): Recycled street w 6% cement

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
5	49	1
		1
		1
		1
		1
		1
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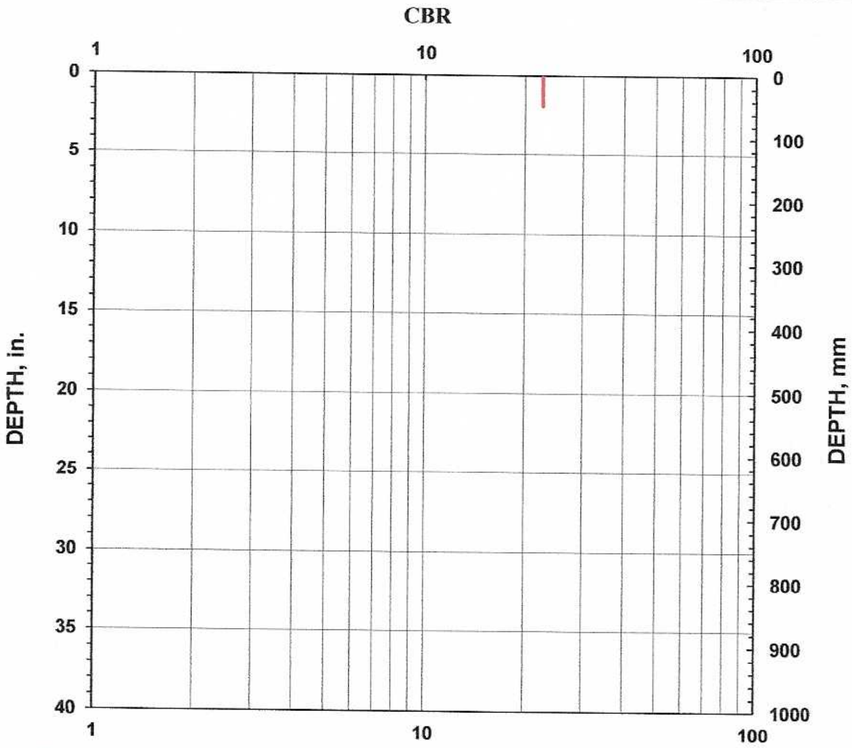

Average CBR 23

DCP TEST DATA

File Name:

Project: *W. Lowden-Hole #1*

Location:

Date: 25-Apr-16

Soil Type(s): Recycled street w 6% cement

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
6	41	1
		1
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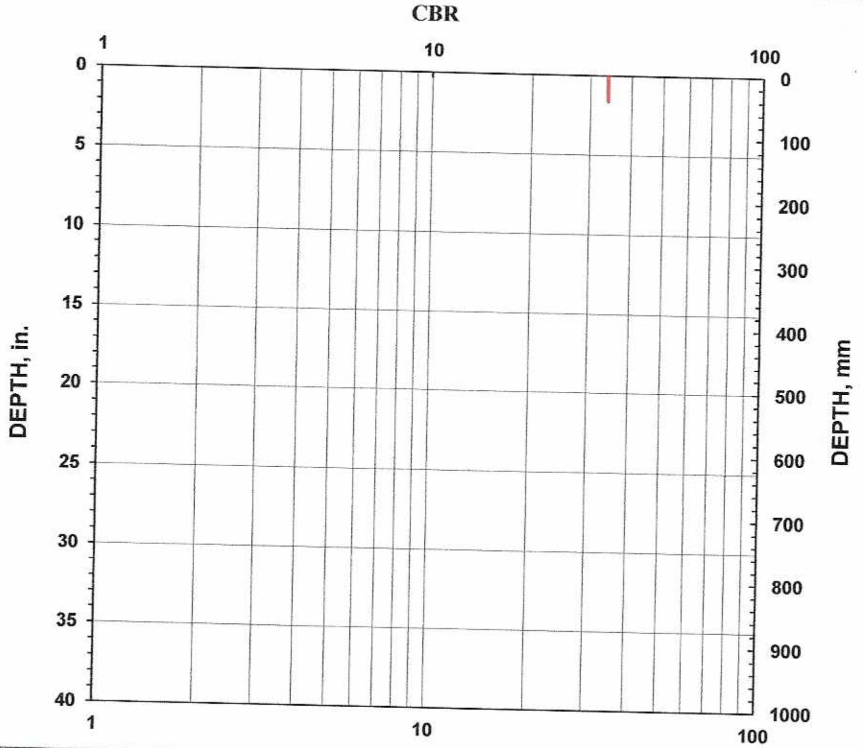

Average CBR 34

DCP TEST DATA

File Name:

Project: *Earl St. w. 6% cement*
Location: 3704 Earl St.

Date: 25-Apr-16
Soil Type(s): Recycled street w 6% cement

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
30	28	1
		1
		1
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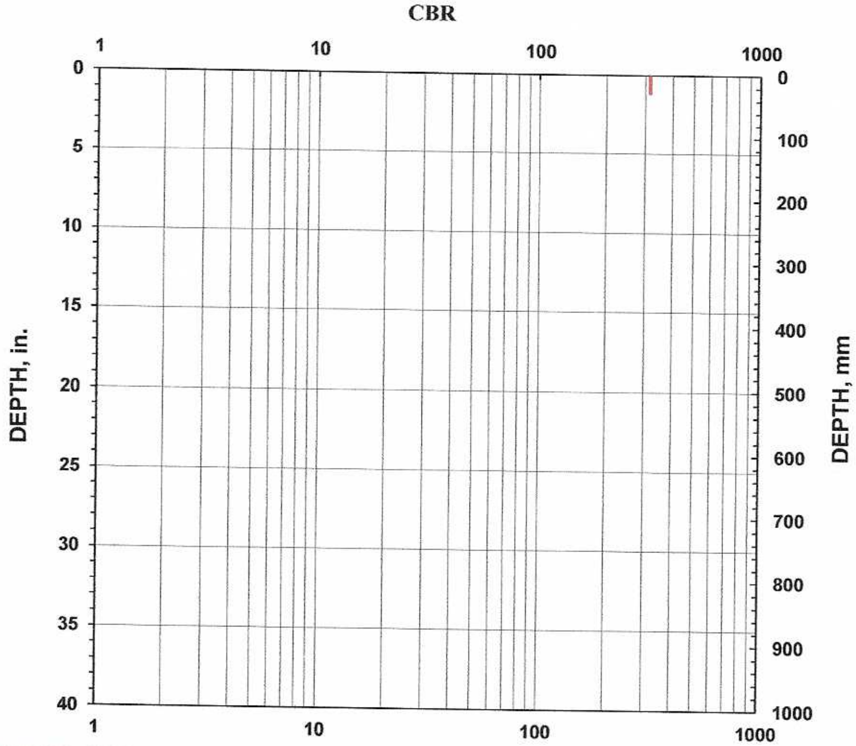

Average CBR 315

DCP TEST DATA

File Name:

Project: *Earl St. -Hole #2 w. 6% cement*
Location: 3717 Earl St.

Date: 25-Apr-16
Soil Type(s): Recycled street w 6% cement

Hammer
○ 10.1 lbs.
◉ 17.6 lbs.
○ Both hammers used

Soil Type
○ CH
○ CL
◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
25	61	1
		1
		1
		1
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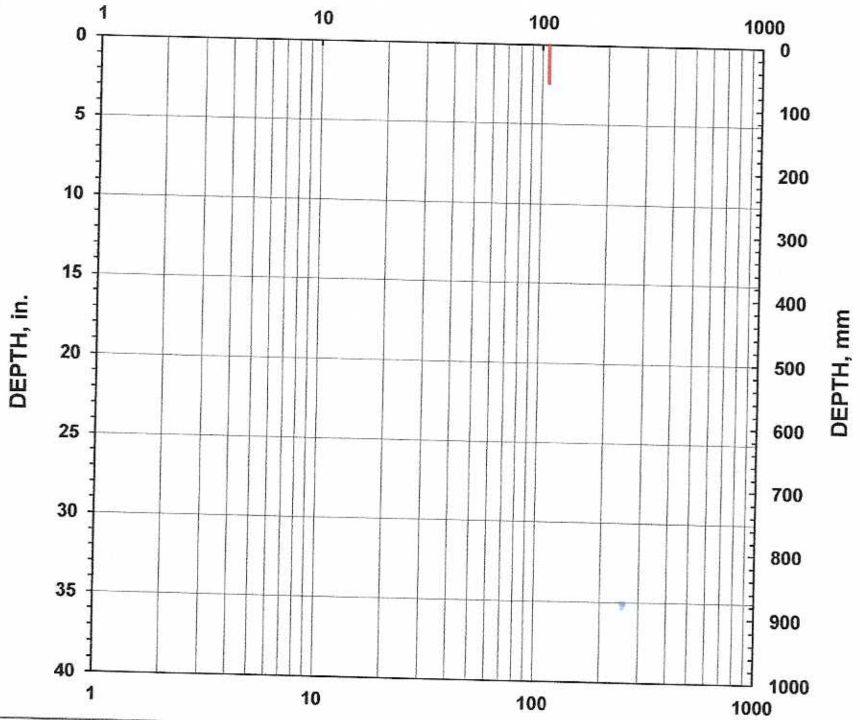

Average CBR 107