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June 26, 2020

Project 17-3531SPT

Mr. Paul Bray
Haz-Tech Drilling, Inc.
Via Email: MTHazTech@gmail.com

Dear Mr. Bray:

Re: Report of Standard Penetration Test Hammer Energy Measurements, Billings, Montana

We have completed the standard penetration test (SPT) hammer energy measurements for your drill rig in Billings, Montana. The drill rig was a Longyear BK-81 truck-mounted drill rig with serial number BK-810193-117.

The hammer energy measurements were performed on May 28, 2020, by Mr. Brett M. Warren, PE, a geotechnical engineer with our firm. The purpose of the hammer energy measurements is to determine how much energy is being transferred from the SPT hammer into the SPT sampler. Accelerometers and strain gauges were used to dynamically monitor the SPT hammer and drill string. The amount of energy transferred from the hammer to the drill string can be calculated using the force and velocity measurements. Testing was performed in general accordance with American Society for Testing and Materials (ASTM) Method of Test D 4633, "Standard Test Method for Energy Measurement for Dynamic Penetrometers," 2010.

Subsurface Conditions

The soil conditions while performing the energy measurements of the drill rig hammer consisted of poorly graded gravel with sand. SPT blow counts in the poorly graded gravel with sand ranged from 9 to 42 blows per foot (BPF), indicating the gravel was medium dense. Groundwater was encountered in the boring, but was not measured. Groundwater was at an approximate depth of 10 feet.

Drill String

The drill string for the automatic hammer consisted of a 24-inch long, 2-inch O.D. standard penetration test split-spoon sampler connected to 2.6-inch diameter NW rods. A 2-foot instrumented AW rod was attached to the top of the NW rod drill string using subconnectors. The instrumented AW rod had an outside diameter of 1.75 inches, and a cross-sectional area of 1.21 square inches. A 2.0- to 2.5-inch diameter steel anvil was placed on top of the instrumented AW rod providing the impact surface for the automatic SPT hammer.

Hammer

The automatic hammer attached to the Longyear BK-81 was reported to be a Diedrich auto hammer. No serial number or logo was visible on the auto hammer. Automatic SPT hammers have a typical ram weight of 140 pounds and are dropped a distance of 30 inches. Therefore, the rated energy of an automatic SPT hammer is 0.35 kip-feet.

Test Sequence

The soil borings and hammer energy measurements were performed on May 28, 2020. The soil boring was performed at the office of TSD Technical Specialists, Inc., in Billings, Montana. The soil boring had

been advanced to a depth of 9 feet prior to our arrival. SPT testing began at approximately 10:00 a.m. and ended at about 11:00 a.m. The soil boring was completed to a depth of 20 feet and energy measurements were obtained at three different SPT test intervals. These SPT test intervals were at 9 to 10 1/2 feet, 14 to 15 1/2 feet, and 19 to 20 1/2 feet.

Instrumentation

We used a Model PAX Pile Driving Analyzer™ to process the signals obtained by two sets of gauges, attached to a 2-foot portion of AW rod. Each set of gauges consisted of one accelerometer and one strain gauge. The gauges were mounted 1.16 feet below the head of the drill string. The data obtained from the PAX was used to calculate several values related to hammer efficiency, such as calculated energy transferred, energy transfer ratio, blows per minute, and maximum force in the drill string.

Hammer Calibration Results

The average transferred energy measured for the Longyear BK-81 (serial number BK-810193-117) automatic hammer was approximately 0.31 kip-feet. The ratio of measured transferred energy to manufacturer's rated energy yields a relative performance measure of the SPT hammer. This ratio ranged from 80.8 to 96.1 percent, with an average being 88.7 percent. The average measured compressive force in the drill string was 34 kips.

Summary

These SPT hammer energy measurements indicate the automatic hammer was generally operating properly. Transfer ratios of 75 to 85 percent are commonly observed for automatic hammers.

General Remarks

Services performed by SK Geotechnical Corporation for this project have been conducted with that level of care and skill ordinarily exercised by members of the profession currently practicing in this area under similar budget and time restraints. No warranty, expressed or implied, is made.

We appreciate the opportunity to perform these services for you. If you have any questions regarding this report, please contact Brett Warren at (406) 652-3930.

Sincerely,



Brett M. Warren, PE
Geotechnical Engineer

Attachments:

Descriptive Terminology
Log of Boring Sheet
Hammer Calibration Results

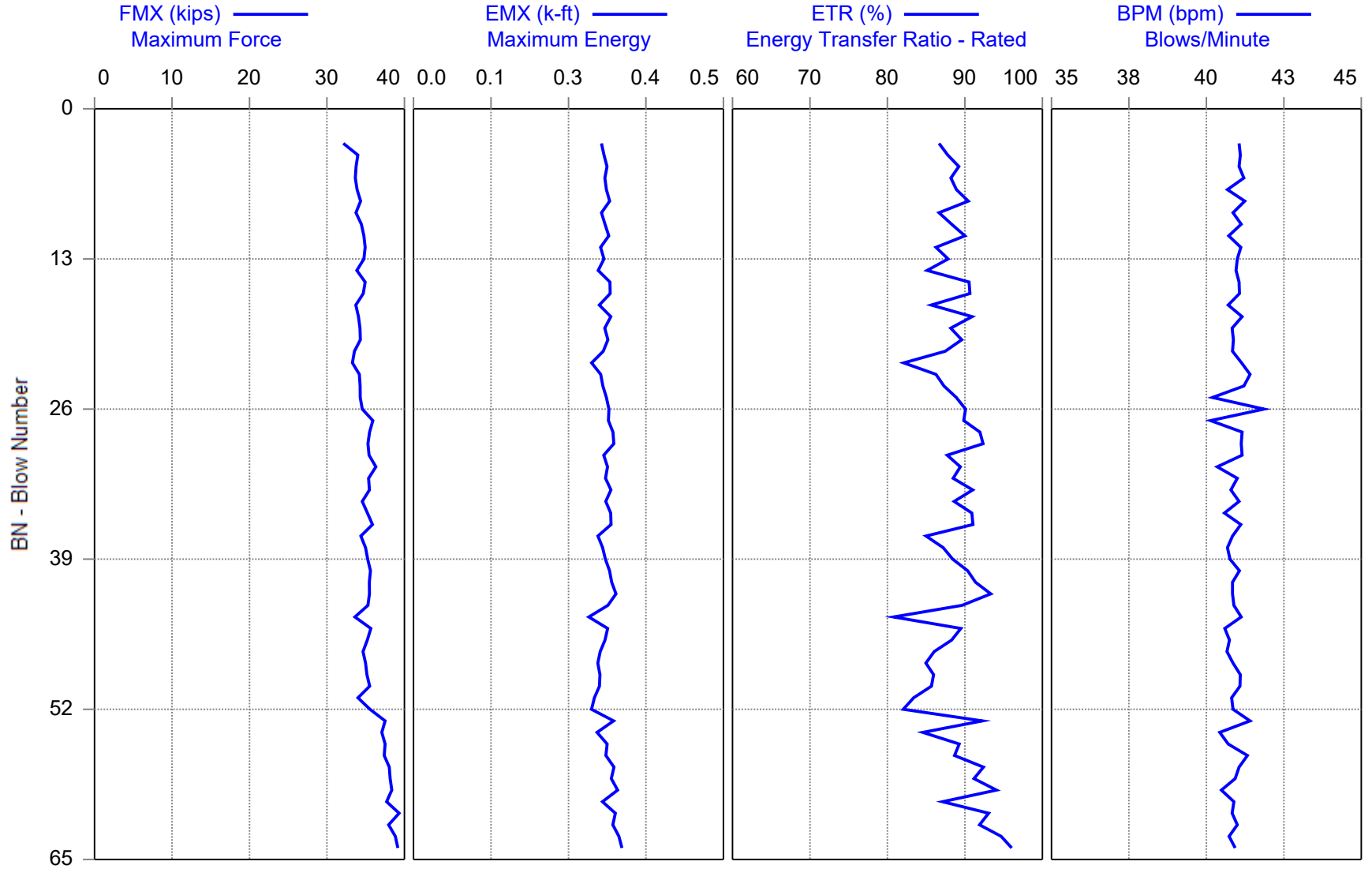


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LOG OF BORING

PROJECT: 17-3531SPT SPT Hammer Energy Measurements Haz-Tech Drilling Billings, Montana				BORING: ST-1			
				LOCATION: Haz-Tech Office/Garage			
DRILLED BY: Paul Bray		METHOD: 4¼" HSA		DATE: 5/28/20		SCALE: 1" = 4'	
Elev.	Depth	Symbol	Description of Materials	BPF	WL MC	qp	Remarks
	0.0						
	9.0		<p>Drilled down to 9' prior to arrival on site.</p> <p>POORLY GRADED GRAVEL with SAND, fine-to coarse-grained, olive brown, moist to waterbearing, medium dense. (Alluvium)</p>	9			Test 1: 9'-10½'
		GP		37			Test 2: 14'-15½'
	20.5		<p>END OF BORING</p> <p>Groundwater encountered, but not measured. Estimated at a depth of 10'. Boring backfilled.</p>	42			Test 3: 20'-20½'

BORING BPF WL-MC QP 3531.GPJ LAGNN06.GDT 6/26/20



Haz-Tech SPT Hammer Calibration - Instrumented AW rod, connected to NW Rod
OP: B. Warren
Date: 28-May-2020

AR: 1.20 in² SP: 0.492 k/ft³
LE: 23.0 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.90

FMX: Maximum Force VMX: Maximum Velocity
EMX: Maximum Energy CSX: Compression Stress Maximum
ETR: Energy Transfer Ratio - Rated CSI: Compression Stress Maximum - Individual Sensor
BPM: Blows/Minute

BL#	Depth ft	BLC bl/ft	FMX kips	EMX k-ft	ETR (%)	BPM bpm	VMX f/s	CSX ksi	CSI ksi
3	72.00	0	32	0.30	86.7	41.1	16.3	26.8	26.9
4	72.00	0	34	0.31	87.8	41.1	17.1	28.3	28.5
5	72.00	0	34	0.31	89.2	41.1	17.4	28.1	28.2
6	72.00	0	34	0.31	88.2	41.2	17.3	28.1	28.2
7	72.00	0	34	0.31	88.9	40.7	17.2	28.2	28.5
8	72.00	0	34	0.32	90.4	41.2	17.3	28.6	28.8
9	72.00	0	34	0.30	86.7	40.9	17.3	28.1	28.1
10	72.00	0	34	0.31	88.3	41.1	17.6	28.7	28.8
11	72.00	0	35	0.31	90.0	40.7	17.5	29.0	29.0
12	72.00	0	35	0.30	86.3	41.1	17.0	29.1	29.1
13	72.00	0	35	0.31	87.8	41.0	16.8	29.0	29.1
14	72.00	0	34	0.30	85.1	41.0	16.9	28.2	28.3
15	72.00	0	35	0.32	90.5	41.1	17.1	29.1	29.3
16	72.00	0	35	0.32	90.7	41.1	17.2	28.9	29.2
17	72.00	0	34	0.30	85.7	40.7	17.2	28.1	28.2
18	72.00	0	34	0.32	90.9	41.2	17.6	28.4	28.4
19	72.00	0	34	0.31	88.2	40.8	17.5	28.6	28.7
20	72.00	0	34	0.31	89.6	40.9	17.4	28.6	28.7
21	72.00	0	34	0.31	87.5	40.8	17.4	28.0	28.0
22	72.00	0	33	0.29	82.1	41.1	16.8	27.7	27.8
23	72.00	0	34	0.30	86.3	41.4	17.0	28.5	28.5
24	72.00	0	34	0.31	87.3	41.2	17.3	28.6	28.6
25	72.00	0	34	0.31	88.9	40.2	17.2	28.6	28.6
26	72.00	0	35	0.32	90.1	41.9	16.8	28.8	28.9
27	72.00	0	36	0.31	89.9	40.1	17.0	29.9	30.1
28	72.00	0	36	0.32	91.9	41.2	17.1	29.6	29.8
29	72.00	0	35	0.32	92.3	41.1	17.0	29.4	29.6
30	72.00	0	35	0.31	87.7	41.2	16.1	29.5	29.6
31	72.00	0	36	0.31	89.4	40.3	16.3	30.3	30.3
32	72.00	0	35	0.31	88.5	41.0	16.6	29.5	29.7
33	72.00	0	35	0.32	91.0	40.8	17.5	29.6	29.7
34	72.00	0	35	0.31	88.6	41.1	16.9	28.8	29.2
35	72.00	0	35	0.32	90.9	40.6	17.7	29.4	29.5
36	72.00	0	36	0.32	91.0	41.1	17.6	29.9	30.1
37	72.00	0	34	0.30	85.0	40.8	17.2	28.6	28.7
38	72.00	0	35	0.31	87.2	40.7	17.4	29.1	29.1
39	72.00	0	35	0.31	88.4	40.8	17.5	29.4	29.4
40	72.00	0	36	0.32	90.4	41.1	17.3	29.7	29.7
41	72.00	0	35	0.32	91.4	40.8	17.2	29.6	29.6
42	72.00	0	35	0.33	93.3	40.8	17.1	29.6	29.8
43	72.00	0	35	0.31	89.6	40.9	16.8	29.4	29.7
44	72.00	0	34	0.28	80.8	41.1	16.1	28.0	28.0
45	72.00	0	36	0.31	89.5	40.6	17.0	29.7	29.8
46	72.00	0	35	0.31	88.3	40.7	16.3	29.3	29.7
47	72.00	0	35	0.30	86.0	40.7	16.4	28.9	29.0
48	72.00	0	35	0.30	85.0	40.9	16.2	29.1	29.2

Haz-Tech SPT Hammer Calibration - Instrumented AW rod, connected to NW Rod
OP: B. Warren SPT Test
Date: 28-May-2020

BL#	Depth ft	BLC bl/ft	FMX kips	EMX k-ft	ETR (%)	BPM bpm	VMX f/s	CSX ksi	CSI ksi
49	72.00	0	35	0.30	86.0	41.1	16.3	29.3	29.3
50	72.00	0	36	0.30	85.7	41.1	16.0	29.6	29.6
51	72.00	0	34	0.29	83.4	40.8	15.3	28.3	28.5
52	72.00	0	36	0.29	82.0	40.9	15.6	29.6	29.6
53	72.00	0	38	0.32	92.2	41.4	16.2	31.3	31.3
54	72.00	0	37	0.30	84.6	40.4	15.3	30.9	31.0
55	72.00	0	38	0.31	89.3	40.7	15.5	31.3	31.3
56	72.00	0	37	0.31	88.7	41.3	15.7	31.2	31.2
57	72.00	0	38	0.32	92.4	41.1	16.0	31.7	31.8
58	72.00	0	38	0.32	91.2	40.9	15.4	31.8	31.9
59	72.00	0	38	0.33	94.1	40.5	16.0	32.0	32.1
60	72.00	0	38	0.30	87.1	40.9	15.4	31.4	31.4
61	72.00	0	39	0.33	93.1	40.8	15.5	32.8	32.9
62	72.00	0	38	0.32	91.9	41.0	15.4	31.6	31.6
63	72.00	0	39	0.33	94.7	40.7	16.1	32.4	32.4
64	72.00	0	39	0.34	96.1	40.9	16.0	32.6	32.7
Average			35	0.31	88.7	40.9	16.7	29.5	29.6

Total number of blows analyzed: 62

BL# Sensors

3-64 F5: [214AW1] 216.1 (1.00); F8: [214AW2] 216.7 (1.00); A6: [K1683] 385.0 (1.00);
A7: [K2755] 311.0 (1.00)

Time Summary

Drive 1 minute 30 seconds 10:46 AM - 10:48 AM BN 2 - 64