



**Dynamic
Measurements
and Analyses**

Job No. 189023-1

Report on: Standard Penetration Test Energy
Measurements
Chester, South Carolina

Prepared for F&ME Consultants
By Thomas G. Hyatt, P.E. and Joel S. Webster, E.I.
March 27, 2018

www.GRLengineers.com

info@GRLengineers.com



March 27, 2018

Mr. Jarod Ford
F&ME Consultants
3112 Devine St
Columbia, SC 29205

Re: Standard Penetration Test Energy Measurements
Chester, South Carolina

GRL Job No. 189023-1

Dear Mr. Ford;

This report presents results of energy measurements obtained on March 23, 2018 during Standard Penetration Test (SPT) sampling. Two automatic hammers mounted on two different drill rigs owned by F&ME Consultants were tested. The two drill rigs included a trailer mounted CME 45 B rig and an ATV mounted CME 550 X rig. All dynamic tests were performed on AW drill rods having J threads. GRL Engineers, Inc. obtained the dynamic measurements using an 8G Model Pile Driving Analyzer® and an instrumented AW-J rod subsection. This report describes the testing procedures and summarizes the test results. Appendix A describes our measurement and analysis methods, Appendix B contains the instrumentation calibrations and certificates, and Appendix C contains a summary of the field data.

PURPOSE AND SCOPE OF WORK

At the request of F&ME Consultants, GRL Engineers conducted SPT energy measurements in general accordance with ASTM D4633-10 during SPT sampling at a site near the intersection of Lowrys Highway and Hardin Strait Rd. in Chester County, South Carolina. Energy measurements on the two rigs were taken during five sampling events at five-foot intervals in dummy soil borings. The starting depth was 28.5 feet for each of the rigs, and ending depths were 50 feet below the existing ground surface. The SPT samples were driven for a total of three, 6 inch increments, or 1.5 feet, and the blow counts for each increment were recorded.

EQUIPMENT

Drilling and SPT Hammer Equipment

CME 45 B Trailer Mounted Drill Rig (Serial Number 303304)

SPT energy measurements were made on an automatic hammer mounted on a CME 45 B drill rig. The drilling method used to advance the boring was hollow stem auger. Energy measurements for this drill rig were collected at a borehole located in Chester County, SC. SPT energy measurements were performed at 5-foot sampling intervals between 28.5 and 50 feet. A total of five energy measurement events were performed for this drill rig.

CME 550 X ATV Mounted Drill Rig (Serial Number 249533)

SPT energy measurements were made on an automatic hammer mounted on a CME 550 X drill rig. The drilling method used to advance the boring was hollow stem auger. Energy measurements for this drill rig were collected at a borehole located in Chester County, SC. SPT

energy measurements were performed at 5-foot sampling intervals between 28.5 and 50 feet. A total of five energy measurement events were performed for this drill rig.

Instrumentation

An 8G Model Pile Driving Analyzer (PDA) data acquisition system manufactured by Pile Dynamics, Inc. was used to collect and process the dynamic measurements of force and velocity. A two foot long subsection of standard AW rod with J tapered threads (S/N 168AWJ) was instrumented with two full bridge foil resistance strain gages and two piezoresistive accelerometers mounted in the midpoint location of the instrumented rod.

Analog signals from the strain gages and accelerometers were conditioned, digitized, processed and stored by the PDA. Output from the PDA for each recorded impact included the maximum calculated maximum energy transfer, (EFV); the energy transfer ratio, (ETR); the maximum calculated rod force, (FMX); maximum rod top velocity, (VMX); the hammer operating rate, (BPM); the maximum computed displacement, (DMS); the final displacement, (DFN); and the maximum compressive stress at the gage location, (CSX).

MEASUREMENTS AND CALCULATIONS

FV Energy Method (EFV)

Energy transfer to the PDA gage location was computed by the PDA using the EFV method and the force, $F(t)$, and velocity, $v(t)$, records as follows:

$$EFV = \int_a^b F(t) \cdot v(t) dt$$

The time "a" corresponds to the start of the record when the energy transfer begins, and "b" is the time at which energy transferred to the rod reaches a maximum value. The EFV Method is currently recognized in ASTM D4633-10, and is the theoretically correct result; therefore, no other energy calculation methods are reported.

Corrected SPT number (N_{60})

While the primary purpose of SPT energy testing is to calculate the maximum transferred energy of each hammer blow, the overall average energy transfer value can be used to calculate the corrected SPT number (N_{60}). To adjust the SPT N-values for hammer performance, the following correction as suggested by Seed for N-value adjustment to 60 percent transfer efficiency (e.g. 210 foot-pounds) was used:

$$N_{60} = \left(\frac{E_m}{210} \right) N_m$$

Where:

N_{60} = Corrected N-value

E_m = overall average measured energy transfer (EFV)

N_m = number of blows for last 12 inches of sampler penetration

A general introduction to dynamic SPT testing methods is included in Appendix A. References for more detailed descriptions of our testing and analysis methods are available upon request.

Any cross-sectional area difference between the GRL rod subsection and the drill rods, any loose connections or changes in area at section joints, or any cross-sectional area differences between the individual drill rod sections could result in stress wave reflections that could influence the energy transfer. The EFV transferred energy calculation method, utilizing both force and velocity records, is theoretically correct and gives energy transfer results that are not significantly affected by cross-sectional area changes or loose connectors. The EFV results are included in Appendix C for all records collected and accepted after checking them for consistency.

RESULTS

Upon return to the office, the records collected by the PDA were checked for consistency and accuracy. For example, records from very weak startup or final impacts were not included in average results. Appendix C contains a representative plot of force and normalized velocity versus time, as well as tables of PDA results for all hammer blows at each dynamically monitored sampling depth. The results include the EFV (transferred energy by the FV method, as recommended by ASTM D4633-10), ETR (energy transfer efficiency for the EFV method), BPM (hammer operating rate), FMX (maximum rod top force) and VMX (maximum rod top velocity). The tables show statistical summaries for the last two 6 inch increments over which the SPT N value is calculated. At the end of each table is a statistical evaluation of these results which include the average and standard deviation.

The table below and the summary tables in Appendix C summarize the average transferred energy values calculated by the EFV method. The records consist of averaged hammer blows from the last 12 inches (i.e. N value) at each dynamically monitored sampling depth. The Energy Transfer Ratio (ETR) is defined as the ratio of maximum transferred energy EFV divided by the theoretical hammer potential energy of 350 foot-pounds (i.e., computed from the 140 pound SPT hammer and the standard 30 inch drop as specified by ASTM D1586-99).

Drill Rig	Avg. EFV (ft-lbs)	Avg. ETR (%)	Range of EFV (ft-lbs)	Range of ETR (%)
CME 45 B S/N 303304	295	84	277 – 317	79 – 91
CME 550 X S/N 249533	283	81	269 – 294	77 – 84

CONCLUSIONS

Based upon the dynamic test data obtained, the following conclusions are presented:

1. Loose connections in the drill string were sometimes observed in the force and velocity records. However, energy transfer values calculated using the EFV equation are not adversely affected by the connectors and therefore are considered a better indication of transferred energy.
2. Dynamic measurements of the transferred energy to the drill rods using the EFV equation ranged from 277 to 317 ft-lbs for the CME 45 B, SN 303304 drill rig. This corresponds to a transfer efficiency ranging from 79 to 91% of the SPT hammer energy of 350 ft-lbs.
3. Dynamic measurements of the transferred energy to the drill rods using the EFV equation ranged from 269 to 294 ft-lbs for the CME 550 X, SN 249533 drill rig. This corresponds to a transfer efficiency ranging from 77 to 84% of the SPT hammer energy of 350 ft-lbs.
4. The average transferred energy (EFV) and energy transfer ratio (ETR) for the two drill rigs tested were as follows:

CME 45 B, SN 303304: Average EFV = 295 ft-lbs; Average ETR = 84%

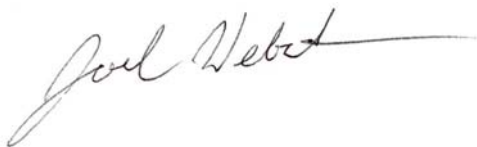
CME 550 X, SN 249533: Average EFV = 283 ft-lbs; Average ETR = 81%

Please review both ASTM D4633-10 and ASTM D1586-99 prior to applying these test results. The energy calibrations reported herein are valid for the same hammer/drill rig, with the same drill operator, same anvil dimensions, and same drilling methods.

We appreciate the opportunity to be of assistance to you on this project. Please contact our office should you have any questions regarding this submittal, require additional information, or if we may be of further service.

Sincerely,

GRL Engineers, Inc.



Joel S. Webster, E.I.



Thomas G. Hyatt



TGH:JSW:dms