Use of Voice-Recognition Systems for Atterberg Limit Tests

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The U. S. Army Engineers Ohio River Division (ORD) has incorporated a personal computer (PC)–based voice-recognition system for data acquisition in its geotechnical engineering laboratory. These systems recognize spoken commands as an alternative to keyboard input, which can be a major benefit considering the poor keyboard environment found in many geotechnical engineering laboratories. Voice-recognition systems have several useful implementations for control of simple tests in a production geotechnical engineering laboratory, one of the simplest being Atterberg limit determination. A system developed at the ORD laboratory for this purpose consists of an IBM voice-recognition system installed in a Zenith Z-248 PC. This system is coupled with a Mettler PE-3600 balance having an RS-232 output. The balance is triggered to make a reading by a digital signal produced by the parallel printer port. A computer program has been written to allow hands-off operation for Atterberg limit data acquisition and reduction. The type of system described does not remove the physical effort involved in conducting the test, but removes the need for data sheets and lessens the chance of calculation errors. Voice-recognition systems are being implemented at the ORD lab for visual classification tests.

The U.S. Army Engineers Ohio River Division (ORD) Geotechnical Engineering Laboratory has been incorporating automation and data acquisition techniques for simple, but common, soil index tests. Data acquisition systems are often easily adapted to shear tests (triaxial and direct shear) because the transducers used for measurement of force and displacement produce electrical outputs. With many index tests, however, weight is often the only parameter that is electronically measureable. The remaining parameters are usually alphanumeric and are recorded by technicians on data sheets.

Computer-based data-reduction systems have been in place in geotechnical laboratories for many years. Although these systems have proven to be indispensible in production testing, it is still necessary to enter the data into the computer via the keyboard. Accurate keyboard entry is an acquired skill. The dusty environment of a production geotechnical laboratory is a less-than-ideal environment for keyboard entry.

At the ORD laboratory, a system has been developed to aid data collection and reduction for Atterberg limit determination. This system uses a personal computer (PC)–based voice-recognition system to input the alphanumeric data, and a computer-operated electronic balance to record the weights associated with the Atterberg limits test.

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ATTERBERG LIMIT TEST

Atterberg limit determination is perhaps the most common test performed by production geotechnical engineering laboratories. It is also one of the easiest tests to perform, aside from the physical effort required for rolling the thread of soil for the plastic limit test and operating the liquid limit device. The only data acquired are water contents and the number of blows to close the groove. In addition to the information detailing the job and sample, the only data recorded by the technicians are the can or tare names, the tare weight, the weight of the tare and moist soil, the weight of the tare and dry soil, and in the case of the liquid limit test, the number of blows to close the groove cut in the sample.

A common procedure used for Atterberg limit tests is as follows:

1. Tare all cans and record can labels.
2. Conduct liquid limit tests, and record weight of tare plus moist soil.
3. Conduct plastic limit tests, and record weight of tare plus moist soil.
4. Place all cans in an oven.
5. After drying, record the weight of the tare plus dry soil.
6. Perform calculations.

The system described in this paper uses the same procedure, but the data is acquired either by voice input or automatically.

VOICE-RECOGNITION SYSTEMS

Voice recognition systems can be considered as an alternative to keyboard input for microcomputer operation. Compared with keyboard entry, voice recognition systems have the advantage that no specific skills are required to use them.

The basic technology used in voice recognition systems has existed for more than 10 years. Earlier systems were expensive and were predominantly the domain of powerful mini- and mainframe computers. Use of the systems was confined mainly to research laboratories. However, like much existing computer equipment, the price of the hardware involved has decreased drastically over the last few years, and many commercial voice-recognition products are available for microcomputers.

The two basic types of voice recognition systems are speaker-dependent and speaker-independent (*1*). Speaker-dependent systems need to be "trained" before use. Following a user-defined vocabulary, the user must repeat each word into a

microphone several times, and each word is digitized by the computer. The computer takes an average voice pattern for the word and stores it on disk. After training, when the user speaks into the microphone, the computer compares the voice pattern measured with those already stored on disk. When an adequate comparison is found, the word is printed on the screen in the same manner as if it were typed on the keyboard.

Speaker-independent systems do not need training. Voice patterns are already stored in the computer for certain words. The technology for these systems has not been developed as fully as speaker-dependent systems, and they are more expensive and less accurate. These systems usually have much smaller vocabularies, and regional accents can cause incorrect words to be interpreted.

ATTERBERG LIMIT TEST SYSTEM

The system used at the ORD laboratory to aid in conducting Atterberg limit tests consists of four components:

- Voice recognition card,
- Electronic balance,
- Automatic balance switch, and
- Microcomputer.

Voice Recognition Card

In this application, an IBM Voice Communication Option board, a speaker-dependent system, was used. This card, coupled with IBM Voice Activated Keyboard Utility software, allows a maximum usuable vocabulary of about 160 user-defined words, depending on the amount of disk storage space and random access memory. The memory resident software used with this system translates the spoken words into the proper keystrokes. Although the system will allow up to 160 words, only 60 words were needed in this application.

A utility program supplied with the board is used to "train" the system. The operator has to repeat each vocabulary word into the microphone five times to store the required voice patterns. This process takes about 20 min to complete.

Electronic Balance

A Mettler PE-3600 electronic balance is used for recording the weights. This balance, as well as other commercially available balances, has an RS-232 (serial) output port. When a weight measurement is triggered by pressing a button next to the balance, a character string is sent to the computer via the serial port. The balance is designed such that the character string is only transmitted if there are no fluctuations in the reading.

Automatic Balance Switch

In order to bypass the button to trigger the balance to make a reading, a relay board was constructed. The parallel (printer) port of a microcomputer is an 8-bit digital-output port. A relay powered from a true bit voltage (4.5 VDC) simulates the pressing of the button on the electronic balance. In this manner, the balance can be triggered to perform a weight reading under software control.

Microcomputer

A Zenith Z-248, an IBM-AT class computer, is used to process the data. The performance of a PC-based voice-recognition system depends on the speed of the personal computer. The Z-248 computer used in this application provides about the minimum acceptable performance for the voice-recognition system described. A hard disk is necessary to store the vocabulary files for all of the users. In addition, a serial port is required to receive the output of the balance, and a parallel port is needed to trigger the balance to make a reading.

Shown in Figure 1 is a schematic of the voice-recognition Atterberg limit system.

SYSTEM OPERATION

A computer program named AUTOBERG was written in Microsoft QuickBASIC to control the operation of the Atterberg limits system. At the start of the program, the user must enter his or her name via the keyboard so that the proper vocabulary file may be loaded. After this, the program is under voice control and the main menu (Figure 2) is displayed. The highlighted words shown on this figure are the key words that control the main menu functions.

The first step in conducting a test is to tare the moisture-content containers. At the ORD laboratory, all of the moisture content tests are named by a letter and two numbers (e.g., A16). The technician first says the main menu command "tare" into the microphone and places an empty container on the balance. The technician then says the name of the container in the standard military verbal alphabet. For the container labeled A16, the technician would say, "alpha-one-six." The program then sends the proper bit sequence out of the parallel port to trigger the balance, and the balance makes the measurement. The output string from the balance is read

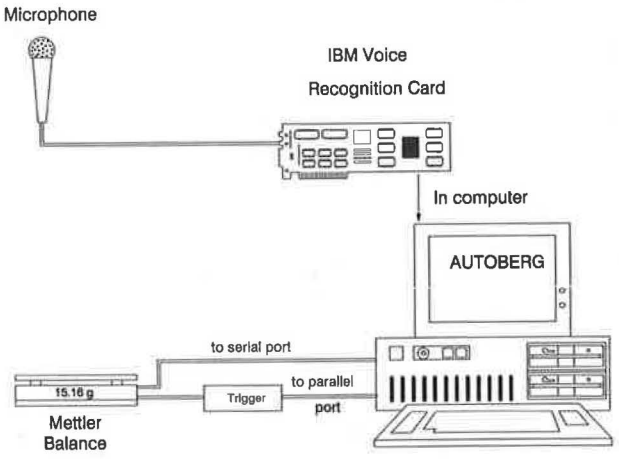


FIGURE 1 Schematic of components used in voice recognition Atterberg limit system.

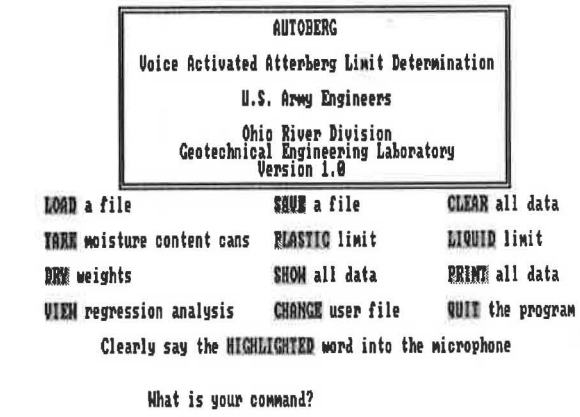


FIGURE 2 Main menu of the computer program AUTOBERG

through the serial port of the computer, and the can name and weight are recorded in a data file. The technician then repeats this process for the tare weight of all the plastic and liquid limit moisture content tins.

The next step is the plastic limit determination. After the ⅛-in. threads of soil are rolled to the proper consistency, the technician places them in a tared moisture content container and places the container on the balance. The technician then says the main menu key word "plastic." The program prompts for the can name, and the techncian says the name in the manner as described above. The weight is automatically taken and appended to the data file.

The liquid limit recording procedure is the same as the plastic limit procedure, except after the measurement of the weight of the moist soil and can, the program prompts for the number of blows. Each digit of the number of blows is spoken into the microphone.

To initiate the procedure for recording the final oven-dried weights, the technician says, "dry" into the microphone. The procedure followed is the same as during the initial taring of the cans. For all procedures, the cans may be weighed in any order. The program correctly associates the correct moist and dry weights and tare weights with the type of test performed on the specimen identified by the can label.

Saying the key word "show" displays the data on the screen in tabular form (Figure 3). The data are automatically reduced

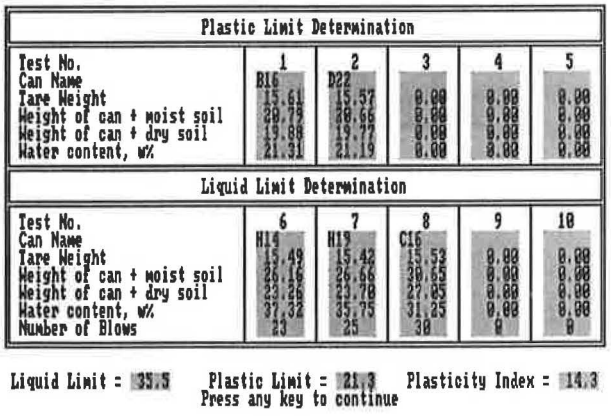


FIGURE 3 Data displayed on the computer screen by the main menu command "show."

as soon as all of the necessary weights have been taken. The plastic limit given at the bottom of the screen is an average of all of the plastic limit tests made in the test series. The liquid limit is calculated on the basis of a linear regression analysis performed on the data. By saying "print," the technician can receive a copy of the data in this form if a printer is connected to a second parallel port.

The key word "view" plots the logarithm of the number of blows versus the water content for the liquid limit test on the computer screen. The "best fit" line determined from the linear regression analysis and the calculated liquid limit are also shown on the screen.

The program also allows Atterberg limit files to be saved and loaded. The filename may be entered by means of the keyboard, or the filename may be spelled in the same manner as the tare names are entered. The file format created by AUTOBERG is compatible with a companion program, LIMITS, written for the ORD laboratory. This program allows the job name, sample number, boring number, and other descriptive information to be appended to the AUTOBERG file. This program will automatically classify the soil according to the USCS system based on the Atterberg limits, and will generate a hardcopy output similar to the U.S. Army Corps of Engineers ENG Form 3838. Shown in Figure 4 is an example of the hardcopy obtained with LIMITS.

BENEFITS AND LIMITATIONS

The voice-recognition Atterberg limits system described is one of the first attempts at integrating alternative input systems into the ORD geotechnical laboratory. Certain advantages have become apparent with its use:

- The record keeping associated with Atterberg limit tests has been simplified.
- Errors associated with manually recording and reducing the data have been reduced.
- Time is saved in preparation of the final report form.

Although this system has proven to be useful in the ORD laboratory, limitations have also become evident:

- The voice recognition hardware must be used in a relatively quite environment. Extraneous noise may be interpreted as spoken words by the computer.
- The technician using the system must "train" the computer to understand his or her individual vocabulary. After that time, the technician must always distinctly pronounce each word.
- Constructing such a system involves a relatively high cost. At the time the system was developed (1988), the price of the hardware was approximately $4,500. The price has decreased somewhat as a result of further developments in voice-recognition systems and computer hardware.

SUMMARY AND CONCLUSIONS

A microcomputer-based voice-recognition system has been developed at the U.S. Army Corps of Engineers ORD Lab-

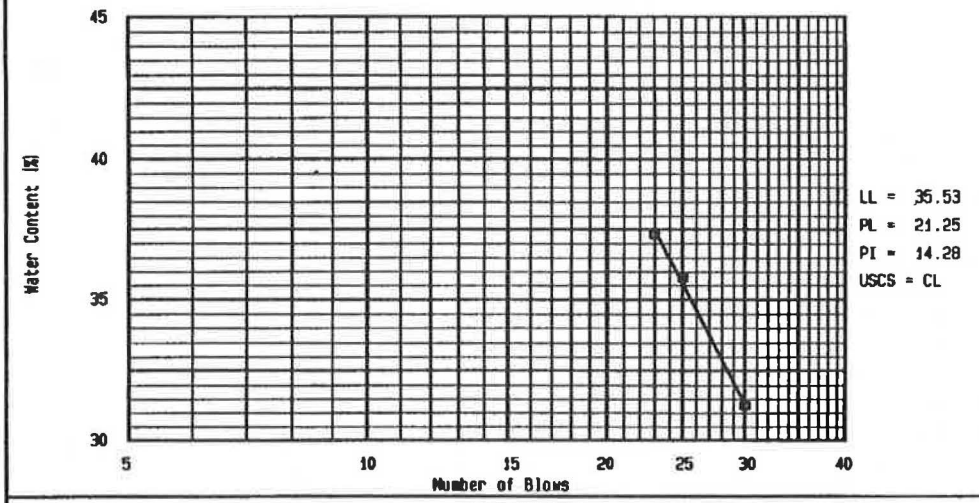
LIQUID AND PLASTIC LIMIT TESTS

Project: ATT Region 1 Fairlawn Virginia — Date: 01-29-1990

Boring No.: B-18 — Sample No.: UD-1

LIQUID LIMIT

Run Number	1	2	3	4	5	6
Tare Number	H4	H9	CMP6			
Tare plus wet soil, g	26.16	26.66	30.65			
Tare plus dry soil, g	23.26	23.7	27.05			
Weight of water, g	2.89	2.95	3.6			
Weight of tare, g	15.49	15.42	15.53			
Weight of dry soil, g	7.77	8.28	11.51			
Water content (%)	37.32	35.74	31.25			
Number of Blows	23	25	30			



PLASTIC LIMIT

Run Number	1	2	3	4	5	6
Tare Number	B-16	DD2				
Tare plus wet soil, g	20.79	20.66				
Tare plus dry soil, g	19.88	19.77				
Weight of water, g	.91	.88				
Weight of tare, g	15.61	15.57				
Weight of dry soil, g	4.26	4.2				
Water content (%)	21.31	21.19				

Remarks:

Technician: Computed by: ABERG Checked by:

FIGURE 4 Hard copy output of reduced Atterberg limits test results.

oratory to aid in conducting Atterberg limit tests. The controlling computer program, AUTOBERG, is under complete voice control. This system uses an electronic balance to make all weight measurements, and all data are automatically reduced. A companion program, LIMITS, classifies the soil specimen based on the Atterberg limits, and produces a report-quality form similar to the U.S. Army Corps of Engineers Form 3838.

Although care need be exercised when operating the system, it has proven to reduce the time required for data reduction and the chance of operator error. Application of voice-recognition technology is currently being extended to visual classification procedures.

REFERENCE

1. W. L. Rosch. 1987. Voice Recognition: Understanding the Master's Voice. *PC Magazine*, Vol. 6, No. 8, pp. 261–295.

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