Interpretation of Boring Logs for Structural Engineers

By Richard P. Weber

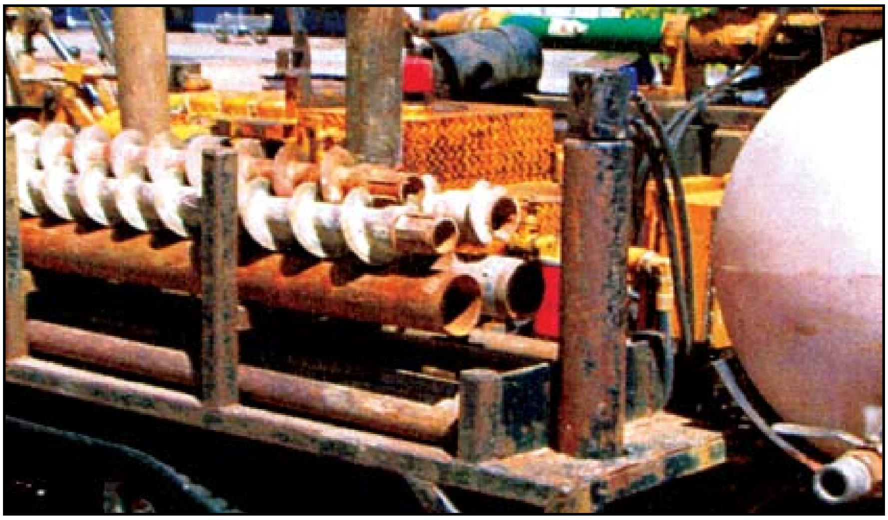

Figure 1: Hollow Stem Augers and Flush Joint Casing

The purpose of any subsurface exploration program is to retrieve information so that the appropriate individual can assess and interpret conditions below the ground surface. One method of exploration is through soil test borings. When borings are taken, a hole is advanced into the ground and samples of the material are taken at defined intervals. The information that is retrieved is recorded on a log. The main purpose of the log is to document the findings and transfer information to others.

Once the information is delivered, it must be interpreted. The purpose of this article is to explain the information presented on a soil test boring log, and show how this information can be properly interpreted.

Borings

Soil test borings include a procedure to open a small-diameter hole in the ground and retrieve samples of the material. ASTM D1586, *Standard Method for Penetration Test and Split-Barrel Sampling of Soils*, specifies the method used for making a boring and conducting the penetration test to yield the value N, *Figure 1*.

In soil, drillers advance the boring using a hollow stem auger (HSA) or flush joint casing (FJC), which is pipe. Most often the boreholes are advanced in 5-foot increments in order to retrieve a sample at each 5-foot depth. In some cases the samples might be taken at more closely spaced intervals, such as 2.5 feet, or at detected changes in soil strata.

In bedrock, the drillers advance the borehole using rock coring methods to retrieve samples of the rock in continuous 5-foot runs. The inspector classifies the rock and notes the degree of weathering and fracturing to assess the rock quality.

Soil Sampling

When the driller reaches the sampling depth, he or she retrieves the sample by driving a standard split spoon sampler into undisturbed soil below the casing using a standardized procedure defined in ASTM D1586 (*Figure 2*).

The driller advances the sampler using a 140-pound weight (hammer) falling 30 inches. Often the driller drives the sampler an additional 6 inches for a total driven distance of 24 inches. Before driving the sampler, the driller marks off 6-inch increments along the rod so that the inspector can record the number of hammer blows required to drive the sampler for each of the 6-inch increments. The sum of the blows for the second and third driven interval (i.e. 6 inches to 12 inches and 12 inches to 18 inches) provides the standard penetration resistance, or N-value. The N-value is the basis for many geotechnical engineering calculations and classification of soil material, relative density and consistency.

Logs

The driller or inspector records all of the information derived from the boring on a written log. ASTM D1586 states what information should be shown on the log. A typical soil test boring log is shown in *Figure 3*. (see page 53)

Background Information

The heading (*circled in red*) provides background information. The ground surface elevation can be derived from an actual survey or interpolation between topographic contours from a site plan.

The groundwater depth is usually shown in this section. If a groundwater observation well were installed in the borehole, it would be noted on the log. Pay attention to the time component that accompanies the groundwater measurement. In the example shown, the groundwater measurement was taken 4 hours after completing the boring. Often the inspector or driller makes a measurement immediately after completing the borings because it is not feasible to leave the borehole open. Within this short time interval, the groundwater level might not have stabilized, especially in slow-draining material or where water was used to flush material from the casing. Therefore, the actual groundwater level could be higher or lower.

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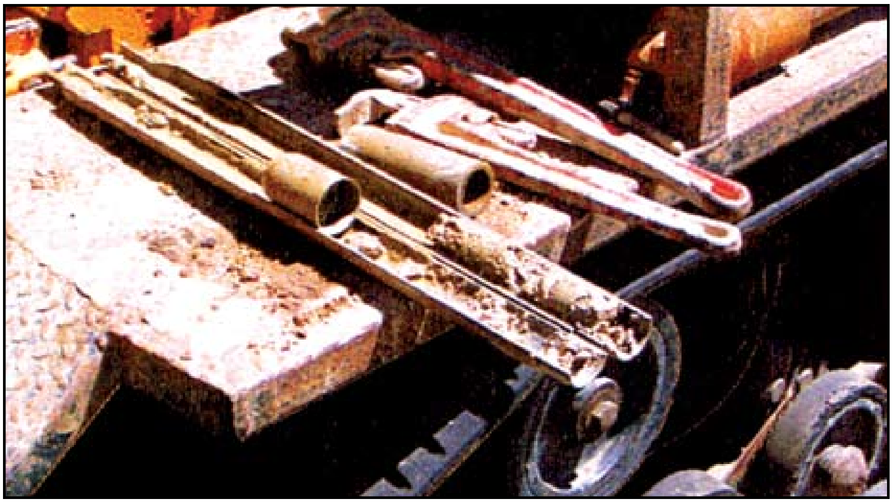

Figure 2: Standard Split Spoon Sampler

The log also provides information on the equipment used. Pay attention to the drilling method used to advance the borehole. On some logs this information might be referred to as "casing". The two types of casing commonly used are HSA and FJC.

Hollow-stem augers are rotated into the ground, and the auger flights remove soil as the casing advances. A plug is placed at the tip of the auger to prevent material from entering the hollow stem. Flush joint casing is driven into the ground using an impact weight, and the material inside the casing is washed out using drilling fluid (usually water).

The type of casing used is important, because it can affect the results of the penetration test and N-value. Avoid using hollow-stem augers to drill below the groundwater level in sand having little to no fines. As the driller removes the plug from the bottom of the auger, there is a volume reduction inside the casing that results in a temporary unbalanced water level between the groundwater outside the casing and the water inside the casing. The unbalanced water level causes a seepage force, which can loosen the soil below the auger or cause the material to flow up into the auger. If the latter condition occurs, it is difficult, if not impossible, to continue the boring. Worse, the loosened soil within the sampling interval below the tip of the auger can result in an artificially low penetration resistance. Thus, the material appears looser, providing inaccurate results.

Sampling Intervals and Results

The columns (*circled in blue*) provide additional information and appear on all logs. Study the information shown for sample S-2. This sample was retrieved beginning at a depth of 3 feet below ground surface (BGS) and continuing to a depth of 5 feet BGS. Although the driller drove the sampler 24 inches, when the driller opened the sampler, there was only 14 inches of material recovered in the barrel of the sampler. This information is shown in the Penetration/Recovery column. The total distance driven is Penetration and the quantity of material recovered is Recovery. The amount of recovery provides a measure of sample quality.

The inspector records the number of blows required to drive the sampler in 6-inch increments in the last column. In the example given for S-2, the blow counts of 5, 6, 10 and 21 indicate that the sampler was driven the first 6 inches with 5 blows (hammer drops), the second 6 inches with 6 blows, and so on.

The sum of the second and third interval (i.e. 6 inches to 12 inches and 12 inches to 18 inches) provides the Standard Penetration Resistance (N). In this example, the N-value is 16 blows per foot. Computer generated logs often provide a plot of the N-value with depth as shown within the *green circled area*. Not all logs show this plot, although it is helpful because it provides a graphical presentation of how the soil resistance changes with depth.

The N-value has been correlated to descriptive terms for the relative density of cohesionless material, such as sand, and the consistency of cohesive material, such as clay. A typical correlation is shown in *Table 1*.

In some cases, usually in organic or cohesive material, the log might include an acronym "woh" or "wor". These acronyms mean "weight of hammer" and "weight of rod". This designation indicates that the material is so soft that the sampler penetrated into the sampling interval under just the weight of the rods (wor) or weight of the rods and hammer (woh) without using any hammer drops to drive the sampler. The distance that the sampler settled is also provided. Thus, "wor/12" would mean that the sampler sunk 12 inches into the sampling interval just under the weight of the rods alone.

Soil Description

When the driller opens the sampler, the soil becomes visible for classification. The area circled in black highlights information derived from observing and classifying the soil. The first column, "Description of Samples", provides a detailed visual description of the material expressed using a classification system. There are several classification systems that can be used, such as ASTM D2488, *Description and Identification of Soils (Visual-Manual Procedure)*, although some engineers might use a combination of several as a personal preference. The purpose of the description is to paint a visual image of the material and to convey components of the sample that will identify the material. Sand, gravel, silt, clay, organic material and pieces of debris should be noted.

Table 1: Relative Density and Consistency of Soil

Cohesionless Soil		Cohesive Soil	
Relative Density	**N-Value**	**Consistency**	**N-Value**
Very Loose	0 - 4	Very Soft	0 -1
Loose	5 - 10	Soft	2 - 4
Firm	11 - 20	Firm	5 - 8
Very Firm	21 - 30	Stiff	9 - 15
Dense	31 - 50	Very Stiff	16 - 30
Very Dense	> 50	Hard	> 30

Ref: Introductory Soil Mechanics and Foundations, Sowers and Sowers (1970)

Often the description will include material such as cobble and boulder. According to ASTM D2488, cobble-size material ranges between 3 inches and 12 inches, and boulder-size material is greater than 12 inches. Drilling characteristics noted by the driller or inspector provide information on whether cobble- or boulder-size materials are present.

The inspector records the total depth of the boring and will terminate the boring for a number of reasons, which are noted on the log. In most cases, the inspector will terminate the boring at the planned depth. In some instances, the inspector will terminate the boring when it is impossible to advance the casing without using methods such as coring. ASTM D1586 also defines termination criteria.

The column entitled "Soil Strata" provides the observer's interpretation of subsurface conditions based on factors such as the similarity of the material retrieved in the sampler, the penetration resistance and the interpretation of drilling characteristics such as how difficult or easy it was to advance the casing and whether there is a grinding noise indicating the presence of cobble- or boulder-size materials. Sometimes, the driller can detect the bedrock surface by drilling characteristics but without actually coring the material and retrieving a sample; this is a judgment call.

The stratification lines between soil units are approximate and based on judgment. Occasionally, the change of material is evident in the sample retrieved, but more often, the change occurs between the sampling intervals.

Conclusion

The soil test boring log is a direct link between the actual subsurface conditions and what is needed for engineering analysis. It is a tool that conveys important data and often, long after the soil samples have been discarded, it is the only remaining evidence of what exists underground. The log is effective when prepared carefully, but it can also be misleading if important details are missing. The guidance in this article will help structural engineers properly interpret the information presented on a soil test boring log.▪

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Figure 3: Soil Test Boring Log

BORING LOG

(Page 1 of 1) **Boring No: B-1**

Project:	Any Project, City, State		
Client:	Project Name	**Project No:**	Project Number
Drilling Subcontractor:	Subcontractor Company Name	**Date Started:**	MM/DD/YY
Drilling Foreman:	Driller's Name	**Date Completed:**	MM/DD/YY
Engineer:	Your Name	**Location:**	Project Location
Ground Surface Elev:	73.5	**Total Depth:**	16 ft.
Ground Water Depth:	9.7 ft after 4 hours	**Drill Rig Type:**	ATV Track Rig
		Drilling Method:	4.25 HSA
Hammer Weight:	140 lbs.	**Split Spoon Diameter:**	ID - 1.375", OD -2"
Hammer Type:	Safety	**Rock Core Barrel Size:**	N/A
Drop:	30"		

Depth (ft)	Sample No.	Sample Depth (ft)	Sample Pen./Rec. (in)	Sample *Blows Per Six Inches/ RQD (%)	Description of Samples (Classification)	Remarks	Soil Strata	N Value (bpf) (20 40 60 80)	PID (ppm)
2.0	S1	1.0 3.0	24/15	4-4-3-5	S1 Silty SAND (SM), fine to medium, trace coarse, 40-45% fines, dark brown and tan.		Fill	7	
4.0	S2	3.0 5.0	24/14	5-6-10-21	S2 Top 7", Similar to S1. Bottom 7", Silty SAND (SM), fine to medium trace coarse, 15-20% fines, 10-15% gravel, tan and brown, moist.			16	
6.0	S3	5.0 7.0	24/19	18-19-14-12	S3 Top 8", Similar to S1. Bottom 11", Silty SAND (SM), fine to medium trace coarse, 35-40% fines, gray and rust brown, black sand at bottom.		Glacial Till	33	
8.0	S4	7.0 9.0	24/15	13-23-39-21	S4 Similar to Bottom of S3.			62	
10.0	S5	9.0 11.0	24/20	9-10-21-20	S5 Sandy CLAY (SC), medium plasticity, 25-30% fine to coarse sand, ~15% fine to coarse gravel, gray and brown, moist.	▼		31	
12.0									
14.0		14.0				1			
	S6	14.0 16.0	24/18	17-44-16-34	S6 Clayey GRAVEL (GC), fractured gravel, 35-40% fines, gray, completely weathered rock.		Weathered Rock	60	
16.0		16.0			Bottom of Boring at 16 ft. Backfilled with cuttings.				
18.0									
20.0									
22.0									

Remarks: 1 Strata change based on drillers observation

**Number of blows required for a 140 lb. hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 24 inches in four 6" increments. The sum of the middle two increments of penetration is termed the standard penetration resistance, N. RQD = Rock Quality Designation. WOH = Weight of Hammer. WOR = Weight of Drilling Rods.*