Comparison of the Humboldt GeoGauge™ With In-Place Quasi-Static Plate Load Tests

Charles R. Nelson, P.E.
Mike Sondag

CNA Consulting Engineers
2800 University Ave. S.E.
Minneapolis, MN 55414

December, 1999

Soil stiffness was measured by two different methods on an existing construction site at the junction of Highway 55 and Minnehaha Parkway in Minneapolis, MN. The soil was fill material composed mostly of sand, with gravel of various size up to 2 inches. Tests were taken on vibratory roller compacted material at three levels of compaction: 2, 4, and 6 passes with the compactor. Though the soil was slightly moist, the moisture content was not adequate to produce appreciable compaction, as evidenced by checking at the surface shown in Photo 1.

Photo 1. Checking of Soil

Photo 2. Humboldt GeoGauge

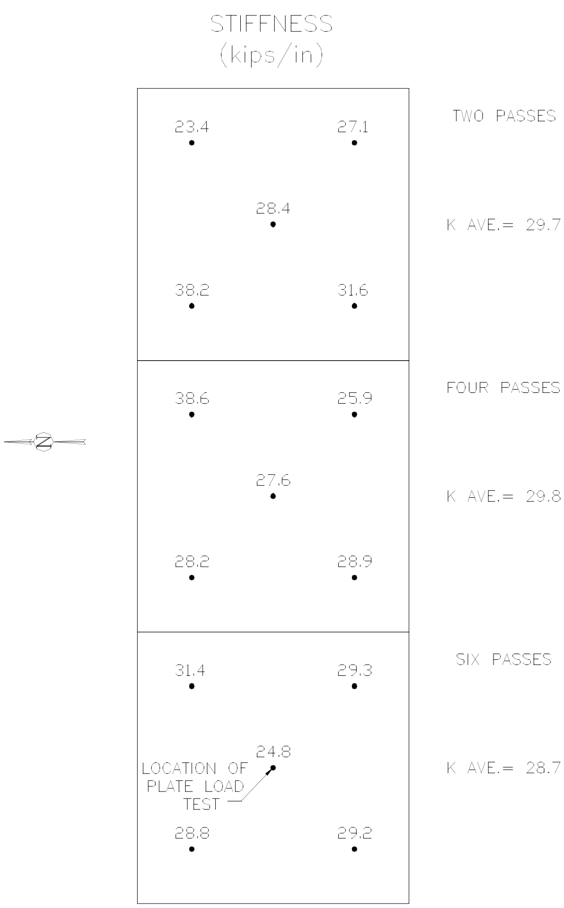

Figure 1. Stiffness Measurements

Humboldt GeoGauge

The first stiffness measurements were made using the Humboldt GeoGauge, shown in Photo 2. The GeoGauge measures the dynamic force deflection response of the soil surface loaded by a 4.5” ring. The GeoGauge operates analogous to a dynamic plate load test. Each GeoGauge test takes less than two minutes, allowing a large amount of data to be collected. The stiffness data collected at the Highway 55 site is shown by the Figure 1 plan view. Three locations are shown, each having 2, 4, or 6 passes with a vibratory compactor.

The stiffness values obtained with the GeoGauge may be converted into Young’s modulus using the following equation:

$$E = K(1-\nu^2)/1.77R$$

where:
K = Stiffness from GeoGauge
ν = Poisson’s ratio, assume 0.35 for soil
R = Radius of GeoGauge ring (2.25 inches)

Instead of the ring-shaped foot, the GeoGauge may also be outfitted with a plate. A similar formula exists for the conversion from stiffness to Young's modulus when the plate is used, though it is not presented here.

The data in Figure 1 is in units of kips/inch. Assuming a Poisson's ratio of 0.35 and using the equation for Young's modulus from the previous page, the average modulus for 2 and 6 compactor passes was calculated. It was anticipated that the soil stiffness/modulus would increase with increasing passes of the compactor. However, the data shows no indication of this being the case, in fact a decrease from 29.7 kips/in (6,543 psi) to 28.7 kips/in (6,323 psi) was observed as compaction increased from 2 to 6 passes. The lack of increasing stiffness can likely be attributed to the fact that the moisture content of the sandy soil was not adequate for the compaction process to take effect. The checking pictured previously in Photo 1 may be evidence that the compactor loosened soil at the surface, causing a slight decrease in stiffness.

Quasi-Static Plate Load Test

The second method of measurement used was a quasi-static plate load device, where the force is applied by a lever system as shown in Photo 3. Instead of a plate a 4.5" diameter ring, similar to the GeoGauge ring, was used. Applied force is measured by a load cell and the deflection of the 4.5" ring is measured by an LVDT (linear variable differential transducer). The ring and LVDT are pictured in Photo 4.

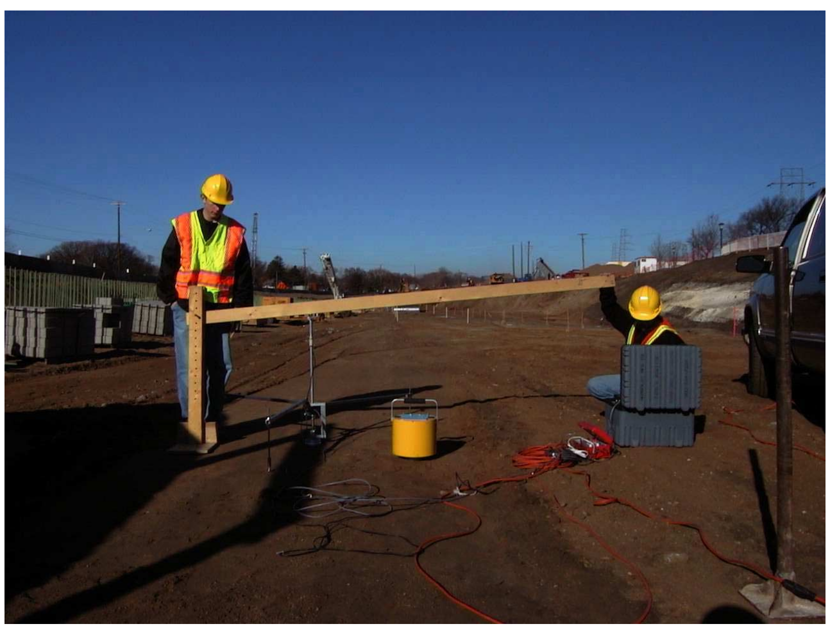

Photo 3. Quasi-Static Plate Load Test

Photo 4. 4.5" Ring and LVDT

Data is recorded on two channels (load and deflection) as the test progresses. The load is applied with the lever system and then released, with deflection measured as the soil deflects and rebounds. This process is repeated a number of times, with the maximum applied load increasing each load cycle.

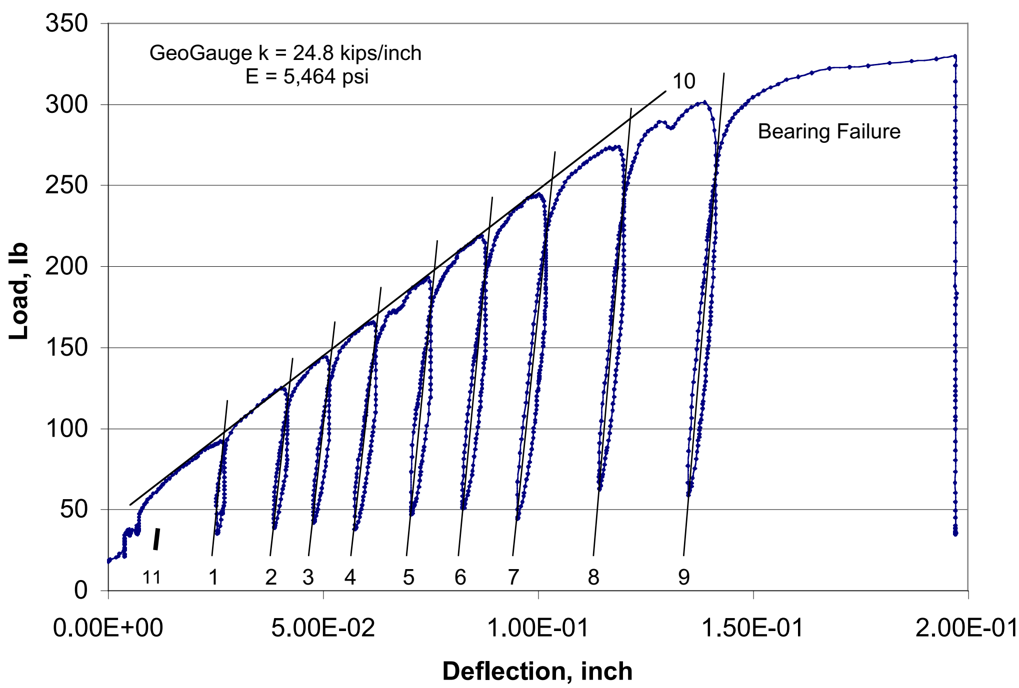

Figure 2. Data Collected at Highway 55, 6 Roller Passes

The data in Figure 2 were collected at the Highway 55 site after 6 vibrating compactor passes. The load does not begin at zero since the weight of the lever assembly is almost 20 pounds. Bearing strength of the soil was exceeded at just above 300 pounds of load. Evidence of this failure is exhibited by the large deflection after the last load cycle, and by the lack of soil rebound at the end of the test. Bearing failure was also evident upon visual inspection.

Static ring stiffness was measured using the slopes of the 9 load/unload curves in Figure 2. The stiffness values obtained from each of the 9 curves are given in the table below:

Curve	Stiffness (kips/inch)	Modulus (psi)
1	28.7	6323
2	24.2	5332
3	23.6	5199
4	22.9	5045
5	28.0	6169
6	28.2	6213
7	26.3	5794
8	31.3	6896
9	30.8	6786

Summary of 9 Load/Unload Curves from Figure 2:

- Average Stiffness = 27.1 kips/inch
- Standard Deviation = 3.1 kips/inch
- Coefficient of Variation = 11.3%

Stiffness along line 10 in Figure 2 is 1.7 kips/inch. This presents a striking difference to the soil stiffness value obtained from the load/unload curves. The choice of using the stiffness from the load/unload curves or from line 10 is obviously very important when designing a pavement or foundation.

Line 11 in Figure 2 approximately represents where the GeoGauge operates in relation to the static plate load test. The gauge weighs about 22 pounds and imparts a small dynamic force to the soil. The stress level for a GeoGauge measurement is therefore generally much lower than the plate load test. GeoGauge deflections are also much smaller than the plate load test..

Comparison of the two stiffness values obtained from the GeoGauge and the plate load test show a good correlation. The Humboldt GeoGauge measured a stiffness of 24.8 kips/inch from the load/unload curves and the quasi-static plate load test averaged 27.1 kips/inch, a difference of less than 10 percent. The two measurements were taken in the same location, with the GeoGauge reading taken first.