METHODS OF SAMPLING AND TESTING
MT 337-10
METHOD OF TEST FOR SOIL STIFFNESS GAUGE

1 Scope

1.1 This method covers the in-place evaluation of the stiffness of base course material for use in roadways by means of electro-mechanical stiffness measurements.

2 Reference Documents

ASTM
D6758 Standard Test Method for Measuring Stiffness and Apparent Modulus of Soil and Soil-Aggregate In-Place by an Electro-Mechanical Device

MT Materials Manual
MT 212 Determination of Moisture and Density of In-Place Materials

Other
H-4140 – Test Method for Using the Humbolt GeoGauge as an In-Place Index of CBR

3 Terminology

3.1 *Stiffness* – the ratio of change of force to the corresponding change in translational deflection of an elastic element.

3.2 *Young's modulus* – the ratio of the increase in stress on a test specimen to the resulting increase in strain under constant traverse stress limited to materials having a linear stress-strain relationship over a range of loading, also called elastic modulus.

3.3 *Poisson's ratio* – the ratio between linear strain changes perpendicular to and in the direction of a given uniaxial stress change.

3.4 *Foot* – the part of the gauge which contacts the ground and imparts force to it.

3.5 *Footprint* – the annular ring imprint left on the ground by the foot of the gauge.

3.6 *Non-destructive testing* – a condition that does not impair future usefulness and serviceability of a layer of soil or soil-aggregate mixture in order to measure, evaluate or assess its physical properties.

3.7 *Seating the foot* – the process of placing the gauge on the ground such that the desired footprint is achieved.

3.8 *Site* – the general area where measurements are to be made.

3.9 *Test location* – a specific location on the ground where a measurement is made.

3.10 *Shear modulus* (G)

$$G = \frac{E}{2(1+v)} \qquad (1)$$

Where:
G = shear modulus, kpsi (MPa),
E = Young's modulus, kpsi (MPa),
v = Poisson's ratio

4 Significance

4.1 This test method is suitable for the in-place determination of a Young's and a shear modulus of soil and soil-aggregate mixtures (3, 4). Stiffness, as measured by this method, is related to modulus (5) from an assumption of Poisson's ratio and from the radius of the foot of the gauge as follows:

$$Kgr \approx \frac{1.77RE}{(1-v^{2})} \approx \frac{3.54RG}{(1-v)} \qquad (2)$$

Where:
Kgr = stiffness of the ground layer being measured, klbf/in (MN/m),
R = outside radius of the gauge' foot, in (m),
v = Poisson's ratio,
E = Young's modulus, kpsi (MPa),
G = shear modulus, kpsi (MPa).

5 Gauge

5.1 Stiffness gauge – an electro-mechanical instrument capable of being seated on the surface of the material under test and which provides a meaningful and measureable stress level and a means of determining force and displacement.

5.2 *Seating sand* – a supply of moist, clean, fine sand passing a No. 30 (600µm) sieve that is sufficiently moist to clump in the palm of the hand. This is used to assist the seating of the rigid foot on hard and rough surfaces or at anytime when additional assistance in seating is required.

5.3 *Principle of Operation* - The force applied by the shaker and transferred to the ground is measured and calculated by differential displacement across the internal flexible plate as follows:

Fdr = Kflex(X2 – X1) + ω2mintX1 (3)

Where:
Fdr = force applied by the shaker, lbf (N),
Kflex = stiffness of the flexible plate, klbf/in (MN/m),
X2 = displacement at the flexible plate, in. (m),
X1 = displacement at the rigid foot, in. (m),
ω = 2πf, where f is frequency, Hz, and,
mint = mass of the internal components attached to the rigid foot and the foot itself, lb (kg).

At the frequencies of operation, the ground-input impedance is dominantly stiffness controlled.

$$Kgr = \frac{F_{dr}}{X_1} \qquad (4)$$

Where:
Kgr = stiffness of the ground layer being measured, klbf/in (MN/m).

By substituting Eq 3 for Fdr in Eq 4, averaging over the operating frequencies and substituting velocity, V, for displacement, X, since the units cancel each other, the ground stiffness is calculated as follows:

Kgr = Kflex $$\frac{\sum_1^n\left(\frac{X_2 - X_1}{X_1}\right)}{n} + \frac{\sum_1^n \omega^2}{n} m_{\text{int}} = K_{flex} \frac{\sum_1^n\left(\frac{V_2 - V_1}{V_1}\right)}{n} + \frac{\sum \frac{n}{1} \omega^2}{n} m_{\text{int}} \quad (5)$$

Where:
n = number of test frequencies used in the gauge,
V2 = velocity at the flexible plate, ft/s (m/s),
V1 = velocity at the rigid foot, ft/s (m/s).

6 Calibration / Equipment Verification

6.1 Follow the recommendation of the gauge manufacturer.

6.2 Field check the calibration whenever any stiffness measurement is in doubt.

Note 1 – Field conditions may not allow the precision of a laboratory calibration and so an appropriate tolerance should be assigned to the field check (for example, ± 5% relative to the value of the stiffness expected).

7 Procedure

7.1 <u>Stiffness measurement</u>

7.1.1 Ensure that the foot is clean and free of soil or other debris.

7.1.2 Turn on the gauge.

7.1.3 Prepare the surface. Lightly brush any loose material away from the test location before seating the foot. If the test location requires leveling, scrape the surface with a square point shovel or with the template provide with the gauge. The surface does not need to be leveled if the gauge can stand on its own.

7.1.4 Lay the template onto the surface being tested and apply a layer of seating sand (1/8 to 1/4 inch thick).(Note 2) Pat down firmly, strike off the sand with a straightedge, place the gauge on top of the sand and rotate 1/4 turn to seat.(Note 3) Ensure that the gauge does not contact any portion of the template.

Note 2 – Use moist or wet, clean and uniform local fines (minus 30 mesh) or commercially available mortar sand for seating the gauge. The moist or wet condition is for cohesiveness of the sand. Dry sand and other cohesionless materials will serve to decouple the gauge from the ground.

Note 3 – Do not apply additional pressure to the gauge when seating and rotating. Follow the manufacturer's recommendation as appropriate.

7.1.5 At least 60% of the foot's annular ring surface must seat or contact the ground to provide consistent stress on the ground for each measurement. Visibly estimate the amount of surface contact from the footprint left by the foot by lifting the gauge off the ground after the measurement is taken. Reseat the gauge and run test again if it is determined that less than 60% of the annular ring made contact with the ground.

7.1.6 Ensure that the external case of the gauge does not come into contact with a trench wall, pipe or any other object.

7.1.7 Take the measurement. (Press “Meas” button. SSG will measure site noise and stiffness as a function of frequency. The gauge will display average stiffness, lb/in (MN/m) or modulus, psi (MPa) or percentage of target. If construction noise is present, try to take the test at a distance greater than 25 yards from the operating equipment.) Take a minimum of three measurements and report the average.

7.1.8 Remove the gauge from the test location and inspect the footprint. If contact is not adequate, repeat the measurement.

8 Report

8.1 The make, model and serial number of the gauge used.

8.2 Name of the operator.

8.3 Project name and number.

8.4 Test locations and average stiffness value rounded to the whole number.

8.5 Moisture content to 0.1 %.

Form 337 STAB
Revised 12-30-2009

Type of Surfacing: ____________________

Summary Sheet No. ____________________

Pit Lab No.: ____________________

Montana Department of Transportation
CAC Surfacing Stiffness – Summary of Test Data

Soil Stability Gauge No. ____________________

Make & Model SSG ____________________

Nuclear Device No. ____________________

Project No.: ____________________ Project Name: ____________________ Tested by: ____________________

Roadway Section No.	Lane and Station of Roadway Section	Lift ____of ____	Proctor Results		Average of Tests on this Section		% of Control Density	+ or – Control Moisture	Stiffness Value	Cure Time Hours/Days	Remarks
			Moisture	Dry Density	Moisture	Dry Density					

Avg. Moisture Value:____________ **Avg. Stiffness Value:____________**

Approved by EPM ____________________ Checked by District Materials Supervisor ____________________

REMARKS:____

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______ Materials Bureau-Helena

______ Construction Bureau