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Study of the Light Weight Deflectometer and Reviews

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ABSTRACT- The lightweight deflectometer (LWD) is currently essential instrument for further characterization of soil and their properties like modulus of elasticity (E) and deflection values. There are a number of commercially available LWD designs that yield different deflection and elastic modulus values. This provides good data to prescribe target deflections and elastic modulus values during earthwork construction analyses, this result gives the proper design for the given location. This paper presents on detailed study of LWD instrument and some of the review papers. The influence of the accelerometer versus geophone, measurement of base plate versus ground surface, LWD rigidity, and applied load pulse were investigated through field-testing. Several Researchers have used stress sensors to measure in-situ stress levels from various loading conditions and devices are shown in literature revive.
The use of a portable light weight deflectometer (LWD) for construction quality control and material investigation for earthworks and road construction. In the field of non-destructive testing of soil, the portable deflectometer devices have discovered , in the modern years, a wide use for in-situ assessment of elastic properties of soils, sub-grade and pavement foundations. The LWD- induced surface wave strain levels at a1m offset from the LWD were found to be on the order of 10.2 to 10.3% compared to the10.3 to 10.4% strain levels associated with conventional small hammer-induced surface waves. The measured low and high strain modulus compares well with published modulus reduction functions. The minimum LWD modulus value was obtained for sand-1, sand-2 and sand-3 layer, which was represents 19.0, 41.7 and 21.6 MPa respectively. The highest coefficient of variation was obtained for sand layers which goes up to 55.8% for sand-1 layer.

***Keywords* –** LWD, Geophone, sub-grade, Deflection, Modulus of elasticity, rigidity, Stiffness.

INTRODUCTION

The Light Weight Deflectometer (LWD) is a portable it was developed in Germany especially as an alternative in-situ device to the plate load test with the ability to overcome accessibility problems for soil investigations and roads under construction. In the recent year, different types of LWD have been introduced in the market, including the German dynamic plate, the Transport Research Laboratory (prototype) foundation tester, and the Prima LWD.
The LWD is a field device that is increasingly being used for quality control/quality assurance (QC/QA) of compacted unbound materials. A falling weight (5-10–15kg) impacts a 200–300- mm-diameter (D) base plate and the resulting peak surface deflection (d0) and impact force are measured. The impact force and base plate diameter is designed to deliver a peak contact stress level (s0) of about100–200kPa to mimic the approximate stress pulse on a typical sub-grade or base layer due to traffic loading on top of a finished pavement. The resulting peak stress and deflection combined with homogeneous, isotropic, linear- elastic half-space theory yields a deformation modulus (Evd) of the soil. In the conventional LWD test a static loading condition (Livneh & Goldberg, 2001; Nazzal et al., 2004; Puppala, 2008; Ryden & Mooney, 2009; Vennapusa & White, 2009).

REVIEWS ON DIFFERENT PARAMETERS USING LWD

The research work is concerned with the compaction of the sub-grade and sub-base layers that comprise a pavement system. While the number and thickness of pavement layers varies generally, the typical structure is shown in “Fig.” 1.

Fig. 1 Typical Layer of pavement structure (Christopher et al., 2006).

Christopher et al., 2006, had provides the two purposes of sub-grade system; firstly, it provides a platform during the construction of the pavement structure; and secondly, it ensures that excessive deflection of the natural soil does not negatively influence the pavement structure. The sub-base strength shall be considers in the design of the pavement system. Therefore, the estimated bearing strength needs to be assuring during construction.

N. Ryden, and M. A. Mooney, 2009, were conducted field experiments on clay, silt and gravel soils to characterize the nature of LWD induced surface waves and to determine both low and high strain moduli. The usable high frequency limit was found to be 300Hz for LWD induced surface waves, enabling the low strain modulus characterization of the top 0.3–0.5m thick soil layer and finally, the measured low and high strain modulus.

Lambert et al., 2008, The portable devices are quick to implement and have been shown to adequately mimic the transient nature of wheel load forces, qualities that make them more appropriate for practical application. Typically, these devices usually measure a single deflection on the center of a bearing plate or on the surface of the prepared material being tested. The measured deflection may relate to the influence of one or more layers of material and could be used to determine the field values of parameters relevant in quality control and quality assurance.

METHODOLOGY AND MEASURING PRINCIPLE

A center geophone sensor measures the deflection caused by dropping a 10 kg hammer freely onto the loading plate. The falling mass impacts load produces pulse of 15-20 milliseconds. The diameter of the loading plate used in this research is 200 mm. Alternatively 100 mm and 300 mm plates are available. The load range of the LWD is 1 to 15 kN. It measures both force and deflection. The measured deflection of the ground is combined with the applied load to calculate the stiffness using conventional Bossiness static analysis. The load cell used in Prima 100 LWD has a resolution of 0.1 kN. The velocity transducer (geophone), which is mounted to the center of loading plate, has a resolution of one µm and range between 1-2200 µm. The standard model has one geophone sensor but models with three geophones, which can provide a simple deflection bowl, are also available Fleming (2000). The measured center deflection is used to estimate the dynamic deformation modulus as follows:

$$E_{LWD} = \frac{K \times (1 - u^2) \times P \times r}{d_c}$$

Where,

E_{LWD} = LWD dynamic modulus

K = p/2 and 2 for rigid and flexible plates, respectively.

d_C = Center deflection

P = Applied Stress

r = Radius of the plate

EQUIPMENT AND TEST PROCEDURE

A. LWD Equipment:

There are several types of LWDs. The LWD measures the deflection of the test layer produced from a given drop weight, drop height, and load according to the American Society for Testing and Materials (ASTM) Specification 2583–07, ''Standard Test Method for Measuring Deflections with a Light Weight Deflectometer.'' The built-in load cell and geophone measure the time history of the load pulse and soil velocity. Sensors may be of several types such as displacement transducers, velocity transducers, or accelerometers. The consequential integration provides a measure of the material displacement, which can be used with a measure of the peak load to determine the modulus values (Tehrani & Meehan, 2010). The following is a general description of the LWD will be Moving from top to bottom, the handle is used to keep the shaft vertical. Next along the shaft is a release trigger, which holds the mass in place prior to dropping, thereby, ensuring a standard drop height (720mm). The mass is dropped to provide an impact force. Buffers, made of either rubber pads or steel springs, catch the falling mass and transfer the impact force to the loading plate. Below the buffers is a measurement device that measures the deflection, and for some models the force. On the bottom, there is a loading plate, which must be in full contact with the ground. Impact load imposed to the plate are measured by a load cell and a geophone sensor mounted at the bottom of the plate measures the resulting deflection. Singh N et al (2010).

B. LWD test procedures:

The testing area should be levelled so that the load plate can be placed on an even surface. Loose particles on the surface should be removed and the load plate must be in contact with the material being tested. The diameter of the test area should be at least 1.5 times larger than the plate diameter Alshibli K (2005).

Table 1 LFWD test results

LAYER ID	LWD (Mpa)	Std.Deviation(Mpa)	CV (%)
Clay 1	181.3	18	11.4
Clay 2	-	-	-
Clay 3	51.5	11.3	18.7
Clay 4	133.9	64	45.7
Clay 5	47.6	8.4	18.4
Clay 6	313.9	38.5	13.5
Clay 7	227.6	73.3	32.5
Clay 8	33.2	0.8	2.5
Clay 9	172.4	2.1	1.5
ClayeySilt-1 (opt.)	32.4	4.6	14.9
ClayeySilt-2 (dry)	48.8	8.6	16.1
ClayeySilt-3 (wet)	29.5	14.2	47.3
Sand-1	19	6.7	56.8
Sand-2	41.7	3.8	14.9
Sand-3	21.6	5.4	28.6
		Average	23.15

THE LIGHT WEIGHT DEFLECTOMETER (LWD)

The LWD dynamic modulus values, corresponding standard deviation and coefficient of variation (CV) values are given in Table 1. There are total of fifteen test cases were conducted for each layer and it was represented by an average value of dynamic modulus. However, the LWD data for clay-2 layer is questionable. The LWD dynamic modulus readings for clay-2 layer were highly incompatible and ranged from 400 MPa to 700 MPa, which is also too high compared to strength results obtained from other tests. The minimum LWD modulus value was obtained for sand-1, sand-2 and sand-3 layer, which was represents 19.0, 41.7 and 21.6 MPa respectively. The highest coefficient of variation was obtained for sand layers, which goes up to 55.8% for sand-1 layer. Summary of Statistics result of the LWD Sample profiles tests as show table 2. Graphical represented in "Fig" 2.

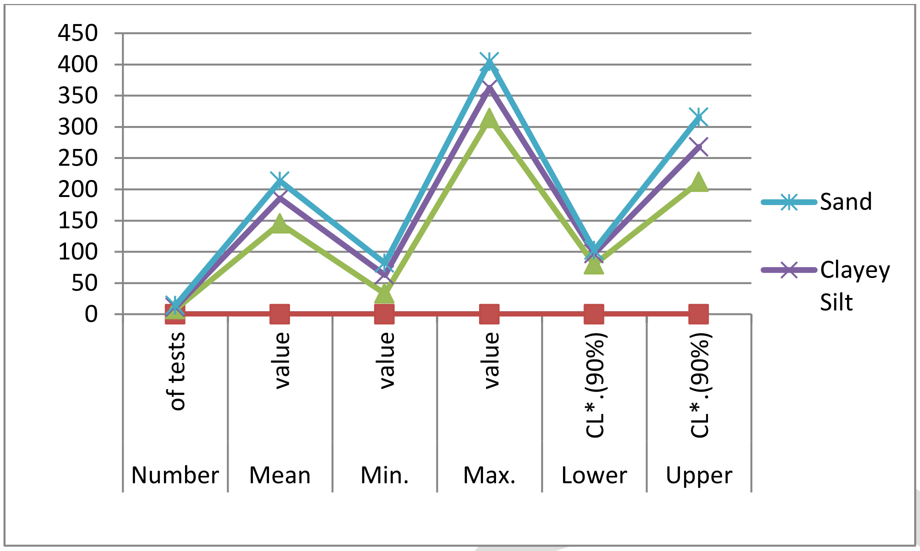

Fig 2 Typical Statistics result of the LWD Sample profiles tests

Table2. Descriptive Statistics of the LWD Results

LWD Dynamic Modulus (MPa)	**No. of tests**	**Mean value (MPa)**	**Min. value (MPa)**	**Max. value (MPa)**	**Lower CL*. (90%)**	**Upper CL*. (90%)**
Clay	8	145.17	33.2	313.9	79.8	212.0
Clayey Silt	3	40.6	29.5	48.8	17.1	56.1
Sand	3	27.43	19.0	41.7	5.5	47.4

LIMITATIONS

This paper reviews the LWD as a field evaluation tool and discusses the test variables and data quality. This concludes that its usefulness and its limitations for a variety of earthwork and road assessment scenarios. Many factors that influence LWD values and these should be considered while designing a quality assurance process in any agency/company. These factors include, but are not limited to, the following: size of loading plate, plate contact stress, type and location of deflection transducer, plate rigidity, loading rate, and buffer stiffness. Again, the moisture content of the material being tested has been reported to significantly influence the field modulus-based measurements. There is also an inverse relationship between water content and soil moduli (Hossain & Apeagyei, 2010; Ryden & Mooney, 2009). Also, in some cases, it is reported that the actual depth of the material being tested is greater than the single layer of material under consideration and therefore is measuring a composite layer composed of the material under consideration and underlying subbase and subgrade materials. The resulting modulus is therefore a composite rather than the modulus of the single layer under consideration (Benedetto & Di Domenico, 2012).

CONCLUSIONS

Light weight deflectometer (LWD) devices are newly established tools for estimating moduli during quality control and quality assurance. LWD devices are used because of they provide a somewhat accurate estimation of a soil modulus from a mechanically simple test.

An investigation was conducted to determine the influence of LWD design characteristics on the measured deflection and, by inference, estimated modulus.

The LWD is a versatile and portable stiffness measuring tool. From the published literature it appears to be increasingly used on a variety of materials/constructions including during construction and in service (on thinly surfaced roads) around the world.

The usable surface wave frequency content at 100–200Hz enables the low strain modulus characterization of the top 0.3–0.5 m thick soil layer, consistent with the measurement depth for the high strain modulus determined by conventional LWD testing.

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