A Detailed Overview of Light Weight Deflectometer (LWD)

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Abstract

As Bangladesh is a developed country now, a main development issue is on building the infrastructure to enhance the economic growth. To secure solid transport system it is required to be compliance with quality assurance to prevent failure and ensure long performance. To check the field density, sand replacement method is very popular in Bangladesh, but it is time-consuming. A light-weight deflectometer (LWD); which has been developed for evaluation of surface stiffness may be employed to estimate the degree of compaction. The Light Falling Weight Deflectometer (LWD) has recently become available in Bangladesh. It is a portable, light weight, user friendly version of Falling Weight Deflectometer (FWD). The LWD has a shallower depth of influence than that of the FWD. It is, therefore, ideal for single layer structural evaluation during construction to provide better engineering parameters for quality assurance and quality control (QA/QC). This study aims at presenting a detailed study of LWD device with its advantages along with shortcomings and discussion of some review papers. From this study it was found that LWD is very effective device to measure the quality of pavement during construction stage. But to get a reliable data, cautionary conditions must be maintained.

Keywords: *Quality assurance, quality control, light weight deflectometer, falling weight deflectometer.*

1 Introduction

Bangladesh is gradually developing country. Road network is one of the key components of any developed nation. Quality control and quality assurance is must for sustainable development of road network. In recent years, alternative quality control methods have sometimes been used to replace or supplement traditional density-based compaction control methods in many developed country. The Light Weight Deflectometer (LWD) is a relatively new modulus-based measurement tool that has significant potential for use as part of the compaction control process (Fleming et al., 2007). A general comparison between sand replacement method, DCP and LWD test are given below:

Table 1. Comparison between sand cone method, DCP method, and LWD.

Method	Advantage	Disadvantage
Sand Cone	• Easy to operate and cheap. • Reliable.	• Time-consuming. • Destructive.
DCP	• Minimal surface disturbance • Simple reliable	• Not suitable for cohesive soil • DCP can break under repetitive drops
LWD	• Fast and easy to operate • Non destructive • One person can conduct the test	• Need a correlation between deflection modulus and other parameters

There are various deflectometer available to measure pavement deflection. Such as- light weight deflectometer, falling weight deflectometer, heavy weight deflectometer, and rolling weight deflectometer. Among them light weight deflectometer is widely used to control the quality of pavement during construction time for its ease use and portability (Ebrahimi and Edil, 2013). A portable falling weight deflectometer is first invented in at Magdeburg, Germany and developed as in situ testing device by the Federal Highway Research Institute, and HMP Company in Germany. (Elhakim et al., 2014). Latterly LWD first introduced by Egypt at 2008. It is also known as light falling weight deflectometer and plate load test. Different types of LWD are commonly available such as HMP LFG, HMP LFG*pro*, Prima 100, Zorn ZFG 2000 etc. But they are common in principle. It serves to determine the soils bearing capacity and degree of compaction of soils. It is easy to handle and particularly suited for intra-company monitoring (HMP LFG Manual, 2017).

2 Reviews on Light Weight Deflectometer (LWD)

In this section, different views regarding LWD are briefly reviewed. Fleming et al. (2007) suggested that the device is useful and versatile as field quality control and pavement investigation tool, if an understanding of the device issues is considered by data users. He suggested that plate - surface contact area is an important parameter in case of LWD. The research shows that

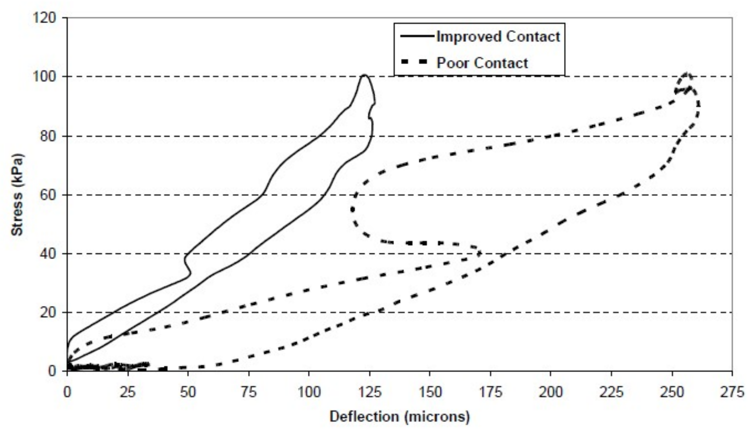

Figure 1. The effect of poor and improved plate-surface contact on the load-deflection trace for a 300mm diameter plate impact test on a well graded crushed rock aggregate.

It also found that regardless of buffer temperature the stiffness remained effectively constant, the only readily observable change was in the reported length of the load pulse, which was seen to increase with buffer temperature from 18 to 20 milliseconds.
Another aspect of the LWD QA/QC has been addressed by Steinert et al., (2008). In his research, he concluded that LWD can be applied as a QA/QC tool to evaluate the strength loss experienced by specific roadways during the spring thaw so the load restrictions can be applied or removed. He recommends that the complex modulus of the particular roadway prone to the load restriction can give enough information of the frost depth and pavement layers condition when comparing to the unfrozen condition of the same roadway during the monitoring season.
Sulewska (2004) found dynamic modulus of deformation obtained by the light drop-weight tester increase with the increase in degree compaction. According to Sing at el. (2010), the depth of influence of the LWD is 1.5 to 2 times the plate diameter. Lin et al. (2006) found the important factor affecting the surface modulus is the loading plate size. The surface moduli from the 100 mm loading plate were about 1.5 times higher than those from the 300 mm loading plate. Shabir and Apeagyei (2010) suggested that LWD test shall be used along with moisture-density test devices for subgrade compaction evaluation (when there is a need to know the modulus). But whenever the LWD is being used only to investigate the uniformity of the construction as a QA/QC tool, the LWD can be used without moisture content and density collection. Another aspect of the LWD QA/QC has been addressed by Steinert et al., (2008). In his research, he concluded that LWD can be applied as a QA/QC tool to evaluate the strength loss experienced by specific roadways during the spring thaw so the load restrictions can be applied or removed. He recommends that the complex modulus of the particular roadway prone to the load restriction can give enough information of the frost depth and pavement layers condition when comparing to the unfrozen condition of the same roadway during the monitoring season.

3 Description of LWD

Light Weight Deflectometer (LWD) is a type of dynamic plate load test, used in earthworks and traffic route construction. It determines the bearing capacity of soil, degree of compaction of soils and non-cemented base course and assists in soil improvement (HMP LFG Manual, Germany). For this study we used HMP LFG$_{pro}$ LWD which load plate diameter is 300mm and weight of drop weight is 10 kg while total weight is 15 kg. LWD can be divided into three groups. 1- Loading Mechanism, 2- Load Plate, and 3- Electronic Settlement measuring instrument.

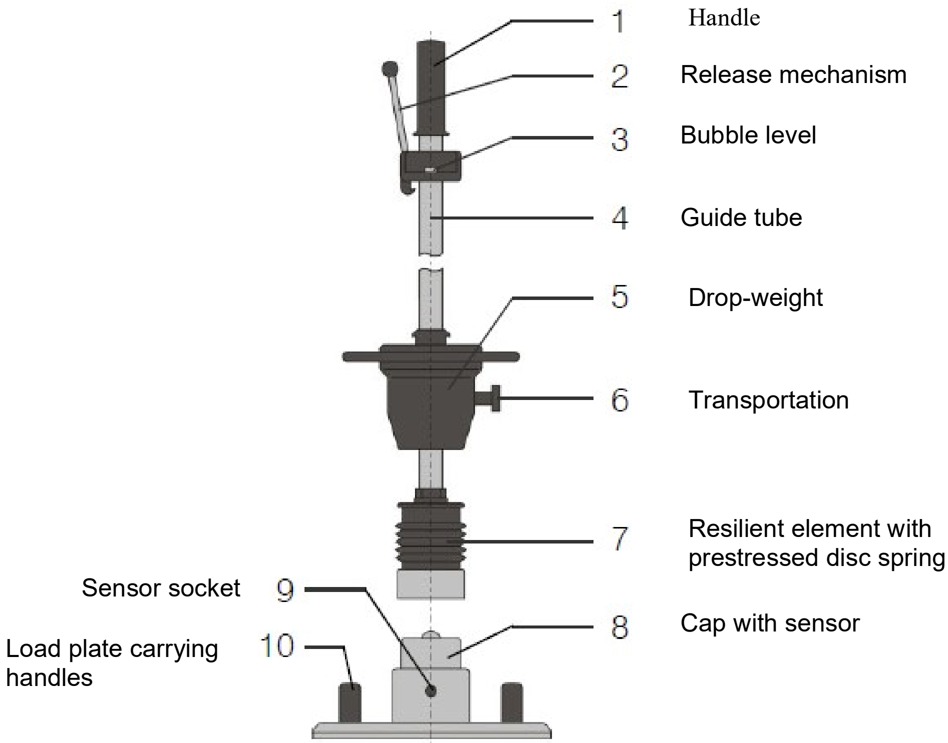

Figure 2. Configuration of LWD

Pre compaction is necessary before running the test. To get the deflection value, first of all, put the load plate on the testing ground. Connect the loading mechanism and the measuring cable onto the load plate. The guide tube and bubble level help to keep the shaft vertical. Next along the shaft is a release mechanism, which holds the mass in place prior to dropping, thereby, ensuring a standard drop height. 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 this measurement device is connected with cable that measures the deflection value in mm, deflection modulus, settlement versus velocity ratio, and settlement curve. 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). The measured center deflection is used to estimate the dynamic deformation modulus as follows:

$$E_{LWD} = K^* (1-u^2)^*P^*r/d_c$$

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

4 Test procedure through LWD

The procedure of testing through LWD is laid down in technical test code for soil and rock in road construction TB StB Part B 8.3/ Issue 2012- Dynamic Plate Load Test by means of light weight deflectometer and in ASTM E2855-11 – Standard Test Method for Measuring Deflections using Portable Impulse Plate Load Test Device.
For this study, the testing area was leveled before conducting the test. Thus the load plate can be placed in 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 equal or larger 1.5 times than the plate diameter (Shivmanth et al., 2015). The test was done by different thickness of sand layer. For this test we use local sand. The test was done on three different layer thickness- 160mm, 200mm, and 300mm.

Table 2. Test Result

No.	Measuring point	Layer thickness (mm)	Settlement Single (mm)	Settlement Average (mm)	E_{vd} MN/m^2	Velocity Single mm/s	Velocity Average mm/s	s/v ms
1	N $23^0$47'11.86" E $90^0$21'22.39"	0	2.950 2.939 2.951	2.947	7.63	509.1 504.4 504.1	505.85	5.82
2	N $23^0$47'12.04" E $90^0$21'22.39"	150	4.654 4.730 4.446	4.610	4.88	585.4 598.7 575.1	586.42	7.86
3	N $23^0$47'12.04" E $90^0$21'22.39"	200	4.388 4.545 4.621	4.518	4.98	534.7 553.7 554.8	547.71	8.24
4	N $23^0$47'11.58" E $90^0$21'22.24"	300	4.842 3.295 3.196	3.778	5.96	532.9 374.3 368.2	425.13	8.88

From this result we can show that, initially surface settlement was 2.947mm. For the 160 mm sand layer the settlement value increases upto4.61 mm which is 56.4% greater than normal surface settlement. For 200 mm the settlement value decreases and it was 53.3% higher than the normal value. Finally for 300 mm sand layer the settlement value reduced about 28.2% initial value. So we can be state that with the increasing of layer thickness, the settlement value is decreasing.

5 Conclusion

Light weight deflectometer (LWD) devices are very helpful devices in the case of quality control and quality assurance of pavement construction. LWD devices are widely used because it gives the soil modulus mechanically by a simple device. At the same time both vertical settlement value and deflection modulus can be determine by LWD. In this study an investigation was performed to determine the influence of LWD design characteristics on the measured deflection and estimated modulus. From the published literature it comes out that the use of LWD increasing day by day in constructions including during construction and in service around the world.
From this test we also found that deflection modulus is increasing with the increase of layer thickness whereas the settlement value is decreasing.

6 Limitations

1. Before test, precompaction is must for three times.
2. To get the GPS data on the test location GPS signal must be displayed on status line.
3. Drop height should be determined for the drop weight by calibration. Re calibration on drop height is required at least annually and after any repair
4. It is suited for coarse grain and mixed grain soils within a maximum limit 63 mm.
5. It can't calculate the deflection modulus more than 275 MN/mm^2.
6. Settlement range is 0.1mm to 2.0mm.
7. Memory capacity up to 1000 test series.

8. In this LWD lithium polymer battery pack is used which must be charged when battery condition is equal or lower than 15%.
9. The readiness for measurement only insists after acoustic signal. The weight is allowed to drop within 6 seconds after the acoustic signal.
10. Failure to catch the rebounding drop-weight will produce undesired result.
11. If one settlement value is deviates by 50%, the test must be repeated.
12. Stored series data cannot be deleted individually. It will be deleted in a group.
13. Sensor could be damaged, if the load plate immersed in water.

7 Recommendations:

1. Wipe the guide tube with oily rag (acid free) to ensure the unrestrained movement of the drop weight
2. Wipe off any dirt from the device after use.
3. Checking shipping and handling lock and oil it slightly in a monthly routine
4. The load plate must be in full area contact. Hollow places may be filled with loose medium sand [lwd manual]
5. It is recommended to transfer the test data from the measuring instrument evenly. In this way transference time will be shortened and multiple data transfer may avoid.
6. The LWD should not be relocated before the drop weight is fixed by means of the transportation lock
7. Grease should not be used to clean the Guide tube. The temperature range may vary from 0^0C to 50^0 C
8. Transportation lock must be used to secure the drop weight while travelling to job to job.

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