CQ Performance testing of an All-Weather Sports Pitch Subbase using LWD

abg creative geosynthetic engineering

Technical Note

Introduction

The construction quality assurance of an all-weather sports pitch subbase is very important to achieving a level playing field and keeping surface irregularities within the set tolerances. A competent and stable subbase is a pre-requisite to maintaining a flat and safe field surface and minimising the impact on the game and its athletes.

Light Weight Deflectometer test

The Light Weight Deflectometer (LWD) test is one of the established and accepted methods for checking structural performance by verifying the adequacy of subbase material compaction during construction.

The LWD is a portable device that assesses the modulus-based compaction of the unbound layers. It is an in-situ test that measures the surface stiffness modulus and the degree of compaction of the material.

The LWD test is suitable for granular, cohesive and mixed soil types up to a maximum particle size of 63mm, however, not more than 15% larger than 40mm (sports pitch subbases are typically Type 3 SHW Clause 805 open graded aggregates having no fines, 40mm down to 6mm, void ratio 30% min). The LWD test can provide an indication of poor compaction and whether excessive water is present within the subbase.

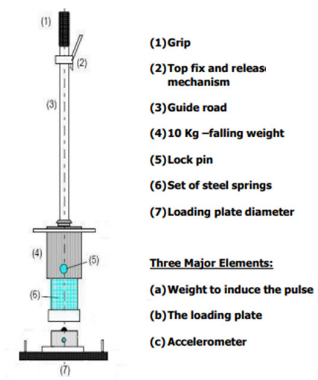

Figure 1: Components of a Light Weight Deflectometer

The zone of influence for the test typically extends between 1D to 2D under the loading plate in case of homogeneous material, where LWD loading plate diameter, D = 300mm. The measurement is made as a '*composite value*' with contributions from all underlying layers - meaning it takes into account all the layers underlying the subbase (*i.e.*, subgrade) that the LWD loading plate is in contact with. In a layered material where the upper layer is significantly stiffer than the lower layer, the extent would be less.

The LWD test simulates a truck with a 10t axle load travelling on a road at 80km/h (50mph).

Calculation Method

In LWD tests the short-term modulus (resilient modulus) is calculated from the measured deflection, based on the Boussinesq's equation assuming the test media to be a linear elastic, isotropic and homogeneous semi-infinite continuum:

$$E_{LWD} = k\,(1 - \nu^2)\,\sigma R\,/s \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where, E_{LWD} = Subbase surface modulus (effective modulus) evaluated by LWD (MPa); k = plate rigidity factor, 2 for flexible plate (π/2 for rigid plate); ν = Poisson's ratio (typical 0.35 for subbase and 0.45 for subgrade); σ = peak stress (kPa) applied on the plate (generally 100kPa); R = radius of the plate (0.150m); and s = peak deflection (mm) at the centre of the plate.

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The subbase surface CBR value can be estimated from the measured field stiffness modulus using equation (2).

$$E = 17.6 \times CBR(\%)^{0.64} \text{ MPa (Powel, et. al, 1984, TRRL) … (2)}$$

Factors affecting the subbase LWD test results:

- Material stiffness of the constituent layers - subbase and subgrade
- Thickness of the subbase layer
- Grading of the subbase aggregates
- Density of the subbase
- Moisture content and the variability of moisture content within the constituent layers
- Plasticity of the materials constituting the layers under plate load influence
- Load and plate size of LWD apparatus
- Seating and contact of load plate
- Recording correct peak deflection
- Presence of WT within the test layers.

Stiffness modulus characteristics of soils:

The following is a rough guide taken from Barounis, et al. (2017) for characterisation of different soils.

For cohesionless soils, E (LWD stiffness)	= 24 – 34 MPa (Medium dense)
	= 34 – 50 MPa (Dense)
	= 50 – 90 MPa (Very Dense)
For cohesive subgrade soils, E (LWD stiffness)	< 22 MPa (Very soft)
	= 22 – 30 MPa (Soft)
	= 30 – 36 MPa (Firm)
	= 36 – 43 MPa (Stiff)

Notes:

1. Modulus based compaction criteria according to the German standard ZTVE-StB 09 (Barounis, et al. (2017) and Choi, et al. (2020)):

Gravels, E (LWD stiffness)	≥ 50 MPa, compaction ≥ 100%
	≥ 40 MPa, compaction ≥ 98%
Sands, E (LWD stiffness)	≥ 40 MPa, compaction ≥ 100%
	≥ 35 MPa, compaction ≥ 98%

2. The Type 3 SHW Clause 805 for open graded low fines aggregates can achieve a maximum dry density (Υ_d) of 17kN/m^3 at 96.5% of MDD compaction, which gives a stiffness modulus of 47MPa. However, in the construction of sports pitch subbases an open graded material of 40mm down to 6mm no fines aggregates with a minimum void ratio of 30% are used, with or without inclusion of geosynthetics, to achieve a surface stiffness modulus of a minimum 40MPa.

Stiffness calculation from given CBR values:

For cohesive subgrade (only) up to 3% CBR,

$$E = 10.34 \, CBR(\%) \text{ MPa (AASHTO, 1993) …………………… (3)}$$

For both cohesionless and cohesive soils for CBR from 3% to 12%,

$$E = 17.6 \times CBR(\%)^{0.64} \text{ MPa ………………………………………… (2)}$$

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The interaction between subbase and subgrade (composite behaviour) is of crucial importance. Therefore it is not only the stiffness of the material or the subbase layer, but the '*composite*' response (*i.e.* stiffness) as a whole of the resilient stiffness, Poisson's ratio and the thickness of each layer that contributes to the response of the load applied on the subbase layer.

Guidance for subbase construction and LWD tests:

The construction of the subbase shall be carried out by the customer's appointed and experienced contractor. The quality control of the materials and construction remains with the customer. The following is a list of general guides.

For the Contractor:

a. Clear and level the subgrade to the required gradient, carry out a few passes with the roller and identify and improve soft/ weak spots, if any.

b. If the in-situ, short-term subgrade surface modulus (or CBR) is found to be less than that used in the design, please inform ABG for a revised design.

c. Install the geosynthetics according to the design of ABG Ltd.

d. During construction every effort should be made to protect the subgrade by completing the subbase layer before rain can soften it. For long-term stability, drainage provision must be provided.

e. The aggregate materials within the subbase shall be 40mm down to 6mm, no-fines, clean, hard, angular, non-frost susceptible, free of organic residues and will not crush under roller compaction.

f. The subbase aggregates to be used should be reasonably dry (~between 4% and optimum, i.e. dry of optimum) to achieve the maximum stiffness modulus.

g. The aggregates shall be imported, laid over geosynthetics without segregation, and compacted.

h. For each construction lift, the minimum thickness of the post compacted layer of the subbase aggregates shall be 2.5 times the maximum aggregate particle size. For subbase aggregates with a maximum particle size of 40mm, the compacted layer thickness shall be greater than 100mm and not exceeding 150mm.

i. The contractor is to ensure compaction of the subbase to a minimum 98% of modified Proctor MDD.

j. A single drum vibratory roller compactor (typically 120" drum 7t roller) shall be used for the compaction of the subbase. On each layer of construction lift, the roller needs to run, as a minimum, until the aggregates do not show any wave ahead of the drum. The final roller pass shall be in static mode.

k. Repeat steps *g* – *j* for all construction lifts.

l. Upon completion of the subbase compaction and prior to conducting the performance tests, the surface should be closed and kept free of compaction equipment and / or construction equipment tyres.

For subbase performance testing agent:

a. Prior to the beginning of the test, the testing agent must confirm that the LWD's loading device, drop height, etc. are calibrated for the intended site-specific test requirements.

b. Carefully clear and level the test area underneath the LWD loading plate without disturbing the compacted surface, and make sure that the test surface is horizontal.

c. LWD testing shall be carried out soon after the completion of compaction. The test must not be conducted if the subbase is frozen or flooded / water saturated.

d. Remove loose oversized aggregates. In case of open graded base material, a thin layer of sand (with a single size sand / nominal size 1.15mm), as is recommended for improving contact for static plate testing (BS 5950; BSI, 1999) can be used to fill in the gaps to provide a smooth and full contact with the plate.

e. The prepared plate contact area must be a minimum of 1.5 times the diameter of the LWD load plate.

f. Position the load plate and rotate left and right approximately 45 degrees to achieve 100% contact between the plate and soil surface.

g. Perform an initial few drops (typically 3 drops) at 100kPa following the manufacturer's instructions for the 'seating' of the test plate. If excessive deflection is noticed, do not continue the test since the materials need additional compaction.

h. If the plate does not seat properly and the plate moves and vibrates, discard the test and the test must be repeated.

i. A test shall be invalid if the operator does not catch the falling weight after it rebounds from the load plate or if the load plate moves laterally. A new test area shall be required, at least 1m away from the original location of testing when the test is invalid.

j. If the deflection is 10% or greater for any two consecutive drops, the material requires additional compaction.

k. The LWD test results will be questionable in case of shallow ground water (less than 1m below formation) or soils with high moisture content.

Notes:

a. To compare the surface stiffness of the geogrid-stabilised subbase layer with that of the underlying subgrade, perform LWD testing on the subgrade before the subbase material is placed. Then perform the LWD testing on the top of the completed, compacted subbase layer. These tests should be performed at the same locations, on the same day that the subbase is placed.

b. The LWD tests on a thinner subbase over a subgrade of plastic soils may not obtain the target surface stiffness modulus due to the high strain behaviour of the plastic subgrade under repeated LWD loads.

c. The LWD tests on a thinner subbase constructed over a drainage geocomposite may not show an improved surface stiffness. This is likely to happen due to the spring effect of the geocomposite, and the result may not demonstrate the actual surface stiffness of the subbase. We suggest the customer creates a test pad as an extension of the main pitch where no geocomposite will be included and conduct the LWD test on the subbase.

d. LWD has significant variability in test results.

References:

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