Complete
Instrumentation Solutions

The history behind the Traffic Speed Deflectometer

Knowledge about the condition of road pavements, the bearing capacity especially, has always been essential for optimum planning of road maintenance and rehabilitation. The very heavy increase in traffic especially at the motorways, has been challenging for the road authorities. Much has happend since the first road measuring equipment was developed. Greenwood Engineering has since the early 1990´s been at the forefront of this technology.

In 1953 A. C Benkelman introduced a new method to measure pavement deflection. The Benkelman Beam (Figure 1) measuring process commences between the wheels of a stationary truck and records the latter half of the deflection bowl as the truck moves away.

Figure 1: Diagram (elevation & plan) of a typical Benkelman Beam.

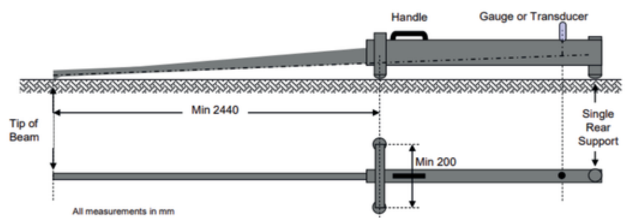
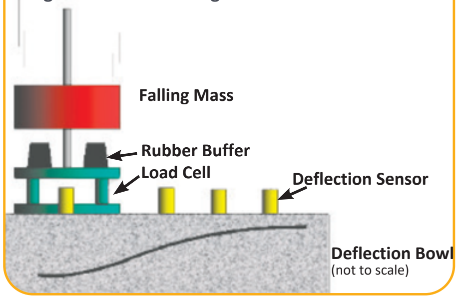


Figure 2: The FWD diagram of deflection bowl



In 1963 Th Falling weight Deflectometer (FWD) was developed from the ’deflectmetre a boulet’ originally devised by Bretonniere. The test method for FWD (Figure 2) requires the device to stand on the road during the testing period of 2-4 minutes.

In the 1960´s The Danish Road Laboratory begins the development of a more automatic equipment, inspired by an American model based on the Benkelman principle.

In 1971 the first test was done by the new Deflectograph, which was a slow-moving device (1,5 km/h).

In 1974 the Deflectograph was fully operational and performed continuous pavement surface deflection tests.
The measurements, according to the Benkelman principle, were carried out using a measurement probe with a sensor mounted between two twin tyres at the right side of the trailer and a dial gauge in the other end. The measurement registered the rebound movement of the pavement surface after the loading.

In 1980 Niels Grønskov, who worked at the Danish Road Directorate started the development of a new and improved Deflectograph (Figure 3). The speed of the vehicle was increased to 6 km/h, the axle with the twin wheels could automatically turn and the bridge was easier to handle. The new Deflectograph was ready to operate in 1986 after Leif Grønskov (founder of Greenwood Engineering in 1992) provided the right data equipment. He invented a new way to sample the data from the road.

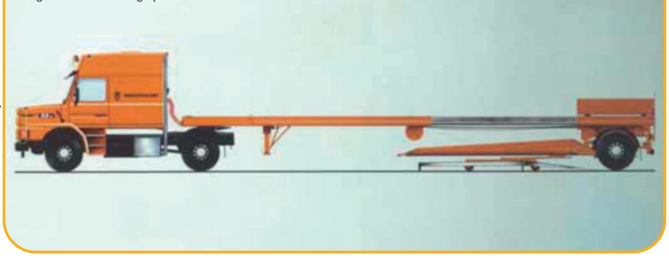


Figure 3. The Deflectograph in 1986.

Consideration for road safety, users and staff as well as for road traffic capacity made the use of these slow vehicles on roads with high traffic intensity inappropriate. New or alternative testing methods or procedures needed to be applied.

In 1995 Greenwood Engineering with CEO Leif Grønskov in front begins the development of a new testing device to solve the problem of using stationary test methods or very slow vehicles on roads with high traffic intensity.

In 1996 the High Speed Deflectograph (HSD) prototype was launched, later known as the Traffic Speed Deflectometer (TSD). By using advanced Doppler laser technology it was capable of performing measurements of the pavement bearing capacity at normal traffic speed. The High Speed Deflectograph increased safety for road users and testing personnel since the testing took place at normal traffic speed (up to 90 km/h). Furthermore, road users were less disturbed since the road did not need to be closed under investigation, either completely nor partly. The High Speed Deflectograph could provide continuous results with a point density at the order of one test point per 20 mm compared to the discrete results from the Falling Weight Deflectometer which often had a spacing of 50 - 100 metres.

In 2004 the Traffic Speed Deflectometer was sold and Greenwood Engineering has continiously developed the technology and initiated a shift of paradigm in global pavement engineering.

The Traffic Speed Deflectometer by Greenwood Engineering

Greenwood Engineering, still at the forefront of technology

Much has happened since the first TSD was launched in 2004, but one thing remains unchanged: The basic premise is to always stay at the leading edge of frontier technology. In 2024 TSD number 22 was delivered to Australia and the development continues.

Generation 1 (2004 – 2008)

The first TSD generation includes TSD 1 and TSD 2. They were equipped with 4 Doppler lasers located in front of the rear axle, built in a standard container. The model used to process the data was a beam model, that assumed the maximum deflection to be directly under the load. This model could provide deflections and SCI_{300} (Surface Curvature Index at 300 mm).

Generation 2 (2009 – 2017)

The second TSD generation includes TSD 3 to TSD 12, except TSD 7. They have 7 Doppler laser, 3 more than the first generation. All the lasers are located in front of the rear axle. This is the first generation built in a costom made insulated trailer, making it possible to control the temperature in the trailer. This is also the first generation with the beam mounted on rails for lateral displacement for performing Doppler relative angle calibration.

Generation 3 (2018 – 2019)

Thethird TSD generationincludes TSD 14 and TSD 15. They are equipped with 11 Doppler lasers, with 3 of them placed behind the rear axle. This is the first generation with lasers placed behind the load and therefore also the first generation with an asymmetrical model for the data. This gives maximum deflection behind the wheels and a more correct description of full deflection bowl. It is also the first generation with an air tunnel around the beam, to optimize the conditions for measurements, and a ground penetrating radar (GPR) for determining layer thickness and locating features in the pavement, below the surface. Further with this generation the viscoelastic back calculation model for processing data was introduced. By using TSD data, it calculates the Elastic moduli, dampening, maximum deflection and strains of the different layers in the pavement.

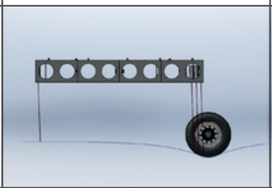
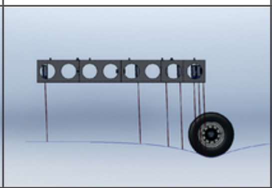
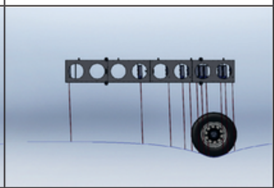
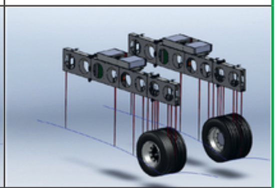
Generation 4 (2020 – now)

The fourthTSD generationincludes TSD 7, TSD 16, TSD 21, TSD 22, TSD 23 and still counting. The 11 Doppler lasers have been upgraded to high frequency lasers (sampling rate 250 kHz). These new high frequency Doppler lasers introduced with the 4th generation TSD proves to be very effective. With a low noise level and high sampling rate, it is possible to locate structural weakness/strains in the road and in the runway within a few centimeters. The beam can be moved automatically, making the calibration process safer, easier and faster. With this generation, it is possible to have two measuring beams, one on each wheel path of the trailer.

Upgrade

Itispossible to upgrade an older vehicle to a newer generation. 11 lasers can be installed, the beam can be updated to move automatically and an air tunnel can be installed to control conditions. Also other equipment such as GPR, texture laser, Surface Imaging Systems (SIS) etc. can be retrofitted to a previously delivered TSD.

Technicals specifications

	Generation 1 (2004-2008)	Generation 2 (2009-2017)	Generation 3 (2018-2019)	Generation 4 (2020-now)
Vehicle number	**TSD 1 + TSD 2**	**TSD 3 - TSD 12**	**TSD 4 + TSD 14 + TSD 15**	**TSD 7 + TSD 16 and newer**
				
Number of sensors in front of rear axle	4 sensors	7 sensors	8 sensors	8 sensors with options for more lasers
Number of sensors behind rear axle	-	-	3 sensors	3 sensors
Laser type	1 kHz Doppler laser	1 kHz Doppler laser	1 kHz Doppler laser	250 kHz Doppler laser
Trailer type	Standard Container	Insulated semi-trailer	Insulated semi-trailer + air tunnel	Insulated semi-trailer + air tunnel
Movable measuring beam for calibration	No	Manual	Manual	Automatic
Number of measuring beams	1	1	1	2 (TSD 16 + 21 + 22)
Ground penetrating radar	No	No	Yes	Yes
Model for fitting data	Classic beam model	Classic beam model	Asymmetrical model	Asymmetrical model
Viscoelastic backcalculation	No	No	Yes	Yes

ABOUT GREENWOOD ENGINEERING

Greenwood Engineering was founded in 1992 by CEO Leif Grønskov. The first project was a road profiler with 17 lasers and inertial system, developed by Leif Grønskov in corporation with Niels Grønskov. Soon after, the first road profiler and The High Speed Deflectometer/Traffic Speed Deflectometer was introduced and numerous of new products have been added since then, including the LaserProf and the other vehicles.

Customers includes:

- Research Institutes and Universities
- Concessionaires
- Road and Highway Agencies
- Airport Operators
- Service providers/Contractors

Greenwood Engineering, with CEO Leif Grønskov in front, is still at the leading edge of frontier technology and provides excellent service and support by a wide range of skilled staff (Ph.D´s, mechanical and electrical engineers, software developers, craftmen etc.). The company are characterized by a dedicated and innovative spirit, a close collaboration with the customers and a very high level of technical in-house knowledge and talent. Some key employees have seniority up to +25 years, some have joined us along the way and some are fresh out of university or Ph.D.

Combined with a strong and experienced sales department and back office, Greenwood is built on solid grounds and continues to offer outstanding products and new developments.

In addition to the road equipment, Greenwood Engineering has invented the MiniProf system, an advanced measuring system for the railway industry. The MiniProf systems are high-precision, full-contact profile measuring tools for monitoring and analyzing the cross-sectional profiles of rail tracks, wheels, brakes, switches and crossings. MiniProf is distributed for a global network of agents and used by a thousands of users around the world.

Greenwood Engineering is located in Brøndby, Denmark just outside Copenhagen and has approximately 50 employees.

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