Equipment for Quality Tests of Materials Used in the Construction of Road Surfaces Carried Out by the Laboratory of the Warsaw Division of GDDKiA in Poland

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Abstract. The article briefly describes the history of the Road Laboratory, its structure and the equipment for quality tests of materials used for the construction of road surfaces carried out by the Team of Asphalts and Mineral-Asphalt Mixtures and the Surface Diagnostics Team of the laboratory of the Warsaw Division of General Directorate for National Roads and Motorways (GDDKiA) in Opacz Kolonia in Poland.

1. The history of the road laboratory in Poland

The Road Research Institute of the Warsaw University of Technology was founded in February 1929 and began its operation in the early 1930s. Apart from research and standardisation works, the institute predominantly provided services. It was a central road laboratory for testing material and soil samples, it developed mixture formulas for the few construction sites out there at that time and carried out tests of samples of finished bituminous and concrete surfaces. The history of operation of road laboratories started shortly following the World War II. In 1948, the then Minister of Road Transport defined their organisational structure in the relevant ordinance. The first research units of this type were established under the auspices of departments of motor vehicles of province offices. Initially, such laboratories were set up in Kraków, Kielce, Katowice (in this case, the laboratory was reactivated, as the unit was already there in 1935), Łódź, Wrocław, Olsztyn and Gdańsk. More laboratories of this type emerged during the period between 1949 and 1954.

During the early years of their operation, the laboratories were run by teams of three employees: a head of the laboratory, a technician and an assistant. The laboratories were usually seated in a single room, in a building located in an industrial zone of a given town/city. Other common locations for these laboratories were basements of buildings belonging to institutions offering accommodation, such as Wrocław University of Technology. The units were expected to carry out research for the improvement and development of road construction methods in Poland. In 1949, the first convention of employees of road laboratories took place. From that moment on, meetings of road engineers were held annually. These meetings still take place today.

The post WWII history of road laboratories was closely connected to the administrative reforms of the state. The initial changes of this type were introduced already in 1952. It was then that Province Road Administration Boards were appointed. The laboratories were incorporated into the structures of these boards. More changes followed in 1975. District Directorates for Public Roads were established.

In 1972, the United Nations launched a programme, under which Polish experts had the opportunity to travel to European states, including France, for internship. Road engineers from the laboratory in
Kraków, Katowice and Poznań took that opportunity. The knowledge and experienced gained through such internship was subsequently adapted to domestic conditions.

In 1986, more transformations in terms of domestic road structures followed. The General Directorate for Public Roads was created, including its nine local divisions. Whereas in 2002, the organisation was transformed into what we know today as the General Directorate for National Roads and Motorways. Road laboratories were present in both of the above-mentioned structures but in the previous decade, they functioned as auxiliary enterprises rendering services for the benefit of national road administration as well as local government administrators and road-building companies. In 2010, following the amendments to the act on public finances, which resulted in the winding-up of the auxiliary enterprises, it was decided that road laboratories would report directly to GDDKiA structures. At that point, modern laboratories were set up in most of the divisions or the existing laboratories were modernised.

Figure 1. GDDKiA laboratory

2. Description of the road laboratory of the Warsaw Division of GDDKiA in Poland

2.1. General description
The Road Laboratory was incorporated into the structure of the Warsaw Division of GDDKiA in the early 2011 as the Technology Department. Today, approximately 4000 samples are analysed annually in the laboratory. The road laboratory in Opacz has been equipped with instruments for controlling the quality of the roads administered by GDDKiA both at the stage of their construction and use.

2.2. Accreditation
The Warsaw Division of GDDKiA filed the application for the issuing of accreditation for the laboratory in June 2013. In order to receive the accreditation, it was required for the laboratory to conform to PN-EN ISO/IEC 17025, which specifies the general requirements regarding the competence of research and calibration laboratories.

The accreditation is granted by the Polish Centre for Accreditation is the official confirmation of the high quality of the tests carried out by the laboratory to test the quality of contracted works.

2.3. The structure of the laboratory
The Technology Department – the Road Laboratory consists of the following five laboratories:

2.3.1. The Team of Asphalts and Mineral-Asphalt Mixtures. The Team of Asphalts and Mineral-Asphalt Mixtures tests the following materials: mineral-asphalt mixtures (MAM), mineral-cement-emulsion mixtures (MCE) and asphalts.

MAMs are tested for the following properties: soluble binder content, post-extraction grain composition of the mineral aggregate, void characteristics, sensitivity to water and freezing, resistance to pavement rutting, stiffness, fatigue resistance, binder drainage, interlayer bonding and hardness (penetration) of mastic asphalt on cubical samples.

Asphalts are tested for the following properties: needle penetration and softening point using the ring and ball method [2].

2.3.2. Aggregate Team. The Aggregate Team analyses the following geometric properties of aggregates according to PN-EN 933 series standards: screen analysis, shape index, flatness index, flow coefficient of aggregates, fragmentation index, sand equivalent and screen analysis in a stream of air [6].

The Aggregate Team analyses the following mechanical and physical properties of aggregates according to PN-EN 1097 series standards: density and water absorbability, bulk density, resistance to fragmentation, resistance to polishing, resistance to abrasion, void characteristics of dry, compacted filler.

The Aggregate Team analyses the following thermal and weathering properties of aggregates according to PN-EN 1367 series standards: resistance to freezing in water and resistance to freezing in the presence of salt; it also carries out boiling test for sonnenbrand basalt.

The Aggregate Team analyses the following chemical properties of aggregates according to PN-EN 1744 series standards: chemical analysis, organic particle content and solubility in water [6].

For the following materials: fine aggregates, coarse aggregates, unbound mixtures, fillers and materials for winter road maintenance.

Additionally, the Aggregate Team tests filler aggregates used for MAMs according to PN-EN 13179 series standards: delta ring and ball test, bitumen number.

2.3.3. Surface Diagnostics Team. The Surface Diagnostics Team carries out the following tests: visual assessment of surface condition, longitudinal profile measurement, transverse profile measurement, measurement of anti-skid properties, surface deflection measurement with a falling weight deflectometer (FWD), measurement of reflective properties of pavement markings, measurement of thickness of pavement construction layers with the georadar method.

2.3.4. Soil and Geotechnics Team. The Soil and Geotechnics Team conducts the following tests: screen analysis, areometric analysis, natural humidity, compaction index, sand equivalent, deformation modulus using VSS plate, dynamic probe, determination of bulk density of the granular soil structure in the Proctor apparatus, yield value according to Casagrande method, yield strength, geotechnical drilling, CBR, dust content, organic particle content, CaCO₃ content, analysis of strength of a cement-stabilised soil.

For the following materials: cohesive soils, non-cohesive soils, stabilised soils, materials used for earth works [4].

2.3.5. Concrete and Bonding Material Team. The Concrete and Bonding Material Team analyses the following properties: density of the concrete mixture, consistency of the concrete mixture, air content in the concrete mixture, density of concrete samples, compression strength, penetration by water under pressure, water permeability, water absorbability, resistance to freezing and tensile strength.

For the following materials: concrete mixture, structural concrete, non-structural concrete, surface concrete, prefabricated elements made of concrete and stone [3].
In total, there are 25 employees of the Technology Department – Road Laboratory of the Warsaw Division of GDDKiA.

3. The Laboratory of Asphalts and Mineral-Asphalt Mixtures

The Team of Asphalts and Mineral-Asphalt Mixtures assesses the fitness of mineral and asphalt mixtures both prior to and following their incorporation into road surface. The quality of the mixtures is assessed prior to the approval of their incorporation into a road surface through, inter alia, composition analysis as well as freezing and rutting resistance tests. What is more, the quality of finished road surfaces is assessed through thickness, interlayer bonding as well as compaction tests.

3.1. Types of tests carried out by the laboratory of asphalts and mineral-asphalt mixtures

a) Soluble binder content according to PN-EN 12697-1

The binder content in a mineral-asphalt mixture should be at such a level, as to ensure suitable void characteristics, maximum compaction and strength of the designed mixture. The correct content of asphalt in an MAM can be determined through the calculations or experimental methods.

The test consists in separating the aggregate from asphalt found in the MAM through extraction.

![Figure 3. Asphalt](image)

b) Determining rutting resistance according to PN-EN 12697-22+A1

Sensitivity to deformations resulting from vehicle traffic is a vital parameter in assessing the performance of an MAM incorporated into a road surface. Pavement resistance to permanent deformations is assessed with equipment capable of simulating vehicle traffic conditions on the road. Wheel trackers are such equipment. A rut is described as a deformation of the cross-section of a lane in the direction of vehicle traffic, along the tracks of the most common passes of vehicle wheels, caused by visco-plastic strain of the asphalt layer(s) or strain of the support layers of the road surface or by both types of strain.
There are the following rut types: structural ruts typically caused by excessive vehicle traffic (reinforcements), ruts resulting from asphalt layer creeping – caused by faults in the design process of an MAM (replacement through recycling), ruts caused by surface abrasion – the degree of occurrence of this type of defect depends on the type of vehicles and their tyres (vehicles with caterpillar tracks, tyres with studs, chains).

The test consists in the measurement of the depth of the rut following a repeated passage of a loaded wheel in a given temperature.

d) **Stiffness test according to PN-EN 12697-26 Fatigue resistance test according to PN-EN 12697-24 using the method of prismatic four-point bending (4PB-PR, temp. 10°C, frequency 10 Hz)**

The test is to determine: the maximum tensile stress [Pa], the maximum tensile strain, stiffness modulus under bending [Pa], phase shift angle, dispersed energy [J/m³/cycle], initial stiffness modulus, No. of cycles before destruction, destructive cumulated dispersed energy [J/m³]

e) **Determining indirect tensile strength and sensitivity to water of asphalt samples**

Testing elasticity modulus through indirect tensile test is to determine MAM resistance to low and high temperatures. Additionally, the test may be used to assess MAM resistance to water and freezing.
f) Determining hardness (penetration) of mastic asphalt on cubical samples according to PN-EN 12697-20

Penetration – one of the factors determining the consistency (hardness) of asphalt. The higher the penetration value, the softer the asphalt. The standard introduces a division of road asphalts into particular types based on the penetration test results in 25°C.

The test consists in measuring penetration value and increment. The test is carried out on cubes subject to a set load in a set temperature.

g) Determining needle penetration according to PN-EN 1426

The penetration test is carried out according to PN-EN 1426 Asphalts and asphalt products. Determining penetration with a needle.

As far as European standards are concerned, for many years now asphalt binders have been classified predominantly based on the penetration test conducted in 25°C. The test consists in the measurement of asphalt consistency conventionally expressed as the depth of penetration of a standard steel needle inserted vertically into an asphalt sample in a set temperature. The load on the needle is 100 g and the time under load is 5 seconds. The unit of penetration is [0.1 mm], i.e. the depth to which the needle sinks into the asphalt sample. Interpretation of the results is easy, e.g. we know that asphalt with a penetration value of 200 [0.1 mm] is softer than asphalt with the penetration value of 100 [0.1 mm], as the needle sinks 20 mm into the former and 10 mm into the latter. Generally, the greater the penetration value, the softer the asphalt. The test can be carried out in various temperatures, although the temperature of 25°C has been accepted as a standard value for asphalt classification purposes.

![Penetrometer](image)

Figure 8. Penetrometer

3.2. Check tests conducted by the Team of Asphalts and Mineral-Asphalt Mixtures

Check tests conducted by the Team of Asphalts and Mineral-Asphalt Mixtures include:

- Soluble binder content in a mineral-asphalt mixture according to PN-EN 12697-1:2012
- Determination of the grain composition of a mineral aggregate following extraction according to PN-EN 12697-2 +A1:2008
- Void characteristics of a mineral-asphalt mixture according to PN-EN 12697-8:2005 item 4
- Compaction index of a finished layer according to PN-EN 13108-20:2008 appendix C
- Volume of voids in a layer according to PN-EN 12697-8:2005
- Layer thickness according to PN-EN 13697-36:2005

4. Surface Diagnostics Team

The main task of the team is to conduct measurements under the Surface Condition Diagnostics system (previously Surface Condition Assessment System). The measurements encompass the whole network of national roads and motorways in the area of operation of the Warsaw Division. The scope of
diagnostics includes the following tests: longitudinal profile and rut measurement, surface friction coefficient and surface deflection measurements. The data is communicated to the Department for the Administration of Roads and Bridges, which is responsible for a comprehensive assessment of the condition of roads nationwide. What is more, post-completion acceptance tests of new road sections in the above-mentioned scope are performed as well as other tests, e.g. pavement marking tests (day and night visibility, colour), transverse profile measurements, tests of vertical signs and georadar tests.

4.1. Description of tests

- **Longitudinal and transverse profile measurements.** The measurements are carried out at 50 km/h, although the value can be adjusted within the range of 20 to 110 km/h, depending on the traffic conditions, without a significant impact on the results. The test consists in measuring and recording, continuously, pavement profiles by laser sensors installed inside a bar attached to the measurement vehicle. Both longitudinal and transverse profile levels of irregularities of the lane surface are registered along the right-hand side wheel track, which is considered representative of the whole lane width. The obtained measurement results are processed into individual and sectional evenness ratings, which are compared with a relevant grading scale.

![Figure 9. Measurement vehicle [1]](image)

- **Measurement of anti-skid properties.** During the measurement, the vehicle is moving along the surface of the tested lane at 30, 60, 90 and 120 (km/h). A reliable friction coefficient is recorded by locking a test tyre on the road surface with 0.5 l/m² of water applied onto it. The measurement assembly is equipped with a 300l water tank, which lasts for 15 km of measurement. The vehicle is travelling parallel to the lane axis, so that the measurement wheel of the assembly is in the right-hand side track of a wheel of an average road user.
Figure 10. Surface diagnostics equipment [11]

a) Surface deflection measurement with an FWD

The test consists in dropping a weigh of a set mass onto a steel plate placed on a surface, which is to ensure a distribution of a point force impulse over a D=300mm wheel.

It is a point measurement conducted with a stationary towing vehicle. There is a pressure plate on the tested surface and there are geophones on the measurement bar.

The weight of a set mass is dropped three times from a set height.

Figure 11. FWD

b) Measurement of reflective properties of pavement markings

The measurement consists in setting the device on the tested surface and triggering the measurement with a button. Measured coefficients are recorded automatically.

Figure 12. Retroreflectometer [7]
c) **Measurement of the thickness of particular road surface layers with the georadar method**

The measurement consists in transmitting an electromagnetic wave of a set frequency through a radio antenna into a medium with known measurement spacing. The electromagnetic wave, when moving through the media of various dielectric constants, is subject to damping, refraction and reflection.

![Georadar](https://example.com/georadar.jpg)

**Figure 13. Georadar [9]**

d) **Automatic surface defect assessment**

The LCMS (Laser Crack Measurement System) made by Canada-based Pavemetrics TM Systems is based on providing a high-resolution 3D image of the road surface. Purpose-built, high speed cameras record the image of the lane surface along with the image of the laser line generated with laser projectors. This method allows us to create a 3D image, which can be used in automatic analyses dedicated to detecting surface defects.

Characteristics of the automatic assessment: measurement speed: up to 100km/h, distance between profiles: 1-5mm (adjustable), horizontal resolution: 4096 points/profile, reading accuracy: 0.5mm, measurements can be carried out during both day and night time, resolution of pictures form the front camera: 1280x960px, macrotexture coefficient measurement, rut depth measurement, identification of excessively low and high values.

e) **Mobile measurement of pavement markings with RTM (Road Marking Tester)**

A dynamic measurement enables obtaining the following data on the pavement markings: night time RL dry method, nigh time RL wet method, day time visibility Qa, skid resistance class – SRT, average marking width, average whiteness percent, line types: continuous, dotted, number of lines, marking start and end points [7].

5. **Conclusions**

The road laboratory of the Warsaw Division of the General Directorate for National Roads and Motorways in Opacz Kolonia in Poland offers a wide range of equipment necessary for the performance of detailed tests. With the high testing capacity as well as highly qualified personnel, the tests carried out in the laboratory significantly affect the quality of roads and improve both the comfort as well as the safety of their users.

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