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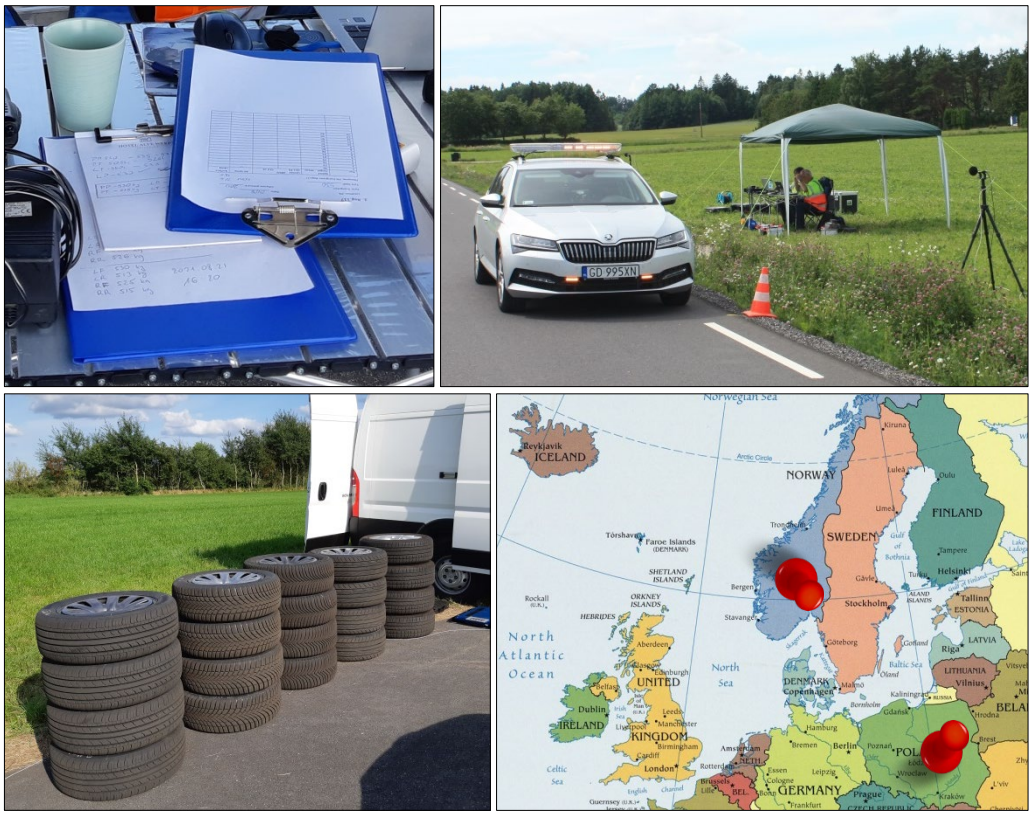

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Technical report on specification of test program, including selection of tyres, vehicle, pavements and test locations

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CONTENTS

1 INTRODUCTION

One of the main objectives of the ELANORE project is to verify representativeness of the rolling resistance and tyre/road noise test methods specified in UNECE Regulation 117 (*Uniform provisions concerning the approval of tyres with regard to rolling sound emissions and/or to adhesion on wet surfaces and/or to rolling resistance*) [1] used directly in the Tyre Labelling Directive.

To verify representativeness of the tyre/road noise a Round Robin Test (RRT) was performed on selected ISO test tracks using a test vehicle and a limited number of sets of passenger car tyres. Additionally, vehicle coast-by noise tests were conducted on selected conventional, most common dense and porous pavements in Poland and Norway. At the same time, together with vehicle coast-by noise, the tyre/road noise was measured at the same locations using the CPX method [2] for all the selected tyres.

This technical report presents a developed test program, including selection of tyres, vehicle, pavements and test locations. It concentrates on tyre/road noise tests only. The test tyres and conventional pavements selected to be used in rolling resistance tests are not reported here.

2 SPECIFICATION OF TEST PROGRAM

The main objective of Work Package 2 of ELANORE project is to verify representativeness of the tyre/road noise test method specified in UNECE Regulation 117 [1] used directly in the Tyre Labelling Directive. Special attention will be paid on verification of representativeness of the standard reference road surface proscribed in the ISO 10844:2014 [3].

This verification was planned to be done by a Round Robin Test (RRT) using the controlled pass-by (CPB) method on selection of ISO test tracks using a vehicle and a limited number of sets of passenger car tyres. Additionally, vehicle CPB noise tests were planned to be conducted on selected conventional, most common dense and porous pavements in Poland and Norway. At the same time, together with vehicle-controlled pass-by noise, the tyre/road noise will be measured at the same locations using the CPX method for the previously selected tyres. At one ISO test track and two locations of conventional pavements the measurements of L_{EQ}-levels were planned to be done.

The specification of test conditions, the selection of test tyres, test vehicle, ISO test tracks, conventional pavements and test locations are presented in detail in the following chapters of this technical report.

3 SELECTION OF TEST TYRES

It was planned in the project proposal as the Task 1.3 of the ELANORE project to purchase about 40 test tyres. These tyres were intended to be tested for rolling resistance and for noise according to the UNECE Regulation 117 both in road conditions on ISO test tracks and on selected conventional pavements as well as in laboratory on drum facility to verify if each tyre is properly labeled by its manufacturer. Some of the tyres were purchased in 4 sets as they were also used for experiments where passenger car must run on 4 identical tyres.

Thus four sets of C1 tyres from currently available on the European market were selected to be used for road tests in ELANORE project for noise. One sample of each set was planned to be (and it was carried out) additionally tested using the CPX method on each ISO test track and on selected conventional pavements in Poland and Norway. The assumption was that the selected tyres shall be within the most common tyre dimensions (width of 205-225 mm and rim size of 16-17 inch) to be fitted on the test vehicle and they shall cover most wide range of noise values given on EU tyre labels (from 1 to 3 noise bars). The 5^{th} set of test tyres shall consist of the ASTM F2493 Standard Reference Test Tyres.

The standard and alternative tyre sizes for the selected test vehicle (see Chapter 4) are 215/55 R17 and 215/60 R16. The performed internet research on the European market showed that 17-inch tyres of that size were potentially available with the EU label noise values ranging from 66 dB and 1 noise bar up to 74 dB and 3 noise bars. The 16-inch tyres are available within a similar range from 67 dB (1 noise bar) up to 75 dB (3 noise bars). One should observe that tyres with extreme values (both low and high) were not very popular on the market. Finally, it occurred that it was very difficult to purchase such tyres because the noise values given on tyre labels change over time without any notice by the manufacturer (e.g. the ordered tyre of 73 dB and 3 noise bars was delivered with a label of 71 dB and 2 bars). That means that nominally the same tyres (with the same EAN code) exist on the market with different EU labels. From the end-user and environmental point of view it is a positive action in case of “loud” tyres but when selecting tyres for testing it forced few times to return the already purchased tyres.

It was decided to select all tyres of one size of 215/55 R17 for the main purpose of noise testing (excluding SRTT tyres which are of the size of P225/60 R16). The listed in Table 1 four sets of C1 tyres have been selected and purchased together with one set of SRTT tyres. It was assumed that EU label noise values of the tyres should be rather equally distributed over the available range.

The selected tyres consist of 2 sets of summer, 1 set of winter and 1 set of all-season tyres. They cover a range of noise values from 67 up to 74 dB given on tyre labels (1 to 3 noise bars).

Table 1. *Tyres selected and purchased in 4 sets dedicated mainly to CPB tests*

Manufacturer	Tread pattern	Season	Tyre size	Load index	Speed rating	Remarks	DOT	FUEL EFFICIENCY	WET GRIP	ROAD NOISE	Noise level
Yokohama	Advan Fleva V701	Summer	215/55R17	94	W		3720	C	A		**67** dB
Michelin	CrossClimate+	All season	215/55R17	98	W	XL	4920	C	B		**69** dB
Bridgestone	Blizzak LM005	Winter	215/55R17	98	V	XL	4820	C	A		**71** dB
Evergreen	EH23	Summer	215/55R17	98	V	XL	1620	E	C		**74** dB
Uniroyal	Tiger Paw	SRTT	P225/60R16	97	S		4020	-	-	-	-

Additionally, 5 other tyres were selected and purchased to cover the whole range of noise values from 66 up to 74 dB (with 1 dB step). They consist of 2 summer tyres, 2 winter and 1 all-season tyre. These tyres were intended to be used in CPX tests during the Round Robin Test on ISO test tracks, on selected conventional pavements in Poland and Norway and on laboratory drum facility covered with road replicas. Furthermore, the standard reference tyre (Avon Supervan AV4), designated H1 according to the technical specification ISO/TS 11819-3:2017 [4] was included in the tests. The details of selected additional tyres are presented in Table 2.

Table 2. *Additional pieces of selected and purchased tyres dedicated to CPX tests*

Manufacturer	Tread pattern	Season	Tyre size	Load index	Speed rating	Remarks	DOT	FUEL EFFICIENCY	WET GRIP	ROAD NOISE	Noise level
Dębica	PRESTO UHP	Summer	215/55R17	94	W		3216	E	C		**66** dB
Kenda	KR501	Winter	215/55R17	98	V	XL	2420	E	C		**68** dB
Vredestein	Ultrac Satin	Summer	215/55R17	98	W	XL	1021	B	A		**70** dB
Continental	AllSeasonContact	All season	215/55R17	98	H	XL	1121	A	B		**72** dB
Momo	W-2 NORTH POLE	Winter	215/55R17	98	V	XL	2520	E	C		**73** dB
Avon	AV4	AAV4	195R14C	106/104	N		4814	-	-	-	-

Summarizing, 11 different tyre types (5 of them in sets of 4 tyres), including the SRTT tyres and Avon AV4 tyre, covering the range of EU label noise values from 66 dB up to 74 dB with 1 dB step (1 to 3 noise bars) have been selected for noise tests. All the details of selected tyres are presented in Table 3. Tyres designated with bold numbers were selected for noise tests using the CPX method. For all the selected tyres appropriate rims, fitting the test vehicle, have been purchased.

Table 3. *Selected tyres dedicated to noise tests*

Manufacturer	Tread pattern	Season	Tyre size	Load index	Speed rating	Remarks	Designation			
Dębica	PRESTO UHP	Summer	215/55R17	94	W		**T1252**			
Yokohama	Advan Fleva V701	Summer	215/55R17	94	W		T1253	**T1254**	T1255	T1256
Kenda	KR501	Winter	215/55R17	98	V	XL	**T1257**			
Michelin	CrossClimate+	All season	215/55R17	98	W	XL	T1258	**T1259**	T1260	T1261
Vredestein	Ultrac Satin	Summer	215/55R17	98	W	XL	**T1262**			
Bridgestone	Blizzak LM005	Winter	215/55R17	98	V	XL	T1263	**T1264**	T1265	T1266
Continental	AllSeasonContact	All season	215/55R17	98	H	XL	**T1267**			
Momo	W-2 NORTH POLE	Winter	215/55R17	98	V	XL	**T1268**			
Evergreen	EH23	Summer	215/55R17	98	V	XL	**T1269**	T1270	T1271	T1272
Uniroyal	Tiger Paw	SRTT	P225/60R16	97	S		**T1273**	T1274	T1275	T1276
Avon	AV4	AAV4	195R14C	106/104	N		**T1182**			

Manufacturer	Tread pattern	DOT				Tread rubber hardness				Noise level	FUEL EFFICIENCY	WET GRIP	ROAD NOISE
Dębica	PRESTO UHP	**3216**				**74**				**66** dB	E	C	
Yokohama	Advan Fleva V701	3720	**3720**	3620	3720	68	**68**	70	71	**67** dB	C	A	
Kenda	KR501	**2420**				**61**				**68** dB	E	C	
Michelin	CrossClimate+	4920	**4920**	4920	4920	63	**63**	63	64	**69** dB	C	B	
Vredestein	Ultrac Satin	**1021**				**65**				**70** dB	B	A	
Bridgestone	Blizzak LM005	4820	**4820**	4820	4720	63	**64**	64	67	**71** dB	C	A	
Continental	AllSeasonContact	**1121**				**63**				**72** dB	A	B	
Momo	W-2 NORTH POLE	**2520**				**67**				**73** dB	E	C	
Evergreen	EH23	**1620**	1620	1620	1620	**71**	70	70	70	**74** dB	E	C	
Uniroyal	Tiger Paw	**4020**	4020	4020	4020	**66**	66	66	66	-	-	-	-
Avon	AV4	**4814**				**71**				-	-	-	-

4 SELECTION OF THE TEST VEHICLE

To perform noise tests planned within the ELANORE project according to Regulation 117, the purchase of a new passenger car fulfilling the UNECE Regulation requirements was predicted in the project proposal (Task 2.2 of WP2). It was also planned that this car will be used as a towing vehicle when performing numerous CPX measurements on selected conventional roads in Poland and Norway.

It was assumed that the selected car must provide the possibility of fitting the tyres described in Chapter 2, what means that standard or optional wheel size provided by the car manufacturer for this vehicle must be compatible with the sizes of selected tyres with a tread width of 205-225 mm and a rim diameter of 16 and 17 inches. It was finally decided that the car should be factory fitted with 17-inch wheels (actually the dominant tyre size).

Tyre/road noise tests were planned to be carried out both on few ISO test tracks in Europe as well as on a number of selected conventional pavements on roads in Poland and Norway. Hence there was a need to ensure the possibility of transport each time to the test site as many test wheels as possible in the trunk of this car, taking into account that the measuring equipment will be also installed there. Therefore, it was decided that the car should have a station wagon body with the largest possible boot volume. The required volume of the luggage compartment with unfolded seats was assumed to be at least 640 liters (including 40 liters for the installation of measuring equipment).

The predicted in the project noise tests using the CPX method will be performed with the use of a special *Tiresonic Mk5* measuring trailer. Therefore, the purchased car must be equipped with a tow bar and adapted to tow a trailer weighing at least 1000 kg. Due to the need to obtain appropriate measuring speeds over relatively short distances, it should be equipped with a petrol engine of a minimum power of 140 kW and with an automatic, minimum 7-speed gearbox. During tyre/road noise tests, it is required to maintain a constant speed while ensuring road traffic safety, hence the car must be equipped with appropriate cruise control device and safety systems.

To conduct CPX noise tests and acquire measurement data, it was planned to permanently install specialized equipment in this vehicle. The installed equipment will be powered mainly from the car's 12 V DC electrical system (appropriate sockets in the passenger compartment and in the luggage compartment are required) and via USB ports (5 V DC sockets). Some devices also require 230 V AC voltage; hence the vehicle should be equipped with such an installation. A light-beam with warning lights will also be installed on the roof of the vehicle, thus roof rails will be required.

The Skoda Superb Combi 2.0 TSI 140 kW (190 HP) fulfilling all the requirements specified above was selected and purchased for the purpose of this project. Of course, this car complies also the requirements of UNECE Regulation 117. The purchased car was shown in Figure 1.

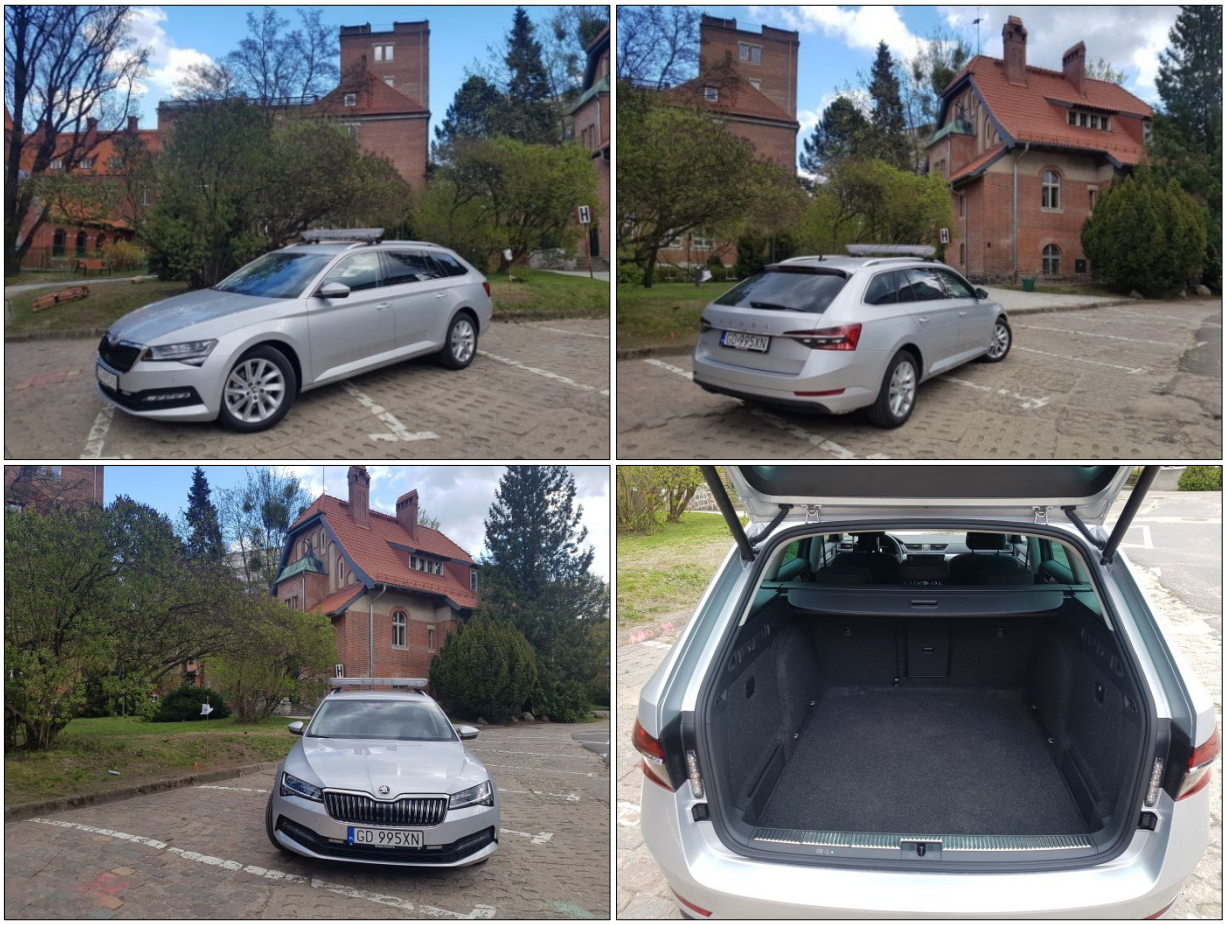

Figure 1. *Skoda Superb Combi 2.0 TSI – the selected and purchased vehicle*

5 SPECIFICATION OF TEST CONDITIONS

Noise measurements using the controlled pass-by method and CPX method were planned to be performed and were conducted with tyre load and inflation pressure according to the values prescribed in the UNECE Regulation 117 [1] (designated *R117* in this report), as well as with a modified test condition named *Light Test* (and designated *LT*).

According to Regulation 117, the tyre load and inflation pressure depend on the maximum load (load index) of the tyre. Using the formulas given in Reg.117, the tyre load was calculated to 530 kg – uniform for all the selected and tested tyres. The inflation pressure was also identical for all tyres – and was set at 200 kPa.

In the modified conditions (*LT*), it was assumed that the tyre load and inflation pressure depend on the particular test vehicle, in this case the selected Skoda Superb. Thus, the tyre load corresponds to the average load condition of this vehicle: car net weight of 1590 kg (including the driver weighting of 75 kg and 90 % of fuel), plus two passengers (each weighting 85 kg) and 80 kg of luggage. For the used test car, the calculated tyre load was 460 kg, The inflation pressure should fulfill the vehicle manufacturer's requirements. The regular inflation pressure for this Skoda Superb was 230 kPa. Table 4 summarizes the two test conditions.

Table 4. *Tyre load and inflation pressure test conditions for both CPB and CPX measurements*

Test condition	Tyre load [kg]	Inflation pressure [kPa]
R117	530	200
LT	460	230
Change in %	*-13*	*+15*

When analyzing the measurement results from CPX tests performed on 3 ISO test track, a very small influence of used test conditions on the recorded noise levels was observed: 0.2 dB on average. Thus, on the ISO4 test track it was decided, **for CPX tests only**, to reduce the tyre load to 320 kg. These test conditions were designated as *LT'*. Such tyre load is used in the standardized CPX method [2] and is much more feasible for a regular CPX trailer. Using this load, it was also possible to compare results of CPX measurements performed on conventional pavements using both CPX trailers: GUT's and SINTEF's under Work Package 4 of this project.

The measurements were supposed to be performed with test speeds corresponding to speeds prescribed in Regulation 117: 70, 75, 80, 85 and 90 km/h. According to Reg.117 at least 4 measurements shall be made at speeds below the reference speed (80 km/h for C1 tyres) and 4 measurements above the reference, giving a minimum of 8 runs. In addition, speeds at 40, 50 and 60 km/h were included to the measurement program to get valuable input data for more precise modeling of traffic noise performed in Work Package 5.

6 SELECTION OF ISO TEST TRACKS

A Round Robin Test on a minimum of three ISO test tracks was planned within the Task 2.5 of ELANORE project. For this purpose it at the beginning of the project 3 ISO tracks located in Northern Europe were selected. Due to the confidentiality of signed contracts, data on the location of individual tracks cannot be disclosed. Unfortunately, due to adverse weather conditions (rain/wind), only a part of the planned measurements was achieved in 2021. Following this, it was decided to perform additional noise tests in 2022 on a selected 4th ISO test track located also in Norther Europe. To distinguish the selected ISO tracks they were designated as ISO1, ISO2, ISO3 (tested in 2021) and ISO4 (tested in 2022).

ISO1, ISO2 and ISO3 fulfill the requirements of ISO 10844:2014 [3]. ISO4 was at the end of its lifetime when the measurements were made. As shown in Table 5, the MPD value at this track is over the allowed limit of 0,70. The track was resurfaced some weeks after our measurements were finished. The absorption value for this track was not available.

Table 5 *Test track information*

Test track	Year of construction	MPD [mm]	Absorption α
ISO1	2015	0.59	0.05
ISO2	2015	0.46	0.03
ISO3	2016	0.47	0.04
ISO4	2014	0.95	-

For all tracks, the MPD values are from measurements using the Surface drone at the time of noise measurements. The absorption value for ISO1 is from certification measurements done by Müller BBM in March 2021 (approximately 5 months before the noise measurements). For ISO2 the absorption value is from certification measurements by Müller BBM at the same time as the noise measurements were done. Müller BBM did also measure the MPD and absorption values in 2017: MPD = 0.43 and α = 0.031 (0.034 in 2021). Thus, there were no principal changes in the texture and absorption on this test track over a period of 4 years.

7 SELECTION OF CONVENTIONAL PAVEMENTS

It was planned in the project proposal as the Task 2.4 to select conventional, most common dense (e.g. SMA11, SMA16, DAC11, CC) and porous (e.g. BBTM8, PAC, DPAC) pavements in Poland and Norway to be used in comparative tests in relation to the ISO standard reference road surface. The pavements were intended to be used when testing tyre rolling resistance in WP1 and WP3 as well when testing vehicle noise (CPB method) in WP2 and tyre/road noise (CPX method) in WP4.

The research carried out towards identification of the most common, conventional road surfaces in Poland showed that the majority of roads have the SMA11 (main roads, highways and high-speed roads) or DAC11 (secondary roads) wearing course. Some highways and high-speed roads are built in cement concrete (CC) technology. In some cases, mainly in city areas when road traffic noise reduction is required, the SMA8 wearing course is used. Porous pavements are almost not existing in Poland. Rough surfaces are also almost completely absent in Poland.

The similar research performed in Norway showed that the main road network, including highways and the secondary roads consists mainly of DAC and SMA, about 2/3 with a maximum chipping size of 11 mm and 1/3 with a maximum chipping size of 16 mm. A few percentages with maximum chipping size 8 mm.

The use of studded tyres is also widespread in Norway. Measurements show that studded tyres sometimes smoothen and sometimes roughen the pavements. The Norwegian pavements on main roads can be considered as medium to rough textured: typical MPD values for SMA16 range between 1 and 1.5 mm and for SMA11 between 0.8 and 1.5 mm.

After a deep analysis, taking into account the physical and financial possibility of performing rather time consuming and complicated pass-by noise tests, it was primarily decided to select 4 test sites (4 in Poland and 2 in Norway) with the following wearing courses: SMA8, SMA11, DAC11 and CC (all 4 in Poland), SMA11 and SMA16 (in Norway) to perform noise comparative tests in relation to the ISO reference pavement using the vehicle coast-by method. Finally it occurred that the selected location of DAC11 pavement in Poland didn't allowed performing safe CPB tests, thus this pavement had to be excluded from the selection. Same problems revealed with the selected SMA11 pavement location in Norway and this wearing course was finally replaced with a MA11 pavement – a Norwegian dense "soft asphalt" with 11 mm maximum chipping size.

It was planned (and done) that tyre/road noise measurements using the CPX method for all the tyres selected in Task 2.1 (see Chapter 2) will be also performed at all these wearing courses mentioned above.

Additional CPX measurements were planned to be performed in Poland in 2023 on DAC11, SMA5, BBTM8, PAC11 and Slurry Seal Gripfibre, but the availability of these wearing courses, especially porous ones, in acceptable technical condition is very limited. When combined with the requirement to select a test site where CPX measurements can be safely performed, it becomes a challenge. Thus the selection of locations of these pavements must be done and confirmed shortly before starting the CPX measurements.

8 SELECTION OF TEST SECTIONS

It was assumed that the considered test sections with conventional pavements should be in good technical condition and of age up to 3 years (up to 2 for porous). This assumption was necessary for the research precision of the verification of representativeness of test methods specified in UNECE Regulation 117 [1].

When selecting test sections with proper conventional pavements for vehicle pass-by noise measurements, one of the most important criteria was the road traffic. The best sections would be the ones closed to road traffic or with a very low volume of traffic. Numerous road construction works were underway in Poland. This made it possible to carry out vehicle pass-by noise measurements on brand new test sections not opened to road traffic yet. A survey conducted among road contractors made it possible to indicate the appropriate locations of test sections with the selected wearing courses.

In Poland noise measurements were finally performed on three road surface test sections, two of them (with SMA8 and SMA11 wearing courses) were located in northern part of the country and one section (EACC wearing course) in eastern part:

1. Pavement **SMA8** was located on a local road close to Bartoszylas village with a speed limit of 90 km/h. This road was repaved in 2019 and is of a very low local traffic only. The surrounding farmlands provided very good acoustics conditions. Figure 2 shows a photo from the measurement location, Figure 3 - a detail of the road surface texture.

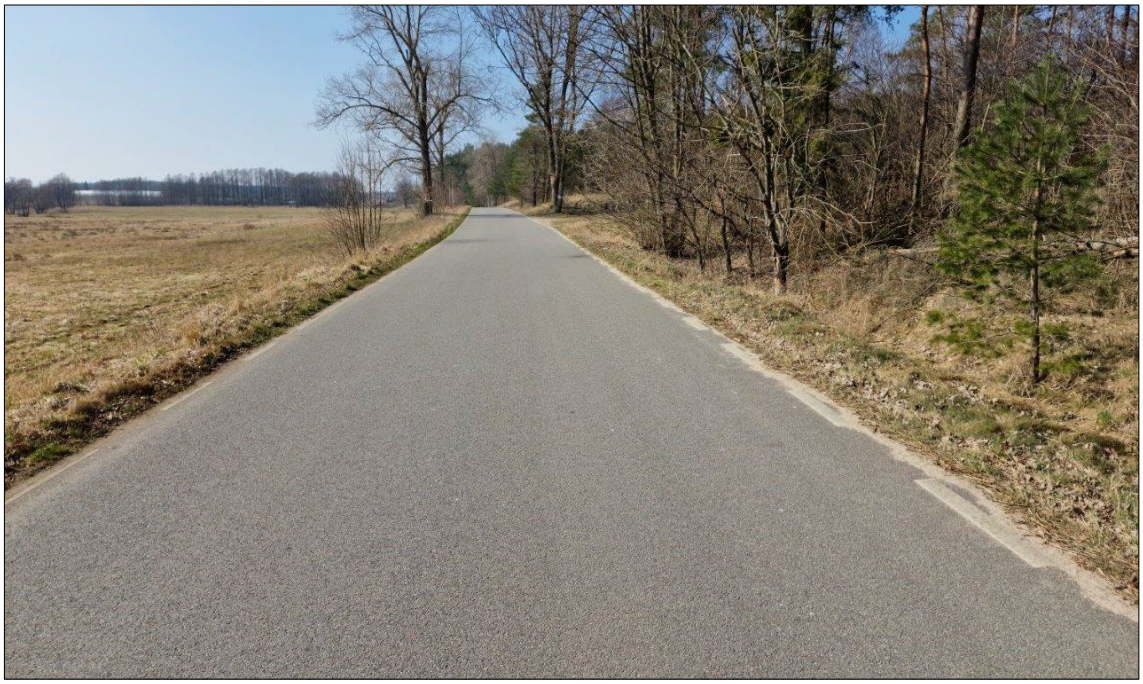

Figure 2. *Measurement location at Bartoszylas (Poland)*

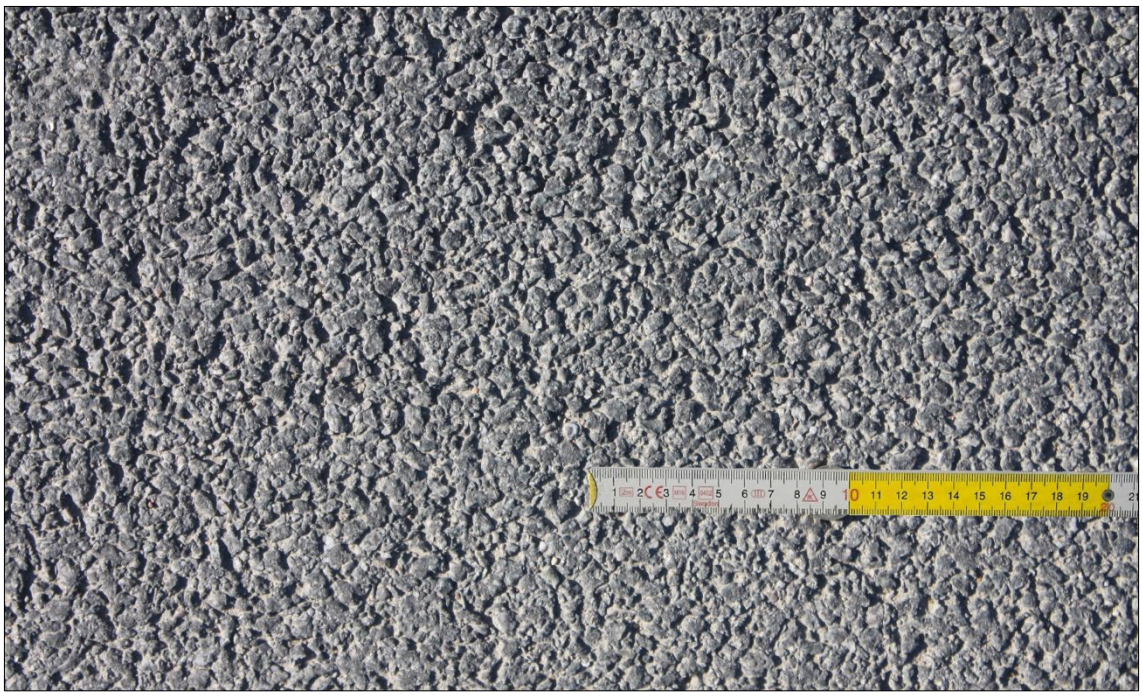

Figure 3. *SMA8 road surface*

2. Pavement **SMA11** was located on the newly built S6 high-speed road in northern Poland close to Szemud town. It was built at the turn of 2021/2022, finished in May 2022 but at the time of measurements (July 2022) the road was still closed to traffic. Figure 4 shows a photo from the measurement location, Figure 5 - a detail of the road surface texture.

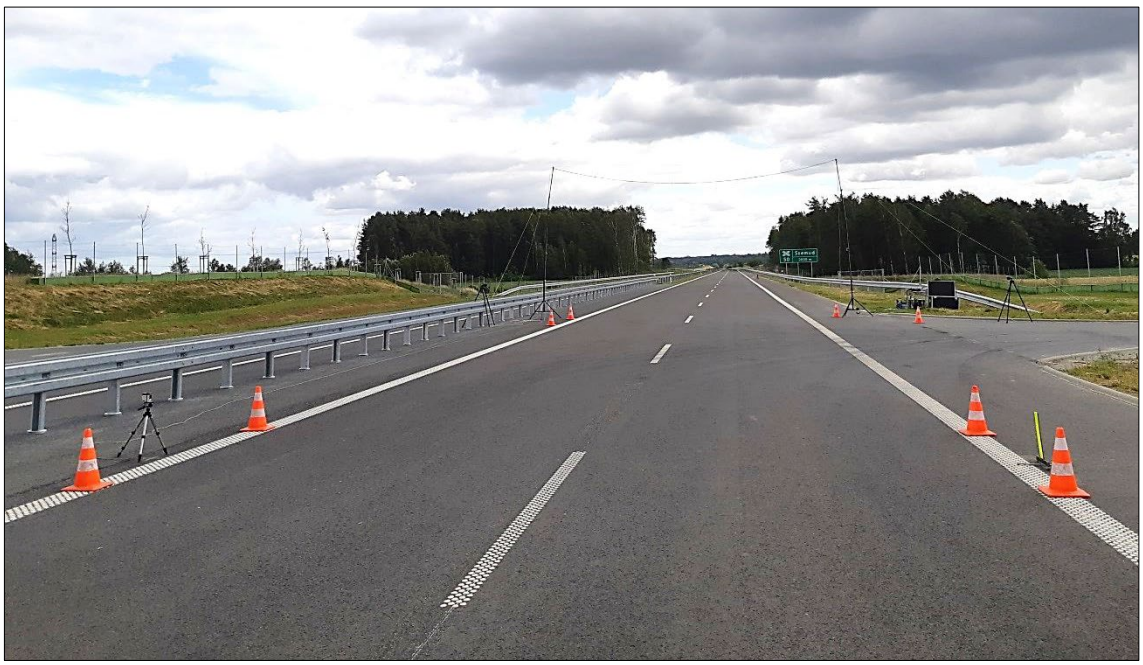

Figure 4. *Measurement location at Szemud (Poland)*

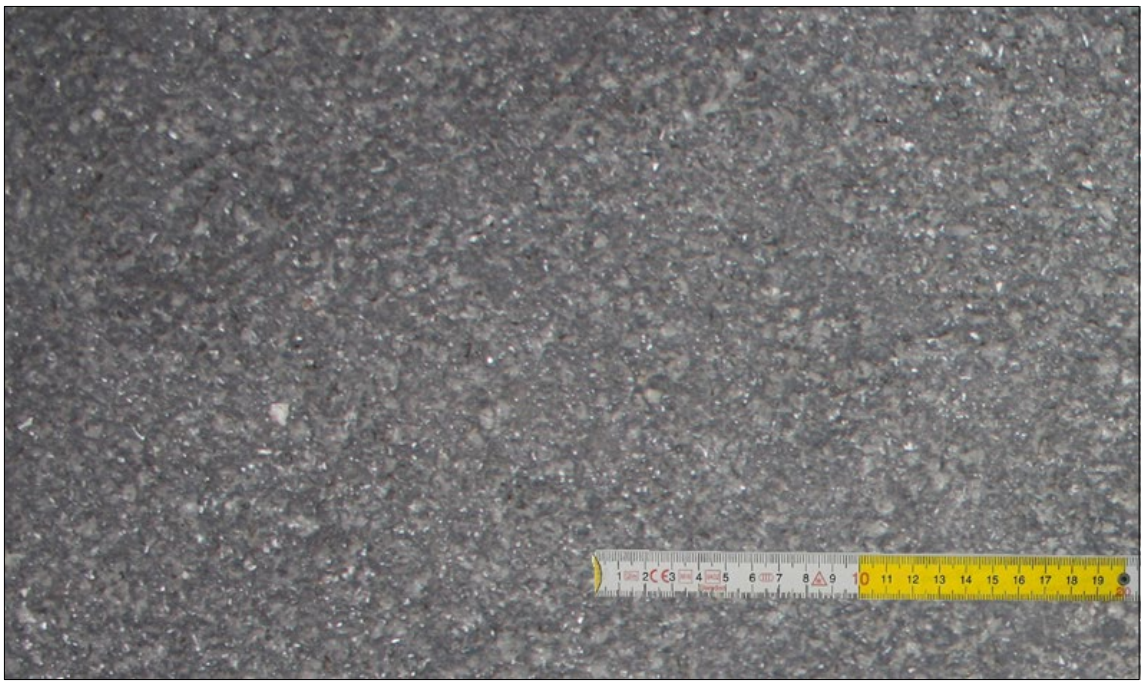

Figure 5. *SMA11 road surface*

3. Pavement **EACC**, produced in exposed aggregate cement concrete technology, was located on newly built S61 high-speed road in north-eastern Poland close to Ełk town. The road surface at the location of test section was laid in 2021 and at the time of measurements (June 2022) the road was still closed to traffic. Figure 6 shows a photo from the measurement location, Figure 7 - a detail of the road surface texture.

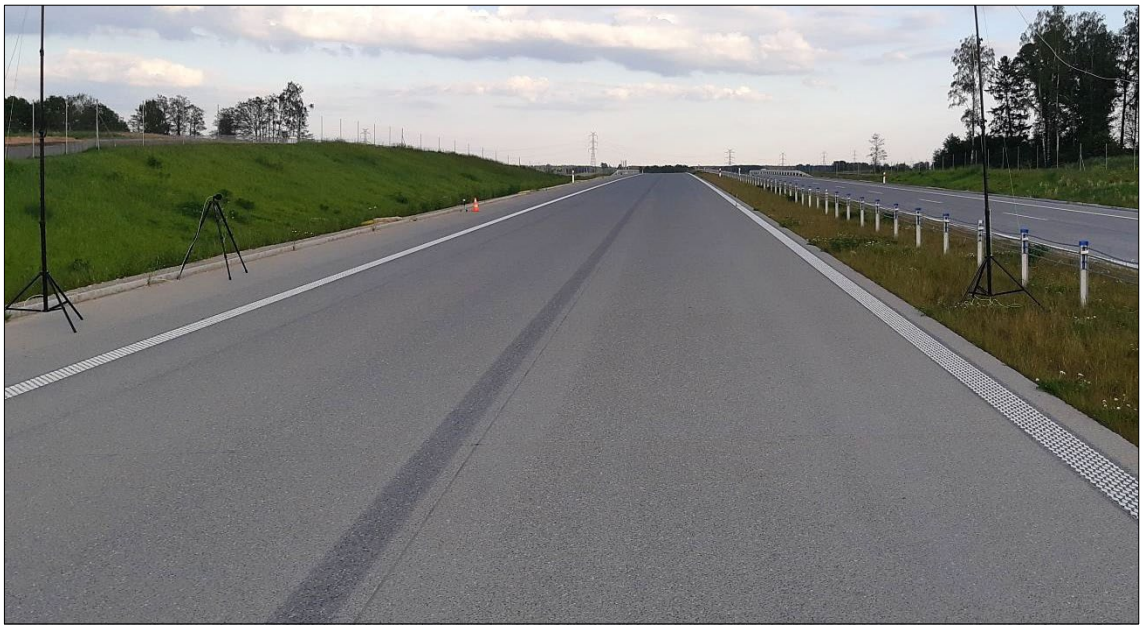

Figure 6. *Measurement location at Ełk (Poland)*

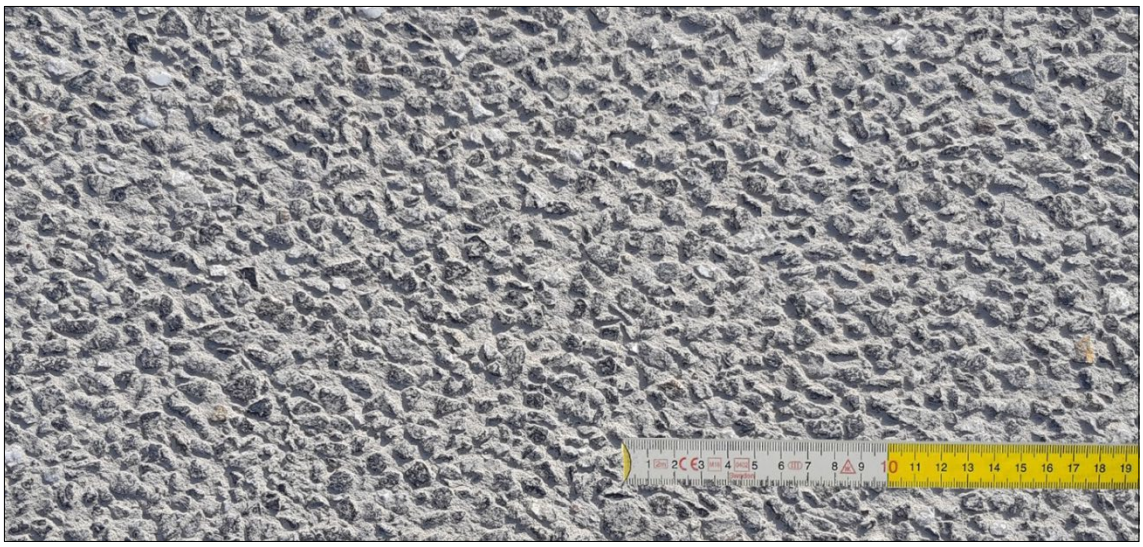

Figure 7. *EACC road surface*

In Norway measurements finally were done on two road surface test sections located on trafficked roads in southern part of the country:

1. Pavement **MA11** was located on road Fv1190 close to Skjeberg village. “MA” is a Norwegian name for a "soft asphalt". It is a dense surface with 11 mm maximum chipping size. Mostly used on low trafficked roads with few heavy vehicles. This pavement was constructed in the summer of 2021, and due to very low ADT (600), the surface seemed to have very little wear after one year. The location of the measurements was on a flat section of the road and with a speed limit of 80 km/h. Figure 8 shows a photo from the measurement location, Figure 9 - a detail of the road surface texture.

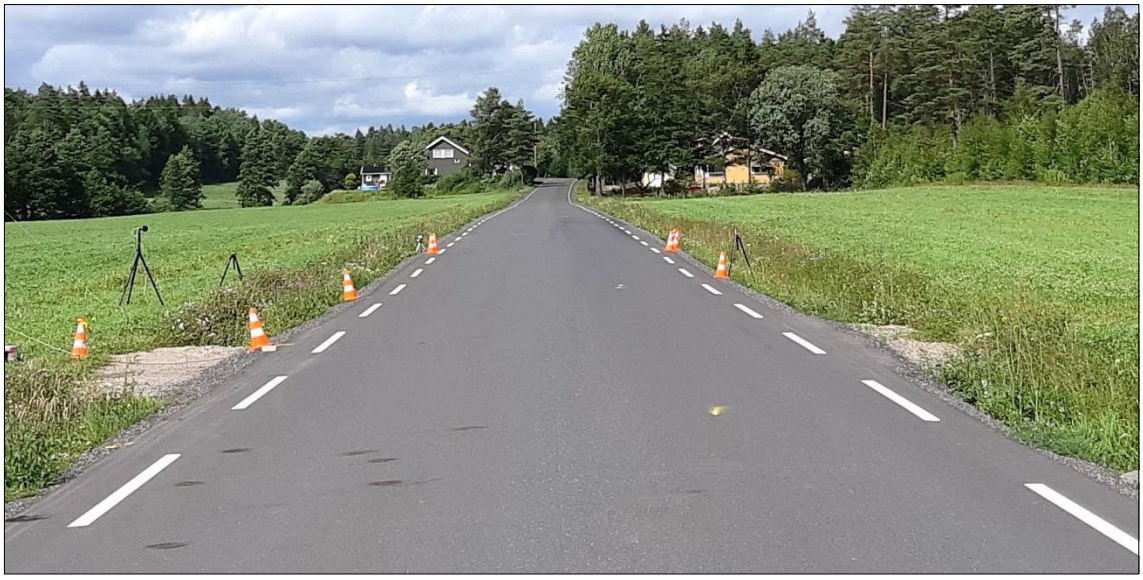

Figure 8. *Measurement location at Fv1190, Skjeberg (Norway)*

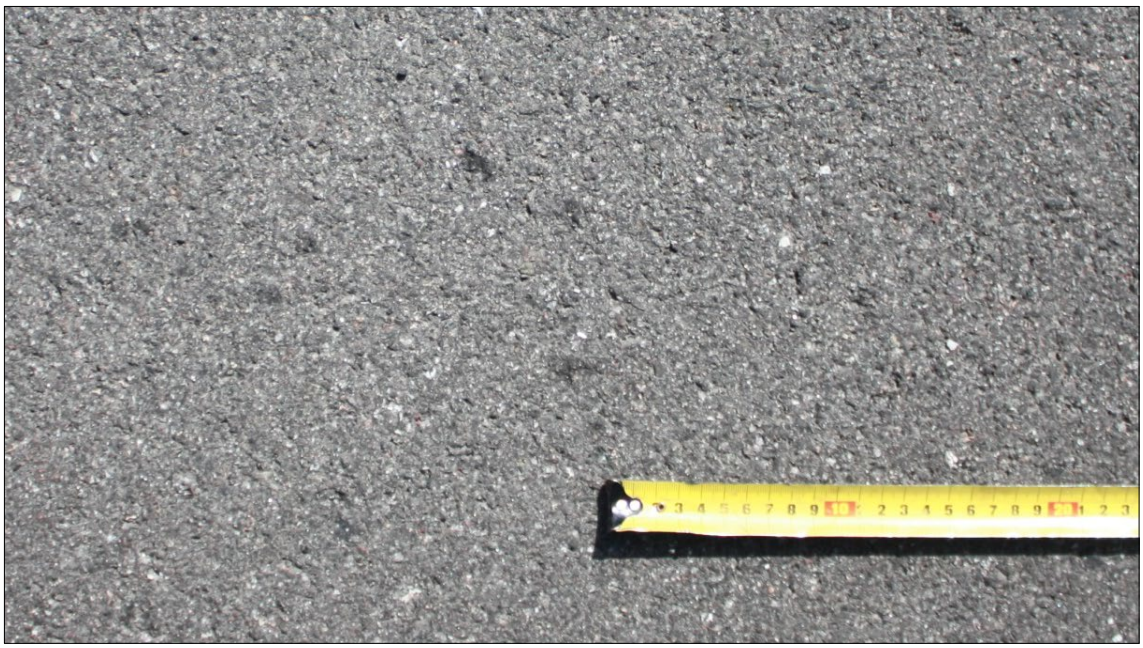

Figure 9. *MA11 road surface*

2. Pavement **SMA16** was located on road Fv171 close to Sørum village. This surface was constructed in 2018 and located at a section of the road with ADT approximately around 6000. The test location was on a flat section with a speed limit of 80 km/h. Figure 10 shows a photo from the measurement location and Figure 11 - a detail of the road surface texture.

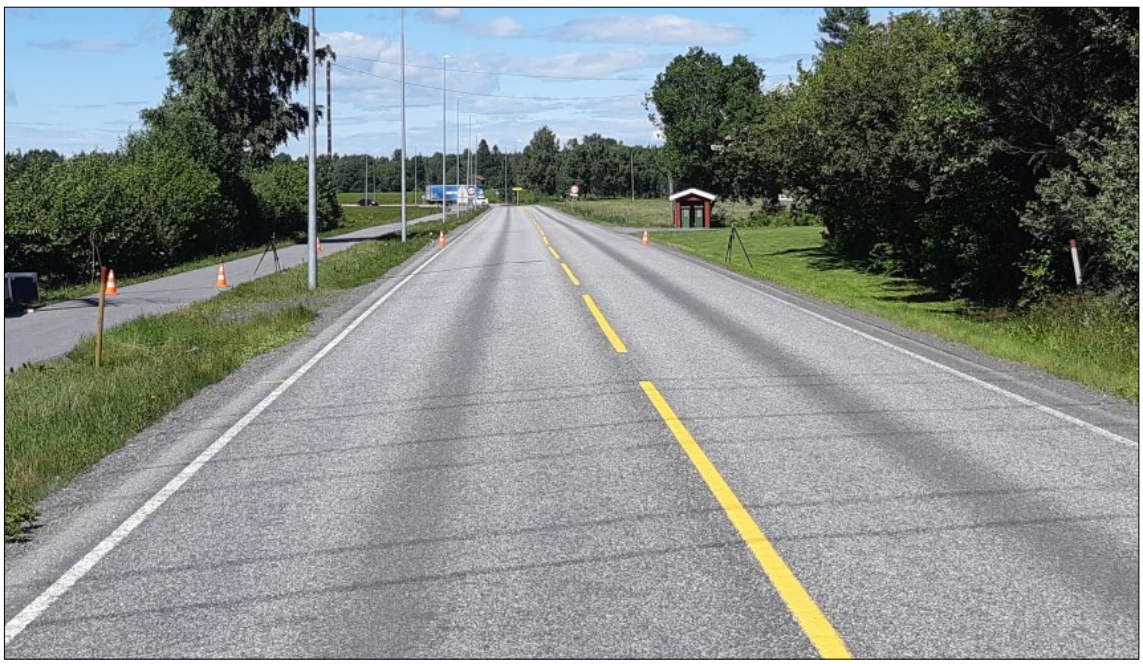

Figure 10. *Measurement location at Fv171, Sørum (Norway)*

Figure 11. *SMA16 road surface*

9 CONCLUSIONS

The Round Robin Test on ISO test tracks according to the test program specified in this technical report was performed between August 20 and August 29, 2021, for test tracks ISO1, ISO2 and ISO3 and on 1-2 July 2022 for ISO4. Due to adverse weather conditions (rain/wind), only a part of the planned measurements was achieved on test tracks ISO1 and ISO3.

CPB noise measurements on conventional pavements in Poland and Norway were conducted in the time period from May 31st to July 29th, 2022. On one test location (SMA8), the measurements were performed for R117 conditions only, due to rainfall.

The measurements of L_{EQ}-levels were performed at the ISO2 test track and at two locations of conventional pavements together with CPB measurements.

The obtained results of conducted measurements were presented in detail in technical report “Final report on the noise measurements on ISO reference surface and on conventional pavements” – TR13-ELANORE-SINTEF-04-(2022) [5].

REFERENCES

[1] Regulation No 117 of the Economic Commission for Europe of the United Nations (UNECE) — *Uniform provisions concerning the approval of tyres with regard to rolling sound emissions and/or to adhesion on wet surfaces and/or to rolling resistance* [2016/1350]
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[2] International Organization for Standardization (ISO): *Acoustics – Method for measuring the influence of road surfaces on traffic noise – Part 2: The close proximity method*, ISO 11819-2:2017, Geneva, Switzerland, 2017

[3] International Organization for Standardization (ISO): *Acoustics – Specification of test track for measuring sound levels emitted by road vehicles and their tyres.* ISO 10844: 2021, Geneva, Switzerland, 2021

[4] International Organization for Standardization (ISO): *Acoustics - Measurement of the influence of road surfaces on traffic noise - Part 3: Reference tyres,* ISO/TS 11819-3:2017, Geneva, Switzerland, 2017

[5] Berge T., Mioduszewski P., Bohatkiewicz J., Hałucha M.: *Final report on the noise measurements on ISO reference surface and on conventional pavements.* ELANORE Technical Report TR34-ELANORE-SINTEF-04 (2022)