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Measurement of the Thickness of the Paint Material on Six Tile Samples from the Inner Surface of an Olympia Odos Motorway Tunnel Using Acoustic Microscopy

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Method

The ultrasonic waves are emitted from the transducer into the coated — painted surface of the tunnel — substrate through the used coupling material (hydrogel/water). The ultrasound propagates from the transducer to the painted substrate and consecutively to the various layers of the paint. Echoes are generated by the various interfaces between the different kinds of materials with different mechanical properties. The echoes are received by the transducer at different time instances, which are proportional to the distance between the interfaces and the transducer. The signal that contains the echoes is called a-scan signal (**fig. 1**). From the Time of Flight (TOF) of two successive echoes, generated by the surface of the coating (A) and the interface between the coating and the substrate material (B) the thickness can be calculated (**fig. 1**). This is a real-time measurement, lasting a few seconds in the case that a set of measurements is acquired in a region of interest of the sample.

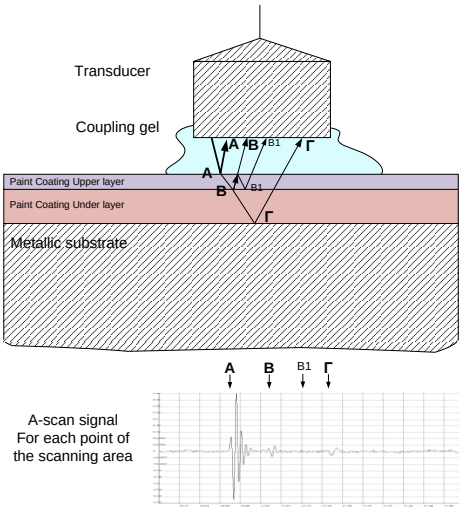


Figure 1 *Kind of measurements per point.*

The value of the propagation speed of the ultrasounds in the coating material is required in order to determine the thickness of the paint layer applied on the metallic substrate. For this reason, a reference film of the coating was created (**fig. 2**). This was prepared by spraying the painting solution on a metallic substrate. The thickness of this reference film was 507.4μm (both layers), measured using the Mitutoyo thickness micrometer with accuracy of 1μm, traceable and certified according to the ISO 17025 standards (tab. 1 & fig. 2).

MEASUREMENT	SUBSTRATE (mm)	SUBSTRATE WITH COATING (mm)	THICKNESS (mm)
1	0.522	1.075	0.553
2	0.514	1.041	0.527
3	0.492	0.885	0.393
4	0.493	0.931	0.438
5	0.536	1.042	0.506
6	0.526	1.065	0.539
7	0.517	1.026	0.509
8	0.512	1.076	0.564
9	0.512	1.006	0.494
10	0.516	1.067	0.551
Average	0.514	1.021	0.5074
Average in μm			507.4

Table 1 *10 measurements of the thickness of sample 0 using the Mitutoyo thickness micrometer with accuracy of 1μm, traceable and certified according to the ISO 17025 standards.*

Then, ten measurements of the TOF in this reference film were taken from both the layers in **fig. 3**. The acoustic speed of the material is calculated as follows:

$$c = \frac{2 \times s}{t} \quad (1)$$

where s is the thickness and t corresponds to the time of flight (TOF) in the material.

Using equation (1), the acoustic speed of the coating was calculated equal to $C_{un} = 3442,9$ m/sec with standard deviation 255,17 m/sec for the paint of the whole layer including the upper and the under layer.

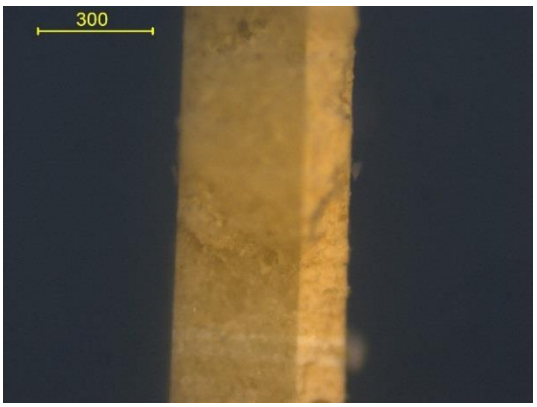


Figure 1 *Optical microscopy image of the reference step sample for the measurement of the acoustic velocity of the two paint materials.*

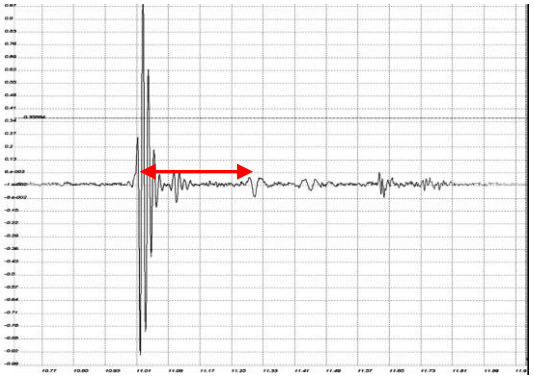


Figure 2 *The a-scan with the echoes of the upper paint material of a thickness of 507μm obtained using the reference painting film (x axis (time in μs, Y axis amplitude of the echo in Volts).*

Measurement of the thickness of the paint layers

Based on the measurement of the acoustic wave propagation speed in the paint layer, and the measurements of the TOF of the wave propagation in the samples (**fig. 1**), the thickness of the paint layer is measured – calculated (**tab. 2**). After the initial examination of the painting response under ultrasonic excitation pulse in the frequency range of 175MHz two layers of paint were revealed (**fig. 4**). This is also confirmed by the provider. In this report the overall thickness of the two layers is measured-calculated.

	Mean value	Standard Deviation
S1	415.73	2.407
S2	321.29	3.037
S3	274.91	1.672
S4	430.64	16.708
S5	322.72	8.813
S6	353.88	10.353
Average value	**353.19**	**7.17**

Table 2 *Thickness measurement of the paint layer of all the Samples (aggregated), according to ISO17025 and EN14127 standards.*

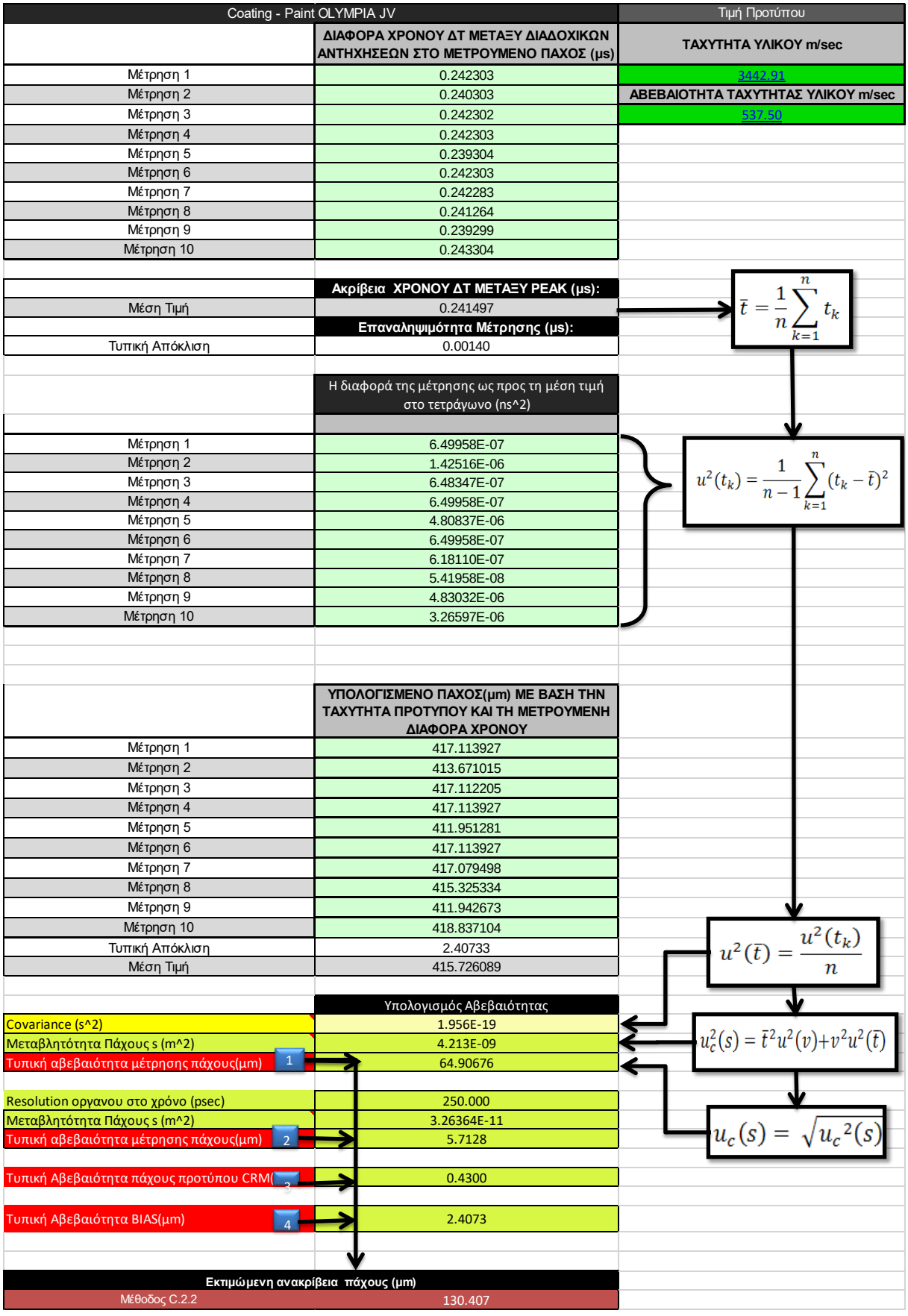
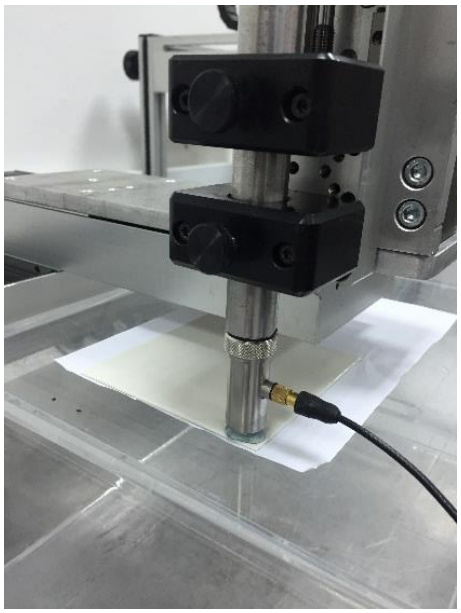


Figure 4 *Thickness measurement of the paint layer of Sample 1, according to ISO17025 and EN14127 standards.*

Areas of the tunnel from which the tiles were acquired according.



Scanning of the paint layers on the tiles using the acoustic microscope infrastructure.