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**Results of ante and post operam
phonometric and traffic flow monitoring**

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1. Abstract

One of the aims of the LIFE MONZA Project is reducing noise average levels within Libertà neighbourhood in Monza, a city in the northeast of Italy. The applied interventions for this purpose are both bottom-up and top-down actions. In the following essay, results obtained from the implementation of top-down actions are reported. The latter consist of the definition of a Limited Traffic Zone – no entry to heavy vehicles –, the implementation of measures for speed limitation in vehicles and, the replacement of the tarmac with low-noise asphalt.

2. Top-down actions

Top-down actions consist of the spreading of new low-noise asphalt and the ban on access to heavy vehicles in the street 'Viale della Libertà'. For the first action, the optimized weaving dense-graded typology was chosen, and the process was concluded in September 2018 (Figure 1). This typology is nonporous and guarantees a noise reduction of 3-4 dB(A) in flowing traffic conditions, moreover, its efficiency lasts for at least 5 years. An analogous road surface was designed and tested by Regione Toscana within the project "Progetto Leopoldo" [1]. This latter intervention was carried out in some provincial roads characterized by flowing traffic conditions. Concerning the ban on access to heavy vehicles in the street 'Viale della Libertà', the resolution n.223/2018 of the City Council, established the threshold of 3.5 tonnes.

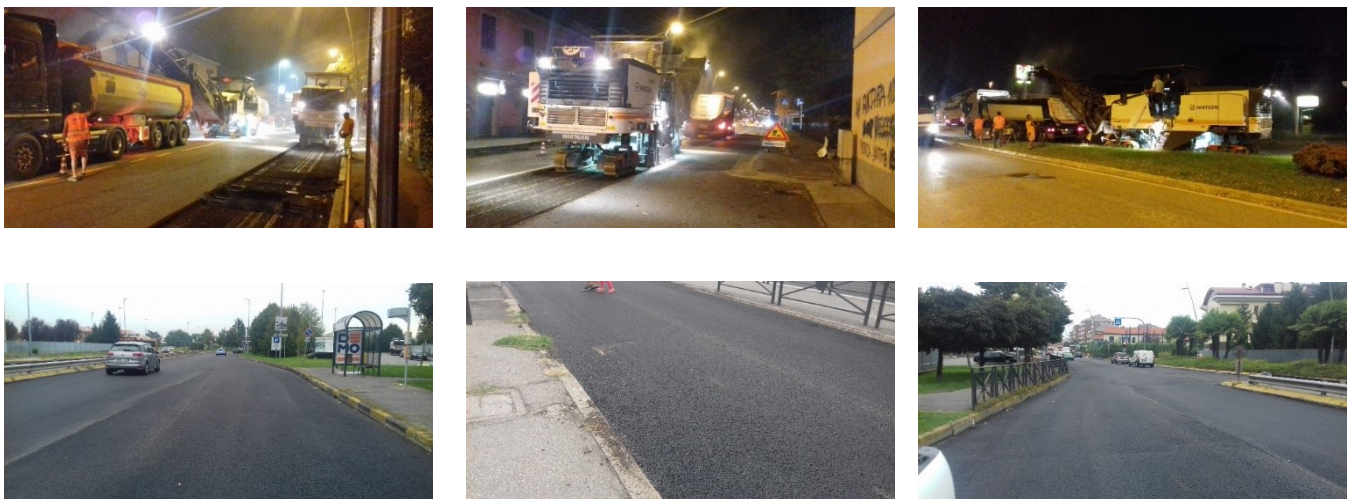


Figure 1 – Spreading of low noise asphalt.

3. The acoustic monitoring within the pilot area

The acoustic monitoring within the pilot area was planned in both the ante-operam and post-operam scenario, using both the measurement chains (class 1) and a new low-cost monitoring system developed within Life MONZA Project.

Monitorings with measurement chains in class 1 were provided for weekly measurements and accompanied by traffic measurements during spring/summer and autumn/winter. These measurements include weekly monitoring campaigns with phonometric control units as well as one-hour short-term measures (SPOT). Whereas, concerning the low-cost sensor network, ten sensors were installed, three of which in correspondence of 'Viale Libertà' and the others were arranged within the neighbourhood. The above-mentioned sensors monitor noise from June 2017 continuously. Technical specifications are listed in [2].

4. Achievements

In this paragraph, a comparison between average noise levels measured with the low-cost system and with the traditional system is presented. Both the results ante-operam and post-operam are studied (Paragraph 4.1). Moreover, achievements in the reduction of average noise levels, following the spreading of low-noise asphalt on Viale della Libertà, were measured with class 1 system and explained (Paragraph 4.2). In the end, the reduction of traffic flow between light and heavy vehicles was considered (Paragraph 4.3).

4.1 Comparison between results achieved with the low-cost system and class 1 system

In Table 1 results are listed. They are achieved ante and post-operam with the low-cost system and class 1 system, in the same week of monitoring. The results of noise monitoring, achieved during the post-operam measurements, show an equal and constant difference of about 3 dB, between sound pressure levels measured with the low-cost sensor and the class 1 system in all the analysed periods (*day*, *evening*, *night*). The above-mentioned difference is explained by microphones' different position: one on the façade of the Civic Center building (low-cost sensor), the other on the roof of the same building (class 1 system). On the other hand, measurements carried out in November 2017, show a difference of 3 dB only during the *night*, whereas during the *day* and the *evening* differences are more emphasized. This latter aspect may be explained as the low-cost sensor was arranged close to activities. In the light of these observations, results achieved during the *day* and the *evening* are not used for the results' comparison (Table 2).

Table 1 - Results achieved with the low-cost system and class 1 system.

	Period	L _{day} (6 a.m. - 8 p.m.) [dB(A)]	L _{evening} (8 p.m. - 10 p.m.) [dB(A)]	L _{night} (10 p.m. - 6 a.m.) [dB(A)]
Class 1 system	Nov-17	59.5	58.8	56.5
Low-cost sensor	Nov-17	64.6	62.5	59.2
Difference		5.1	3.7	2.7
Class 1 system	Jan-19	57.5	53.7	50.3
Low-cost sensor	Jan-19	60.4	57.0	53.0
Difference		2.9	3.3	2.7

Table 2 - Results achieved with the two systems for ante-operam and post-operam monitoring.

	Period	L _{day} (6 a.m. - 8 p.m.) [dB(A)]	L _{evening} (8 p.m. - 10 p.m.) [dB(A)]	L _{night} (10 p.m. - 6 a.m.) [dB(A)]
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Class 1 system	Nov-17	59.5	58.8	56.5
	Jan-19	57.5	53.7	50.3
Difference		2	5.1	6.2
Low-cost sensor	Nov-17			59.2
	Jan-19			53.0
Difference				

4.2 Results achieved with traditional measurement system method

A comparison between the monitoring activity during the summer and the winter in the ante-operam (November 2017, May 2017) and post-operam (May 2019, January 2019) intervals was conducted in terms of noise levels, which were measured by the sensor positioned in the street 'Viale della Libertà'. This comparison was possible thanks to the results achieved during the measurements' campaign conducted using traditional measurement system (Class 1 system).

Concerning the average weekly levels, Table 3 shows the levels measured during the four measurements' campaigns, two of which during the winter and two during the summer (ante-operam and post-operam). In Table 4, the average reduction of sound pressure levels - measured ante-operam and post-operam - is displayed. It is 2,5 dB(A) during the *day* [D], 4,9 dB(A) during the *evening* [E] and 5,9 dB(A) during the *night* [N].

Table 3 – Measured levels achieved during the weekly monitoring's campaign ante-operam and post-operam.

	month-year	Noise Indicator L_{eq} dB[A]		
		D	E	N
ANTE OPERAM	May-2017	59,2	58,5	55,8
	Nov-2017	59,5	58,8	56,5
POST OPERAM	Jan-2019	57,5	53,7	50,3
	May-2019	56,2	53,8	50,2

Table 4 – Noise reduction in dB[A] achieved during three reference periods (winter, summer and mid-season campaign)

Nov17 / Jan19 dB[A]			May17 / May19 dB[A]			Average difference Post operam - Ante operam dB[A]		
DAY	EVE	NIGHT	DAY	EVE	NIGHT	DAY	EVE	NIGHT
-2,0	-5,1	-6,2	-3,0	-4,7	-5,6	-2,5	-4,9	-5,9

4.3 Reduction of traffic flow in 'Viale della Libertà'

Concerning the traffic flow data, elaborated thanks to the control units, it is possible to notice a good correspondence between the summer and the winter measurements' campaigns, both in the daily and nightly conditions. A smaller correspondence is observed during the *evening*, but it cannot be considered significant as it interests a span of 2 hours.

The difference between the data measured in the ante and post-operam campaigns, shows a spread and coherent reduction of traffic flow of approximately 5%, referring to the so-called TGM. TGM stands for average daily traffic. The percentage is even higher with reference to heavy vehicles: about 17% comparing winter data and 29% comparing summer data.

This outcome proves that the attenuation is due to the actions carried out for the optimization of 'Viale della Libertà'.

Concerning the average weekly levels, the traffic flow data and the relative percentage reduction are shown in Table 5. The data were measured during the four measurements' campaigns, two of which during the winter and two during the summer (ante-operam and post-operam). In Table 6, traffic flow concerning heavy vehicles and the relative percentage reduction are displayed. Traffic flow is measured during the above-mentioned four measurements' campaigns

Table 5 – Average daily traffic flow measured during the weekly monitoring's campaign ante-operam and post-operam.

Ante and post-operam comparison of traffic flow (average daily traffic)									
	ANTE OPERAM			POST OPERAM			ANTE/POST		
TGM	May 2017	Nov 2017	AVERAGE	Jan 2019	May 2019	AVERAGE		Nov 2017/ Jan 2019	May 2017/ May 2019
D	12781	13519	13150	12675	11774	12225	D	6,2%	7,9%
E	1272	1537	1405	1529	1326	1428	E	0,5%	-4,2%
N	1607	1757	1682	1772	1721	1747	N	-0,9%	-7,1%
TOT	15659	16813	16236	15976	14821	15399	TOT	5,0%	5,4%

Table 6 – Heavy vehicles' traffic flow measured during the weekly monitoring's campaign ante-operam and post-operam.

Ante and post-operam comparison of heavy vehicles' traffic flow									
	ANTE OPERAM			POST OPERAM			ANTE/POST		
HEAVY VEHICLES	May 2017	Nov 2017	AVERAGE	Jan 2019	May 2019	AVERAGE		Nov 2017/ Jan 2019	May 2017/ May 2019
D	217	180	198	146	155	150	D	-19%	-29%
E	11	9	10	11	8	10	E	28%	-23%
N	14	9	12	8	7	8	N	-17%	-46%
TOT	241	198	219	164	170	167	TOT	-17%	-29%

5. Conclusions

In conclusion, the actions carried out in 'Viale Libertà' provide excellent results in terms of noise reduction from road traffic. Particularly, the class 1 system for measurements shows a reduction of sound pressure levels of 2 dB(A), measured during the *day* between ante and post-operam. During the *night* and the *evening*, the reduction reaches 5-6 dB(A).

Concerning the traffic flow data, the introduction of a Limited Traffic Zone – no entry to heavy vehicles – involved a significant reduction in terms of vehicles' transit: 17% during the winter campaign and even 30%

during the summer one. Light vehicles' traffic flow is decreased as well: the data show a reduction of about 5% between ante and post-operam.

6. Acknowledgements

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7. References

[1] D.G.R. Toscana n. 157, *Risultati del progetto Leopoldo. Conoscenze acquisite sulle pavimentazioni stradali e linee guida regionali*, March 11th, 2013.

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