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ENVIRONMENTAL EFFECTS FROM VIBRATION EMITTED FROM THE OPERATION OF URBAN HIGHWAYS: A MEASUREMENT CAMPAIGN AT ATHENS RING MOTORWAY NETWORK

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Abstract

In order to record and evaluate the vibration and ground noise levels emitted from road traffic during operation of “Attiki Odos” (Athens Ring Motorway) in the most unfavourable road section (as far as the traffic flows and the near by sensitive urban environment is concerned), a full monitoring program [1] was executed regarding the recording and evaluation of the vibration velocity at the nearest to the road edge residence buildings in 5 representative locations along the network. The selection of these locations was made in accordance to the prevailing land use conditions the relevant "hard" and "soft" soil conditions, and the distance from the road edge, so that the most unfavourable conditions of vibration velocity diffusion were ensured, based on the road system's operation data.

1. INTRODUCTION –VIBRATION CRITERIA

The “**Attiki Odos**” motorway i.e. the “Elefsina – Stavros – Spata Airport & West Peripheral Ymittos Avenue” called also the “Athens Ring Motorway network” presents the following main technical characteristics:

- Total length = 65,20 Km. - Service roads network = 31,3 Km. - Secondary road network = 150 Km.
- Interchanges = 32 & Bridges = 104
- Tunnels = 38 & Rail bridges = 37
- Pedestrian passerelles = 15
- Tunnels & C&C = 63 (total length of 15,64 Km.)
- Services surfaces = 122.000 m²
- Inter urban railway line & Urban metro network in the middle island (see photo 1)



In Greece the most usual vibration & ground borne criteria (both indices & limits) for construction & operation phases of transportation infrastructure (road & railway networks) are presented in tables 1 & 2 hereafter:

Table 1. Max permissible vibration levels suggested in Greece according “CHABA Report NTIS AD-A044384” for construction phases of major transportation infrastructure projects [2]

	SUGGESTED VIBRATION LIMITS	
	Acceleration rms ⁽¹⁾	Vibration velocity ⁽²⁾
Residential & other buildings	0,5 έως 1 m/sec²	13 έως 28 mm/sec
Monuments & Sensitive buildings	0,05 m/sec²	1,3 mm/sec

⁽¹⁾ H.E. Von Gierke NTIS Report AD-A044384

⁽²⁾ for frequencies >10 Hz vibration velocity in mm/sec = 28.4 * acceleration rms (m/sec²)

The most severe limit - as per various international standards for extremely sensitive buildings - is set at 0.08 - 0,12 mm/s. In Greece the most severe implementation of such a criterion was enforced in Athens Metro construction for the protection of the New Acropolis Museum & the archaeological area of Keramikos with max respective vibration limits of 0.16 mm/s up to 0.2 mm/s. During operation and especially in combined road & railway transportation infrastructure such as the “Attiki Odos” network the max permissible vibration levels were set (according to the relevant environmental terms) as follows:

- 0.5 mm/s for residential buildings &
- 0,2 mm/sec for archaeological areas

2. MEASUREMENT'S MONITORING SETUP

The vertical vibration velocity fluctuation was recorded and analyzed in both time & frequency domain in the 5 respected locations (presented in table 2 and the relevant maps hereafter) using:

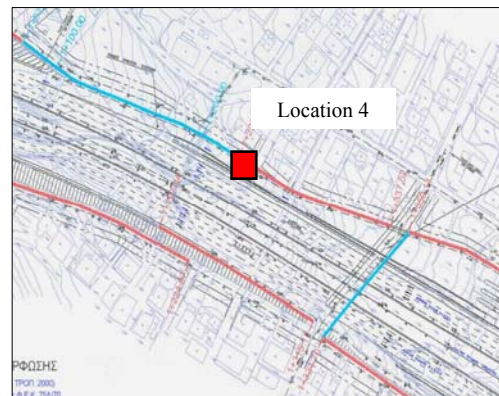
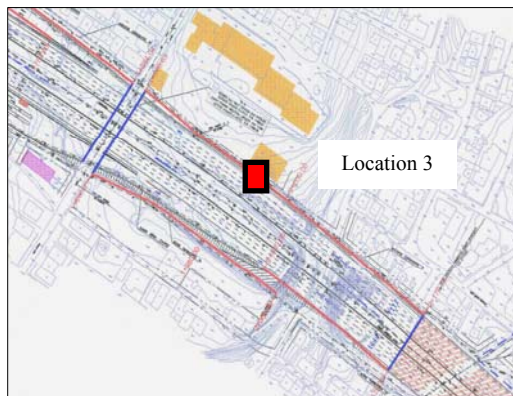
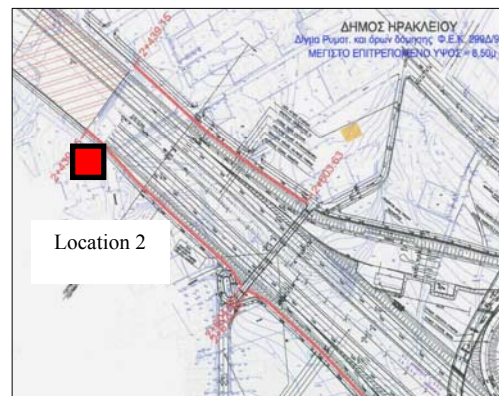
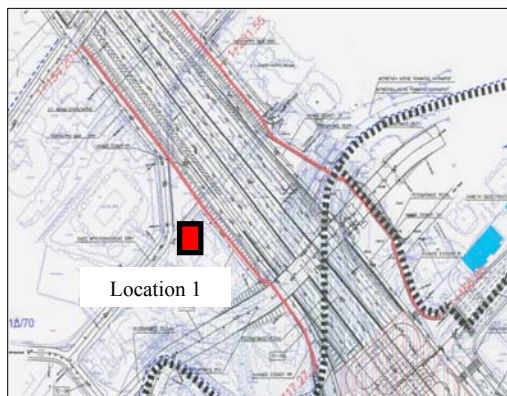
- sensitive 731 A accelerometers and power supplier systems, the WILCOXON's P31 amplifiers and a TEAC RD-130TE digital recorder. The sensors' sensitivity is 10 V/g, while the amplifier has 450 Hz filters,
- a B&K's 2131 frequency analyzer for the analysis of the recorded levels of the vibration velocity (reference: 10-9 m/sec) at the frequency breadth from 10Hz till 200 Hz,
- a converter from analogue to digital and suitable anti-aliasing filters, so that the digitalisation of signals could be achieved. The sampling speed was 1 kHz.

With the above extended monitoring program a complete file of recordings was established, using the project's road traffic as the main and practically the only important source of excitation rendering possible to fully investigate any repercussion in the quality of the human

constructed environment and the sensitive land uses and possible exceeding of permissible limits, as well as to determine dominant frequencies possibly influenced by the operation of the road transportation system in question.

Table 2. Measurement's Location & relevant Map areas

Location	Motorway section	Adjacent land use
1	A11	Residential area
2	A09	Residential area
3	A08	School
4	A08	Residential area
5	A08	School



3. RESULTS & CONCLUSIONS

The relevant results are presented hereafter as follows:

- in Figures 1 to 5 the 1/3 octave band analysis of the vibration velocity in dB ref 10⁻⁹ for each location,
- in Figures 6 to 10 the relevant time histories of the recorded vibration velocity in mm/sec for each location.
- In table 3 the relevant maximum vibration velocity in z axis and the corresponding ground borne noise level in dB(A) –in the range from 10Hz till 200 Hz – is also calculated and presented

Table 3. Max vibration velocity (z axis) & ground borne noise level at all locations

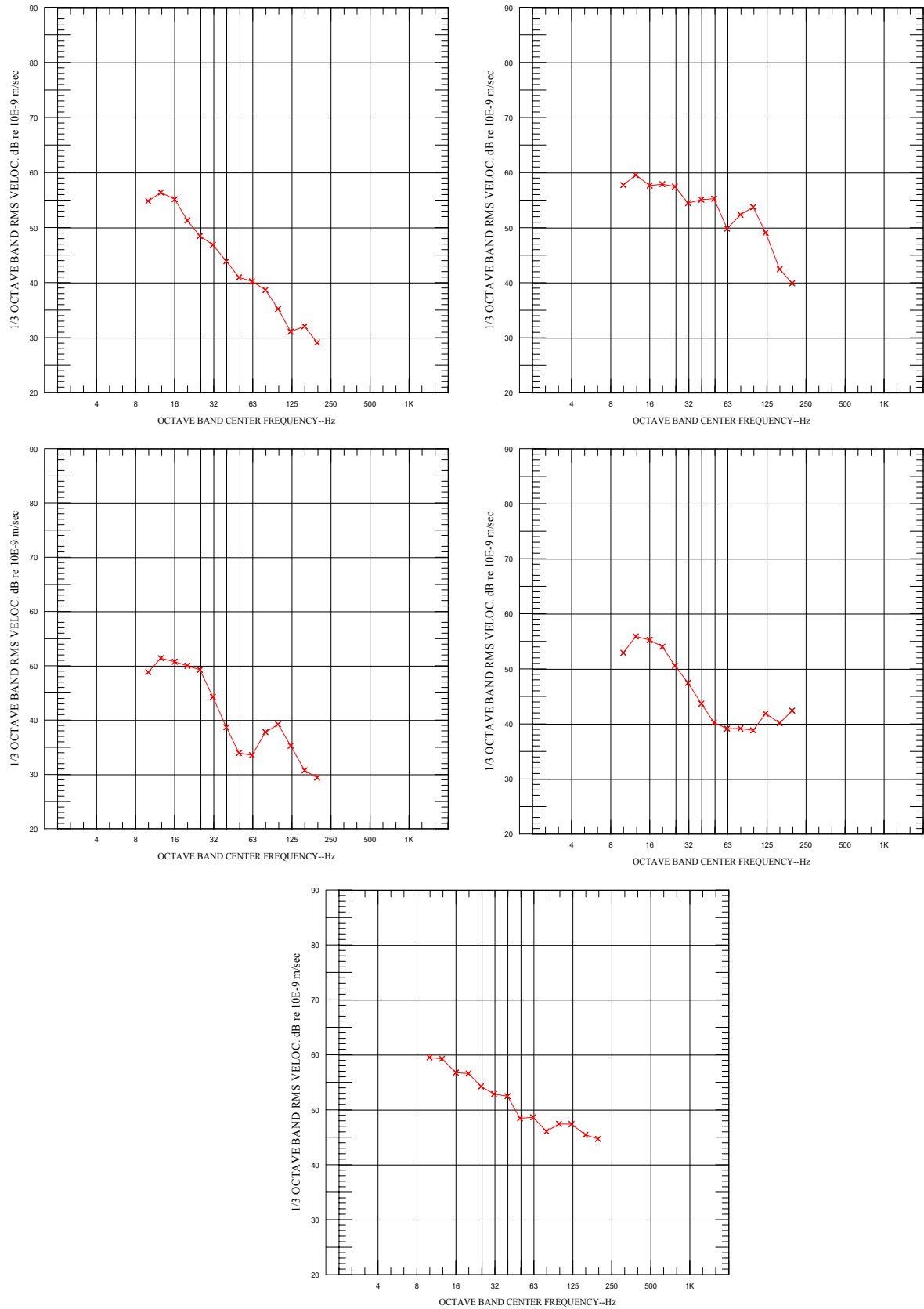
Location	Vibration velocity (mm/sec)	Ground borne noise level dB(A)
1	0.0086	11,5
2	0.0035	17,7
3	0.0150	11,5
4	0.0330	14,1
5	0.1000 ^(*)	16,9

^(*) Heavy lorry passage in the service road (Motorway main corridor levels range : 0,03-0,05 mm/sec)

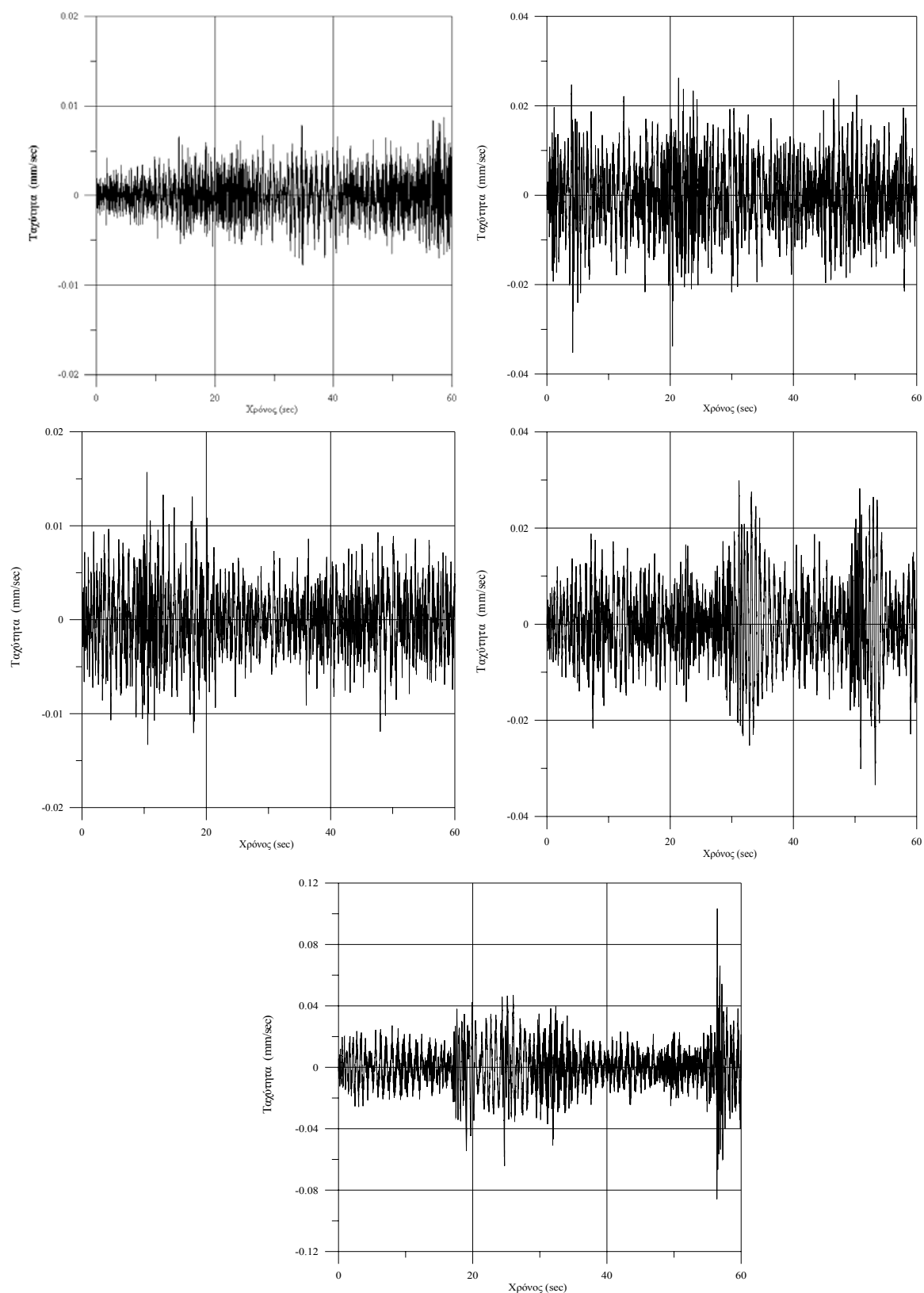
Based on the results presented hereafter, all vibration & ground borne levels from “Attiki Odos” operation measured in all locations were founded extremely low and within the above presented criteria & limits with the exception of the location 5 where heavy lorry passage in the service road were recorded in levels above the common human sensitivity criterion of 0,08 mm/sec but still below environmental limits as described above.

REFERENCES

- [1] Prof. C. Vogiatzis (TT&E Consultants): *Attiki Odos Vibration Monitoring program from road network operation*, Attiki Odos 2004-2006
- [2] Von Gierke, H.E.: *Guidelines for Preparing Environmental Impact Statements on Noise, Committee on Hearing, Bioacoustics, and Biomechanics Assembly for Behavioural and Social Sciences* (CHABA), Working Group 69, For : National Research Council, NTIS AD A044384, 1977.



Figures 1 & 5 : 1/3 octave band analysis of the vibration velocity in dB ref 10-9 for each location



Figures 6 & 10 : Time histories of the recorded vibration velocity in mm/sec for each location