
The Interior Comfort of Buildings When Generating Structural Noise from the Turbulent Flow of Air from the Ventilation Conditioning Systems That Equip the Public Buildings

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Abstract: - This study analyzes the mechanisms underlying the generation and propagation of structural noise induced by turbulent airflow in HVAC installations, as well as its overall impact on indoor comfort. It presents the main noise sources, structural transmission paths through building components, and technical mitigation solutions to reduce adverse effects on occupants. Furthermore, this paper presents two case studies to investigate the influence of turbulent-airflow-induced structural noise on occupant acoustic comfort and identify the factors governing its propagation within the building structure. The applied research methodology is based on characterizing noise sources in ventilation systems, evaluating turbulent flow regimes, and analyzing vibration and structural noise propagation through structural elements. These assessments form the foundation for proposing a specialized periodic evaluation procedure. The results, together with the evaluated sound insulation methods (Case Study No. 1), highlight the direct relationship between HVAC operational parameters, turbulence intensity, and perceived noise levels in occupied spaces. Ultimately, the study demonstrates that optimizing flow regimes and adopting appropriate structural measures can significantly mitigate acoustic discomfort. The novelty of this work lies in its integrated approach to the interaction among turbulent flow, structural noise, and indoor comfort in public buildings, emphasizing the decisive impact of HVAC operational parameters on building acoustic performance.

Keywords: - acoustic comfort, structural noise, vibrations, turbulent flow, HVAC systems, public buildings, harmful noise to humans.

1. INTRODUCTION

Noise levels in public buildings are strongly influenced by Heating, Ventilation, and Air Conditioning (HVAC) installations. Turbulent airflow occurring within ducts, flow control devices, and mechanical equipment generates sound pressure fluctuations that propagate through the structural elements of the building.

Recent scientific literature has investigated the mechanisms of noise generation within HVAC systems, the propagation of acoustic waves through ductwork, and the effectiveness of various noise attenuation strategies, including sound attenuators,

sound-absorbing materials, and optimized ventilation network geometries [1-3].

Although these contributions have significantly advanced understanding of aeroacoustic phenomena, most studies treat turbulent airflow, airborne noise, and structural vibrations in isolation, lacking an integrated framework to evaluate their combined impact on indoor acoustic comfort [4].

Consequently, a critical research gap persists regarding the correlated evaluation of air turbulence effects on structural noise generation and indoor acoustic comfort in public buildings, as well as the identification of specific HVAC operating parameters that most significantly govern these phenomena [5], [9,10].

Turbulent flow regimes occur frequently in ventilation systems due to high airflow velocities, thermal gradients within conveyed air streams, sudden cross-sectional changes altering duct velocity distributions, and local flow disruptions caused by elbows, dampers, or distribution grilles.

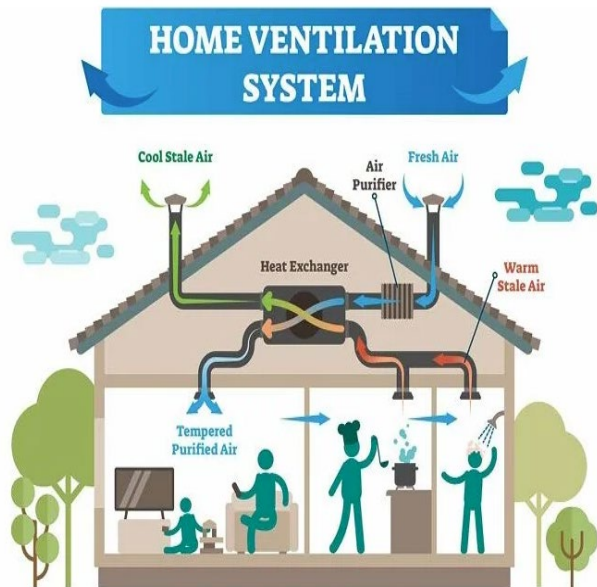


Figure 1. General representation of the factors that can generate turbulent airflow and noise in HVAC duct systems

Within this context, the present study proposes an integrated analytical approach to evaluate the interaction among turbulent flow, structural noise, and indoor comfort. The novelty of this work resides in the simultaneous evaluation of these interrelated phenomena and in clarifying the impact of HVAC operating parameters on the noise levels experienced within occupied spaces. Furthermore, this research contributes to the field by establishing technical recommendations for the design, configuration, and operation of ventilation and air-conditioning systems aimed at mitigating structural noise and enhancing occupant comfort [18-20].

Regarding the broader thematic scope, international literature provides substantial theoretical and empirical research concerning the prediction of flow-generated noise from HVAC components [21, 22, 25, 26]. Building upon these foundational sources, this paper carries out a comprehensive investigation into noise generation in mechanical ventilation systems.

In addition, previous technical studies have investigated flow-induced noise and vibration in axial fans [4], general noise control strategies in buildings [5], and comprehensive overviews of noise control and HVAC acoustics [6]

1.1. Environmental Regulations and Best Practices, Standards Driving Green Development

Driven by growing environmental awareness, global regulatory frameworks governing industrial facilities, such as asphalt mixing plants, have become increasingly stringent.

For instance, under U.S. EPA standards, particulate matter emission limits for asphalt production have been reduced to 0.03 pounds per ton of finished product, mandating the installation of continuous emission monitoring systems. Similarly, national frameworks such as China's "Comprehensive Emission Standards for Air Pollutants" and specific pollutant emission standards for the asphalt industry have enforced strict operational thresholds.

Concurrently, local authorities have enacted specialized environmental policies tailored to regional conditions, including environmental protection zones and restrictions on high-polluting fuels. In response to these mandates, the industry has adopted best practices such as achieving ultra-low emissions through green technology upgrades, implementing ISO 14001 environmental management systems to standardize operations, conducting regular staff training, and maintaining transparency with the public.

2. SPECIFIC TECHNICAL REQUIREMENTS AND REGULATED PARAMETERS

2.1. The Environmental Impact of Asphalt Plants

Asphalt mixing plants produce substantial operational noise (typically ranging from 75 to 110 dB), originating from mechanical equipment such as mixing drums, exhaust fans, burners, pneumatic gates, and material conveyance systems. Mitigating these acoustic emissions requires targeted sound insulation and mechanical adjustments throughout the facility [30-32].

Against the backdrop of rapid global infrastructure expansion, asphalt remains a primary material in road construction. Consequently, asphalt mixing plants are subject to intense scrutiny regarding their environmental footprint, encompassing air quality, water resources, noise pollution, and carbon emissions. This section examines the environmental impact of asphalt mixing plants, reviews current mitigation practices, and outlines future trends toward green asphalt production.

2.2. Overview of Asphalt Mixing Plants: Operating Principles and Type Differences

An asphalt mixing plant is a specialized industrial facility that heats and blends aggregates (such as sand and gravel) with asphalt binder in precise proportions to produce asphalt mixtures that meet specific engineering standards. The operational workflow includes raw material storage, drying, heating, screening, volumetric batching, and mixing.

Technologically, asphalt plants fall into two primary categories: batch-type mixing plants and drum-type mixing plants, each presenting distinct environmental operational characteristics:

- **Batch-type plants** operate on a discrete batching cycle, where aggregates are dried and heated prior to entering the mixer to be blended with asphalt. Although this sequential process facilitates precise mix design control, it tends to produce concentrated particulate and exhaust emissions during heating.
- **Continuous drum-type plants** combine drying and mixing within a single rotating drum. While this process generally uses less energy, it distributes exhaust emissions more continuously, complicating collection and localized treatment.

Understanding these operational differences is essential for evaluating environmental impacts and implementing effective acoustic and emission control strategies.

2.3. Air Pollution: Sources and Control Technologies

Air emissions represent a primary environmental concern in asphalt production. Aggregate heating and binder blending generate air pollutants, including particulate matter ($PM_{2.5}$, PM_{10}), volatile organic compounds (VOCs), carbon monoxide (CO), and nitrogen oxides (NO_x). In the presence of sunlight, VOCs and NO_x undergo photochemical reactions contributing to ground-level ozone formation, while fine particulate matter poses respiratory health risks to plant personnel and surrounding communities.

Deploying integrated air pollution control technologies significantly improves the overall environmental performance of asphalt manufacturing facilities.

2.4. Noise Pollution: Sources, Impacts, and Noise Reduction Solutions

Operational noise in asphalt plants primarily stems from heavy machinery, including crushers, drying drums, draft fans, and front-end loaders. Sustained operational sound pressure levels frequently range between 85 and 100 dB, significantly exceeding standard residential daytime

thresholds (typically 55 dB). Prolonged exposure to high noise levels can cause noise-induced hearing loss among workers and disrupt sleep, stress, and anxiety in neighboring communities.

To mitigate acoustic impact, industry standards mandate a combination of structural and operational noise control measures:

- **Equipment Selection & Isolation:** Prioritizing low-noise equipment designs, fitting high-noise machinery with sound-isolating enclosures, and mounting rotating equipment on vibration isolators.
- **Facility Layout Optimization:** Grouping noise-intensive operations away from property boundaries and installing acoustic barriers along transmission paths.
- **Operational Scheduling:** Restricting high-noise operations during nighttime hours to minimize community disturbance.

Implementing these integrated measures can reduce boundary noise levels by **20 to 30 dB**, significantly improving the surrounding acoustic environment.

In accordance with Romanian normative standards [13], [27], [28], ambient noise levels are evaluated using the A-weighted equivalent continuous sound pressure level $L_{Aeq,T}$ calculated as:

$$L_{Aeq,T} = 10 \log_{10} \left(\frac{1}{T} \int_0^T \left(\frac{p_A(t)}{p_0} \right)^2 dt \right) \quad (9)$$

where: T is the measurement duration interval; $p_A(t)$ are A-weighted instantaneous sound pressure; p_0 is the reference sound pressure (20 μPa).

Table 1. Maximum permissible indoor noise levels for different building types and room destinations during day and night occupancy regimes

Type of building	Room	Day [dB(A)]	Night [dB(A)]
Housing	Living room	35	30
	Bedroom	30	25–30
	Kitchen	40	—
	Bathroom	40	—
Offices	Individual office	35–45	—
	Meeting rooms	30–35	—
Education	Classrooms	30–35	—
	Amphitheater	25–30	—
Hospitals	Lounges	30	25–30
	Operating rooms	~25	~25
Hotels	Rooms	30	25–30

Notes:

1. The values listed in Table 1 refer to continuous equivalent noise levels (L_{Aeq}).

2. Nighttime is defined as the rest interval, typically, between 22:00 and 06:00.
3. Specified thresholds apply to noise generated by building service installations and external noise transmitted indoors.
4. For impulsive or tonal noise components, standard penalties/corrections must be applied.

Pursuant to applicable regulatory frameworks [13], Table 1 summarizes maximum permissible indoor noise levels across various building categories and room destinations for daytime and nighttime conditions.

The subject of this paper—evaluating building indoor acoustic comfort under structural noise induced by turbulent airflow in public facility HVAC systems—has been addressed conceptually in general acoustic literature [7-9]. The methodology presented herein aligns with normative requirements based on empirical in-situ measurements.

3. EXPERIMENTAL EQUIPMENT USED

The methods used were in accordance with the standardized requirements for public buildings [13], [29] as well as for industrial buildings [12].

The outdoor noise level was measured in accordance with the testing procedures specified in the applicable standards [12], [15-17].

The measurements that were carried out in two different case studies, carried out in four case studies, were carried out with the following equipment used for acoustic determinations:

- Integrating sound level meter/ Brüel&Kjær-Denmark/ 2250/ 2575704 series with 1/2" condenser microphone/ Brüel&Kjær-Denmark/ 4189/ 2573596 series/ $U = 0.3$ dB;
- Acoustic calibrator/ Brüel&Kjær-Denmark/ 4231/ 2574144 series / $U = 0.3$ dB.

The experimental methodologies employed in this investigation strictly adhered to standardized provisions for public [13], [29] and industrial facilities [12]. We conducted external sound level measurements in accordance with standard testing procedures [12, 15-17].

Acoustic determinations across the evaluated case studies were performed using the following calibrated instrumentation:

- **Integrating Sound Level Meter:** Brüel & Kjær (Denmark), Type 2250, Serial No. 2575704, equipped with a 1/2" condenser microphone, Brüel & Kjær Type 4189, Serial No. 2573596 (Expanded measurement uncertainty $U = 0.3$ dB).
- **Acoustic Calibrator:** Brüel & Kjær (Denmark), Type 4231, Serial No. 2574144 ($U = 0.3$ dB).

3.1. Requirements

Compared with the reference literature [10, 11] and governing boundary noise standards [15], we evaluated the empirical results against building acoustic comfort standards for public interest structures [12, 13] using established practical testing protocols [14].

In 2024, we conducted two measurement campaigns over a 6-month interval to evaluate major noise-generating sources associated with Case No. 1 and Case No. 2, as detailed below.

3.2. Case study no. 1

At the request of an asphalt and asphalt-mixture production company, we conducted acoustic measurements to evaluate noise levels emitted by ventilation ducts, exhaust chimneys, mechanical drive motors, gearboxes, and exhaust fans serving the production facility.



Figure 2. Location of asphalt mixture production plant (background noise measurement context)



Figure 3. Dust extraction fan serving the asphalt production plant [20]

The manufacturing plant is located adjacent to the ring road of a medium-sized city in Romania. The primary noise sources are illustrated in Figures 2 through 6.



Figure 4. Dust exhaust ductwork of the production facility



Figure 5. Exhaust stack for combustion gases from the asphalt plant



Figure 6. Thermal oil boiler and burner assembly

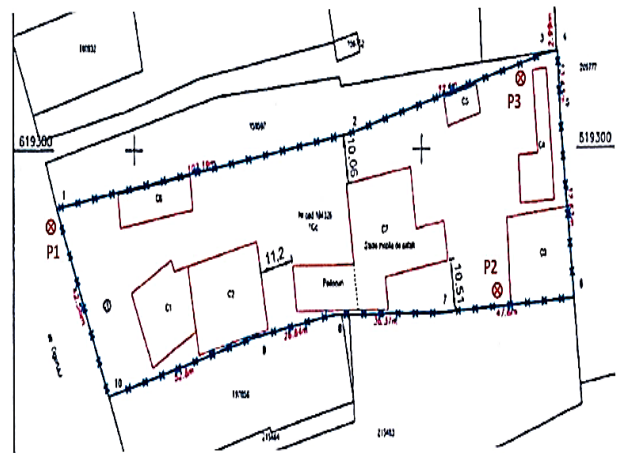


Figure 7. Layout of measurement points P1 and P2 relative to noise sources shown in Figures 2–6

Noise source locations and structural vibration points associated with the facility are highlighted in red.

Based on sound level measurements at sampling points P1 and P2, we derived average operational values across 12 monitoring intervals, as summarized in Table 2.

Table 2. Average noise levels measured over 5-minute sampling intervals across 12 monitoring periods at points P1 and P2 (Figure 7)

No.	Background noise level [dB]	Noise levels	
		Point 1 [dB]	Point 2 [dB]
1	57,6	68,9	72,5
2	58,6	70,63	72,44
3	58,1	70,01	72,35
4	58,1	70,14	72,35
5	58,4	69,73	72,35
6	58,4	69,2	72,36
7	58,6	69,35	72,35
8	58,6	69,32	72,35
9	58,6	69,33	72,33
10	58,6	69,35	72,31
11	58,6	69,25	72,3
12	58,6	69,4	72,25
Average	58,41	69,55	72,35

The measured acoustic data were compiled into an accredited test report, providing the technical basis for a judicial expert assessment required by national regulations.

Evaluating these initial values against legal boundary limits [15], the expert assessment established that operational sound pressure levels exceeded allowable thresholds:

- Residential Boundary Limits: Permissible daytime limit is 55 dB(A); nighttime limit is 45 dB(A).

- **Mixed-Use Boundary Limits (Residential /Commercial):** Permissible daytime limit is 55 dB(A); nighttime limit is 45 dB(A).

To achieve regulatory compliance, a three-stage acoustic mitigation strategy was recommended to the plant operator:

- **Stage 1 (Non-invasive mitigation):** Enhancing direct sound enclosure and acoustic isolation of localized noise sources.
- **Stage 2 (Laboratory optimization):** Constructing a replica duct system under laboratory conditions matching operational parameters to evaluate silence configuration performance.
- **Stage 3 (Invasive mitigation):** Installing specialized duct silencers directly into the operational ventilation network near major sound generation sources.

Approximately six months following the initial baseline survey, the facility owner implemented structural acoustic modifications and requested follow-up measurements to evaluate noise reductions along the exhaust ductwork and equipment.

The acoustic treatments implemented by the operator included:

a) Drive Motor Acoustic Enclosures: Installing dedicated sound-isolating enclosures around electric motors (Figure 8)



Figure 8. Acoustic enclosure installed over the main drive motor of the asphalt station

b) Duct Thermal & Acoustic Lagging: Encapsulating gas and dust exhaust ductwork with high-density mineral wool insulation layers to enhance sound absorption (Figure 9).



Figure 9. Exhaust and hot air ductwork insulated with mineral wool blankets

c) Integrated Sound-Absorbing Enclosures: Erecting acoustic partitions surrounding multi-source assemblies, including drive motors, exhaust turbines, blowers, mechanical gears, and duct manifolds (Figure 10).



Figure 10. Sound-absorbing barrier wall encompassing major mechanical noise sources

d) Perimeter Acoustic Wall with Fog Curtain System: Constructing a 3-meter-high concrete perimeter boundary wall topped with an innovative high-pressure water fog curtain system around the facility perimeter.

This system pressurizes water to 10 bar and discharges it through micro-nozzles, atomizing the liquid into a dense mist/fog curtain that extends 2,5 meters above the wall coping. Oriented inward toward primary noise-generating assets, this combined barrier wall and mist system helps attenuate airborne sound propagation while capturing fugitive dust, smoke, and hot gases (Figure 11).



Figure 11. High-pressure (10 bar) perimeter mist curtain system mounted on the boundary wall

After installing these acoustic insulation solutions, we conducted post-intervention sound pressure level measurements using the same calibrated instrumentation at identical sampling locations (P1 and P2, Figure 7) to ensure full measurement traceability. Table 3 summarizes the post-mitigation acoustic data.

Table 3. Noise levels measured across 12 monitoring intervals following the implementation of acoustic mitigation measures

No.	Background noise level [dB]	Noise levels	
		Point 1 [dB]	Point 2 [dB]
1	57,3	58,9	69,5
2	58,4	60,63	69,4
3	58,2	60,01	69,3
4	58,2	60,14	69,4
5	58,4	59,73	69,4
6	58,3	59,2	69,4
7	58,6	59,35	69,35
8	58,6	59,32	69,35
9	58,6	59,33	69,33
10	58,6	59,35	69,31
11	58,6	59,25	69,3
12	58,5	59,4	69,25
Average	58,36	59,55	69,36

3.3. Conclusions for Case Study no. 1

Comparing the baseline measurements (Table 2) with the post-intervention results (Table 3) yields the trends shown in Figure 12.

Because baseline ambient noise levels (excluding plant operational sources) remained essentially constant across both testing campaigns (~58.4 dB), the net sound pressure level reductions achieved at point P1 and point P2 were 14.4% and 4.1%, respectively.

Analysis of baseline data indicates that the differential between background noise and measured operational sound level at P1 was relatively small (11.1 dB), placing P1 within the near field of distributed facility noise sources. Conversely, at point P2, the baseline differential was higher (13.9 dB), confirming its proximity to a concentrated high-intensity noise source.

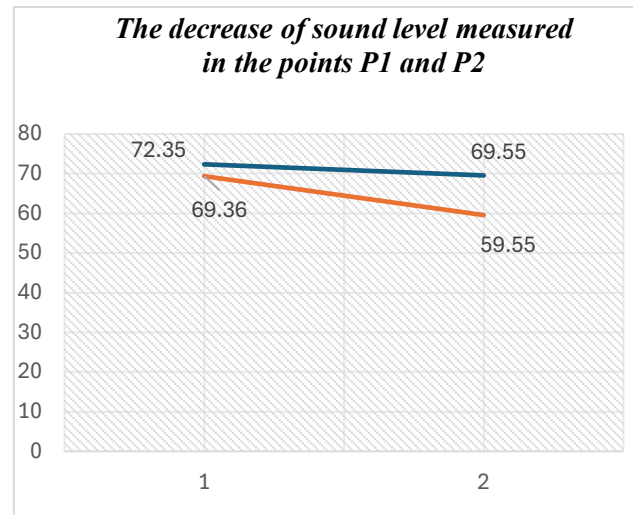


Figure 12. Reduction in average sound pressure levels following acoustic treatment implementation.

Post-intervention data (Table 3) demonstrate that under stable background noise conditions:

- At Point P1, the differential between background noise and total measured sound pressure dropped to just 1.2 dB, corresponding to an average noise level reduction of 10.0 dB.
- At Point P2, the differential between background noise and operational sound pressure was reduced to 9.8 dB, representing an average sound level reduction of 3.0 dB.

These results confirm that the acoustic retrofits yielded a 10 dB noise attenuation at measurement point P1 and a 3 dB attenuation at point P2.

4. HVAC SYSTEM DUCTWORK IN PUBLIC BUILDINGS

In public building applications, sheet metal ventilation ductwork can act as a significant acoustic generator and transmission path, with sound radiation characteristics strongly dependent on duct wall thickness and flow velocity.

Typically, Air Handling Units (AHUs / C.T.A.) are installed on building rooftops, within basements, or inside dedicated mechanical equipment rooms. Standard engineering practice aims to limit interior noise transmission to regulatory thresholds [15]. When operational noise exceeds allowable limits,

technical space soundproofing or AHU relocation becomes necessary.

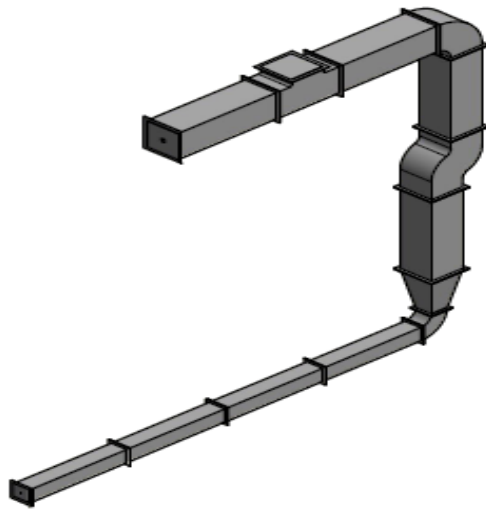


Figure 13. CAD isometric view of the evaluated ventilation duct assembly

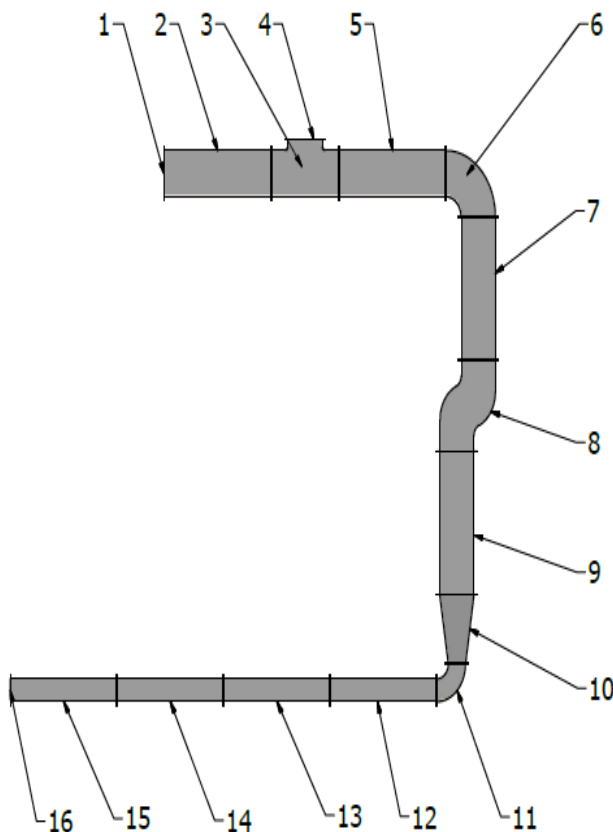


Figure 14. 2D mechanical layout and component callouts of the duct assembly.

To quantify aeroacoustic duct behavior, we conducted an experimental study on a standardized duct assembly section with representative geometric configurations, as illustrated in Figures 13 and 14, and detailed in Table 4.

Table 4. Technical specifications and bill of materials for the experimental ventilation duct section

Position in drawing	Component Name & Structural Specifications	Quantity
1, 4	End cap 400 x 400 mm	2 pcs
2, 5, 7, 9	Straight duct section (400 x 400 mm, length 1200 mm)	4 pcs
3	Equal Tee (400 x 400 mm, length 800 mm)	1 pc
6	90° Elbow (400 x 400 mm, centerline radius length 600 mm)	1 pc
8	Offset transition piece (400 x 400 mm, length 700 mm)	1 pc
10	Rectangular reducer (400 x 200 mm, length 400 mm)	1 pc
7.	90° Elbow (400 x 200 mm, length 300 mm)	1 pc
12, 13, 14, 15	Straight duct section (200 x 200 mm, length 1200 mm)	4 pcs
16	End cap (200 x 200 mm)	1 pc

4.1. Different methods of sealing ventilation and air conditioning (HVAC) ducts

- The most effective method when used for flanges at joints with bolt or corner fasteners.

These flanges are sealed with gaskets made of EPDM, rubber, or polyurethane foam, which, if installed correctly, provide a uniform seal.

This sealing method is recommended for professional HVAC system ducts.

- Another additional sealing method used for flanges, joints, and corners is the application of a sealant or silicone sealant applied with special gun-type devices.

These sealants or silicones can be acrylic and are used for corrections or additions to seals of ventilation systems.

- Aluminum adhesive tape is widely used in practice; it is resistant to temperature and moisture but is not technically recommended.

a) Flange Connections with Gaskets & Corner Clamps: Flanged joints secured via corner bolts and intermediate perimeter clamps utilizing elastomeric gaskets (EPDM, closed-cell rubber, or polyurethane foam). When correctly compressed, this approach provides robust, uniform joint sealing and is the standard practice for high-performance commercial HVAC ductwork.

b) Elastomeric / Silicone Sealants: Applying liquid-applied acrylic or elastomeric silicone sealants along flange faces, transverse seams, and corner

joints using caulking guns. This method serves as a primary seal or supplementary remediation measure in air distribution networks.

c) **Aluminum Foil Pressure-Sensitive Tape:** Frequently used in field installation for quick joint taping. Although resistant to moisture and moderate temperature fluctuations, it is generally not recommended as a primary structural sealing method in professional specifications.

4.2. Case study no.2.a

A. Duct Sealing via Corner Clamps and Self-Adhesive EPDM Gaskets Only

The experimental duct section (Figures 13–14, Table 4) was evaluated on a test bench at the manufacturer's facility to analyze two sequential sealing configurations (Figures 15 and 16).

For each sealing configuration, key aerodynamic and acoustic parameters were measured across variable fan speed operating points:

- Mean duct airflow velocity (m/s);
- Volumetric airflow rate (m^3/h);
- Radiated acoustic noise emitted by the variable-speed supply fan and duct casing.

Acoustic measurements were recorded near the supply fan source and along the primary duct joint located 1.5 m downstream, as depicted in Figure 15.



Figure 15. Experimental acoustic test setup for ductwork aeroacoustics measurements

Figure 16 details the mechanical flange connection, sealed with corner bolts, perimeter clamps, and self-adhesive EPDM gasket strips.

Experimental results for the baseline EPDM gasketed flange configuration (Case Study 2a) are presented in Table 5.



Figure 16. Rectangular duct transverse flange joints sealed with corner clamps and EPDM gasket

Table 5. Measured acoustic and aerodynamic parameters for duct joints sealed with flanged corner clamps and EPDM gaskets (Case Study 2a).

No.	Noise level from the fan [dB]	Noise level from ducts [dB]	Air velocity in the ducts [m/s]	Duct air flow [m^3/h]
1	46,86	48,53	0,16	112
2	46,92	48,59	0,17	120
3	47,52	49,21	0,19	134
4	48,14	49,85	0,21	148
5	48,47	50,19	0,22	155
6	49,28	51,03	0,33	233
7	49,35	51,11	0,34	240
8	49,56	52,49	0,35	248
9	49,67	52,88	0,36	254
10	49,54	55,30	0,38	268
11	51,17	55,57	0,39	275
12	50,32	55,58	0,75	524
13	50,77	56,82	0,76	528

4.3. Case study no.2.b

B. Supplemental Duct Sealing via Gray Silicone Application over EPDM Gasketed Flanges

Following baseline testing, the experimental duct network was disassembled, re-sealed by applying a continuous bead of gray industrial silicone sealant over all flanged seams and corners (Figure 18) in addition to the EPDM gaskets, and subsequently re-tested under matching supply fan operational ranges.



Figure 18. Reassembled ductwork featuring a combined EPDM gasket, corner clamps, and secondary silicone sealant

Table 6. Measured acoustic and aerodynamic parameters for duct joints sealed with EPDM gaskets, corner clamps, and supplemental gray silicone sealant (Case Study 2b).

No.	Noise level from the fan [dB]	Noise level from ducts [dB]	Air velocity in the ducts [m/s]	Duct air flow [m ³ /h]
1	44,49	46,95	0,71	478
2	46,96	49,56	0,76	512
3	49,39	52,12	0,79	532
4	50,12	53,53	0,81	546
5	50,28	53,71	0,84	566
6	50,52	53,96	0,88	593
7	51,47	54,98	0,91	613
8	51,84	62,67	0,95	660
9	52,17	63,06	0,98	681
10	52,75	63,77	0,99	688
11	53,02	64,09	1,15	799
12	53,40	64,55	1,16	806
13	53,89	65,26	1,17	819

Table 6 summarizes the empirical results obtained under supplemental silicone sealing conditions.

4.4. Conclusions related to the case study no.2

Comparing equivalent operating points in Table 5 and Table 6 shows that applying supplementary silicone sealing to conventional EPDM gasketed flange joints reduces radiated duct noise by up to 7 dB at comparable volumetric airflow rates and air velocities.

Furthermore, evaluating operating point 2 in Table 5 ($V = 0.17$ m/s, $Q = 120$ m³/h, $L_{\text{duct}} = 48.59$ dB) against operating point 2 in Table 6 ($V = 0.76$ m/s, $Q = 512$ m³/h, $L_{\text{duct}} = 49.56$ dB) reveals that enhanced joint airtightness yields over a 50% increase in effective

duct air velocity and delivered flow rate for equivalent overall radiated noise levels, confirming significant pneumatic efficiency gains.

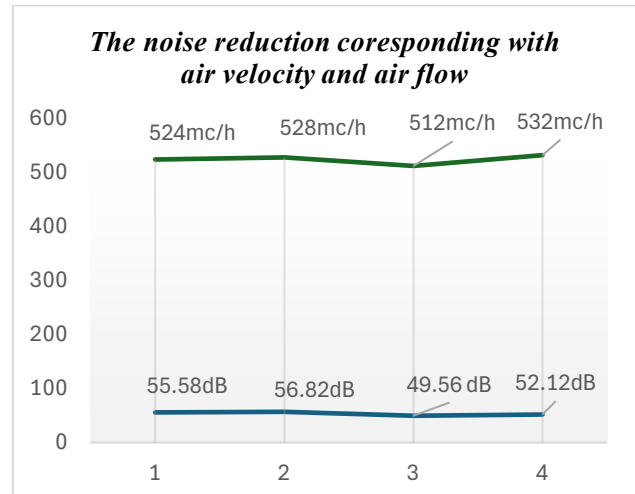


Figure 19. Graphical comparison of duct noise reduction versus airflow rate and velocity based on comparative bold datasets from Tables 5 and 6

5. FINAL CONCLUSIONS

In accordance with normative acoustic standards [13], Case Study no.1 demonstrated that secondary acoustic treatments are mandatory to reduce operational noise levels below the 70 dB threshold [27], as outlined in Stages 2 and 3 of the testing programs.

It is critical to emphasize that prolonged exposure to industrial noise levels between 70 dB and 85 dB poses significant auditory risks, contributing to progressive hearing fatigue, stress, and systemic physiological disorders [23], [24]. Consequently, building a dedicated laboratory test bench that simulates dynamic operational noise and turbulent flow regimes is essential for evaluating specialized duct silencer configurations.

Pending laboratory validation demonstrating at least 6 dB attenuation, we will submit an engineered sound attenuation solution tailored to the installation's specific spectral characteristics to the facility operator.

Furthermore, based on in-situ test outcomes, we recommend extending experimental testing under controlled laboratory conditions using geometrically matched duct sections operating under equivalent flow regimes to optimize silencer positioning relative to primary acoustic sources.

To assess overall compliance, Table 7 synthesizes the empirical noise levels recorded in Case Studies no. 1 and no. 2 against the allowable normative indoor noise thresholds established in Romanian normative C 125-2013 [13].

Table 7. Synthesis of experimental test results compared against normative indoor noise thresholds [13]

Maximum noise levels depending on the type of public buildings [13]				
Inhabited	Offices	Education	Hospitals	Hotels
Day diet 40 dB	Regime day 45 dB	Regime day 35 dB	Regime day 30 dB	Regime day 30 dB
Night regime 30 dB	Night regime -	Night regime -	Night regime 30 dB	Night regime 30 dB
Case study 1 – Initial stage noise levels				
Average noise level background			58.41 dB	
Average noise level at point 1			69.55 dB	
Average noise level at point 2			72.35 dB	
Case study 1: Noise level after improvements				
Average noise level background			58.36 dB	
Average noise level at point 1			59.55 dB	
Average noise level at point 2			69.36 dB	
Case study 2a- The noise stage of sealing A				
Average fan noise level			50.77 dB	
Average Duct Noise Level			56.82 dB	
Case study 2b - The noise stage of sealing B				
Average fan noise level			46.96 dB	
Average Duct Noise Level			49.56 dB	

The primary objective of the acoustic evaluations conducted across the four experimental scenarios was to verify compliance with international standards [16], [17] by comparing measured sound power and pressure levels against regulatory maximums [13]. Based on these determinations, the following technical conclusions are drawn:

The average values of background noise measured during the day in case study no. 1 are much higher than the maximum noise levels, depending on the type of buildings of public interest [13], which allows us to state that the area where the measurements were made is a highly polluted area from a noise point of view. It is recommended to relocate the noise sources to distances that allow us to obtain the noise values regulated by the standard [13].

The values of the average noise levels to be measured during the day in points P1 and P2 for case study no. 1 are much higher than the maximum noise levels depending on the type of public interest building [13]. Even if, in case study no. 1, sound insulation measures were taken, these were insufficient, which is why it is necessary to build a hall that would contain all the sources of noise

inside, followed by the repetition of the tests carried out in these two case studies.

If, after the technical proposal mentioned above has been made, the values of the sound power levels measured at the two points do not comply with the limit values regulated by standard [13], then the noise-generating equipment must be replaced by other more modern, quieter equipment and then the measurements related to the sound power levels emitted in the 3 points must be redone.

If, in this case, the legal regulations [13] are not satisfied, the factory with the noise-generating sources must be relocated at a sufficient distance to comply with the legislation in force.

The average noise values measured during the day for the fan as well as for the HVAC ducts in case study 2 are higher than the maximum values regulated in the standard [13], which is why these pipes are recommended to be soundproofed with a mineral wool casing with an aluminum foil outer shell and then retested according to a procedure like the tests performed.

If, when repeating the tests mentioned in the point above, values lower than the standardized values [13] are obtained, then these ducts must be mounted only in false ceilings insulated with wool.

1. Baseline daytime ambient noise levels measured in Case Study no.1 significantly exceed allowable normative thresholds across all public building categories [13], indicating that the surrounding environment suffers from substantial background acoustic pollution. It is recommended to relocate major external noise sources to sufficient distances to satisfy statutory boundary requirements [13].

2. Average operational sound levels recorded at points P1 and P2 during initial testing in Case Study no.1 far exceeded permissible public building thresholds [13]. Although post-mitigation acoustic treatments achieved measurable sound reductions, overall noise levels remain above allowable limits. Consequently, we strongly recommend constructing a fully enclosed acoustic building hall around all internal machinery, followed by comprehensive re-testing.

3. If post-enclosure sound pressure levels still fail to comply with legal limit values [13], existing high-noise machinery must be replaced with modern, low-noise equipment, followed by acoustic re-evaluation at sampling points P1, P2, and P3.

4. Should complete mechanical equipment replacement still fail to satisfy statutory limits [13], the industrial manufacturing facility must be relocated to an appropriately zoned industrial area maintained at a sufficient distance from sensitive receptors.

5. Average operational noise levels recorded for the supply fan and duct assembly in Case Study 2 exceed standard indoor comfort limits [13]. It is recommended that air distribution ductwork be acoustically lagged using mineral wool insulation covered with an outer protective aluminum jacket, followed by standardized acoustic re-verification.

6. If post-insulation measurements satisfy target acoustic thresholds [13], ductwork installations within public buildings should be strictly routed within acoustic false ceiling plenums lined with sound-absorbing mineral wool insulation.

Leading industrial organizations are increasingly integrating key environmental performance indicators (KPIs) into corporate governance structures, accelerating green manufacturing practices.

In alignment with global net-zero carbon targets and sustainable development frameworks, technological innovation in asphalt mixing plants is rapidly accelerating. Modern low-emission burners feature precision combustion control systems capable of reducing nitrogen oxide emissions by over 30% while dampening combustion noise. Intelligent control systems optimize heating profiles and material ratios in real time, reducing overall unit energy consumption. Furthermore, modular and mobile plant architectures reduce land footprint and transport-related emissions through flexible deployment.

Looking forward, the "green asphalt" paradigm is transitioning from experimental research to full-scale commercial deployment. Breakthrough innovations—including low-VOC asphalt additives, carbon capture and storage (CCS) integration within mixing facilities, and solar-powered industrial production models—are poised to redefine sustainable infrastructure development. In the future, asphalt production facilities will serve not only as material suppliers but as active contributors to the circular economy and low-carbon industrial development.

Managing the environmental footprint of asphalt mixing plants represents an operational challenge that the industry must actively address. Through technological innovation, optimized operations, and proactive regulatory compliance, the industry can turn these challenges into opportunities for sustainable transformation.

From emissions control and resource recycling to energy conservation and decarbonization, every technological advancement pushes asphalt production toward a more environmentally sustainable future. As core stakeholders in transportation infrastructure development, industry operators must increase investments in green

technologies, adopt best operational practices, and embed environmental stewardship across all manufacturing stages. Only through this holistic approach can societal infrastructure demands be met while protecting public health, natural ecosystems, and long-term environmental sustainability.

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