Acoustic measurements on waste water installations and solutions to limit residents annoyance

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Summary

Acoustic measurements have been carried out on waste water pipes under different mounting configurations. The vertical pipe can be either straight or bended (with two 45° bends); a horizontal pipe is also considered. The laboratory measurements are performed following the EN 14366 standard allowing to evaluate the structure-borne sound characteristic level and the normalized airborne sound pressure level for each configuration. The attachments to the supporting wall (vertical pipe) or floor (horizontal pipe) are either rigid or "acoustic" i.e. including a resilient element. Constant flow rates are taken into account, as well as a water discharge corresponding to a toilet flushing or a basin emptying depending on pipe diameter. The effects of the different configurations, mounting conditions, and water circulations are presented, analyzed and discussed. These laboratory data are then used in the CSTB AcouBat software in order to evaluate air-borne and structure-borne noise levels associated with such waste water installation and assess different solutions in order to limit residents annoyance (comfort level Class B of the ISO/DIS 19488 for service equipment noise).

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1. Introduction

Noise generated by waste water pipes in buildings is real source of annoyance often mentioned by multifamily buildings residents. In-situ measurements associated to water supply and evacuation noise in Korean buildings have been reported in [1-2]; noise levels were rather high and found to affect acoustic comfort in the living spaces. In order to reduce this noise disturbance, building acoustic design can be based on laboratory characterization of such waste water systems following the European standard EN 14366 [3]. The obtained characteristics associated to airborne and structure-borne noise can then be used to evaluate in-situ noise levels following the European standard EN 12354-5 [4].

Laboratory acoustic measurements have been carried out on waste water pipes under different mounting configurations. The vertical pipe can be either straight or bended (with two 45° bends); a horizontal pipe is also considered. The measurements are performed following the EN 14366 [3] standard allowing to evaluate the structure-borne sound characteristic level and the normalized airborne sound pressure level for each configuration. The attachments to the supporting wall (vertical pipe) or floor (horizontal pipe) are either rigid or "acoustic" i.e. including a resilient element. Constant flow rates are taken into account, as well as a water discharge corresponding to a toilet flushing or a basin emptying depending on the pipe diameter. The effects of the different configurations, mounting conditions, and water

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circulations are presented, analyzed and discussed. These laboratory data are then used in the CSTB AcouBat software in order to evaluate air-borne and structure-borne noise levels associated with such waste water installation and assess different solutions in order to limit residents annoyance (comfort level Class B of the ISO/DIS 19488 [5] for service equipment noise).

2. Laboratory measurements

The measurements performed following the EN 14366 [3] standard, use constant flow rates. However, in-situ water evacuation is rarely stationary over time. In the case of a toilet flushing or a wash basin emptying for example, the flow rate reaches a maximum value soon after triggering the event and then diminishes in matter of seconds. So the physical phenomena involved can be rather different than those in the laboratory, when the flow rate is supposed to be kept within ± 5 % of the stated value during measuring time.

Furthermore, it should be mentioned that in-situ measurements take usually into account that transient behavior of such service equipment since it is generally prescribed to measure the maximum sound pressure level with either a Slow (1s integration) or Fast (0.125 s integration) time weighting depending on the European country. In France, the Slow weighting is used and for comparable measured and predicted results, it is customary to base prediction on the waste water pipe characteristics obtained for a flow rate of 2 l/s. Therefore, in this study, polypropylene pipes with two different diameters (58 mm representative of wash basin evacuation pipe and 110 mm representative of toilet evacuation pipe) are tested following EN 14366 standard with the constant flow rates 0.25, 0.5, 1, 2 and 4 l/s depending on pipe diameter. It should be noticed that the small diameter pipe tested in this project is out of the scope of the EN 14366 standard concerning pipes with interior diameter of 70 mm at the minimum. However, the flow rates are adapted and lowered and the same procedure is followed.

Several configurations have been evaluated: straight vertical pipe, bended vertical pipe (including 2 45° elbows), and a horizontal pipe (also mounted with 2 45° elbows rather than a single 90° elbow). For each configuration, the pipe is tested with rigid connectors and with resilient anti-vibration connectors, and eventually with a heavy mass type cladding. In addition, airborne and structure-borne sound characteristics are also determined for transient water flow; the constant water flow inlet is either replaced by a suspended toilet for the largest diameter pipe tested or a wash basin for the smallest diameter pipe tested. The airborne and structure-borne noise levels are expressed in terms on maximum level with the Slow and Fast weightings.

The toilet reservoir corresponds to 6 l and the wash basin to 5 l of water. For space reason, the falling height is reduced from 5.80 to 4.88 m.

The maximum value of the sound pressure level is measured and normalized to an equivalent absorption area of 10 m² to have direct comparison to the standard L_{an} et L_{sc} spectra. It should be noted that the determination of L_{sc} also involves a normalization with respect to the acoustic properties of the wall compared with the properties of a reference wall; it is done in the same way as the procedure described in the EN 14366 standard and used for constant water flow rate. An average over 12 consecutive water discharges is used for the spectra of maximum sound pressure level presented in this paper.

A schematic of the experimental setup is shown in Figure 1 in the case of constant water flow rate measurements. In Figure 2, the toilet and the wash basin used for water discharges are depicted.

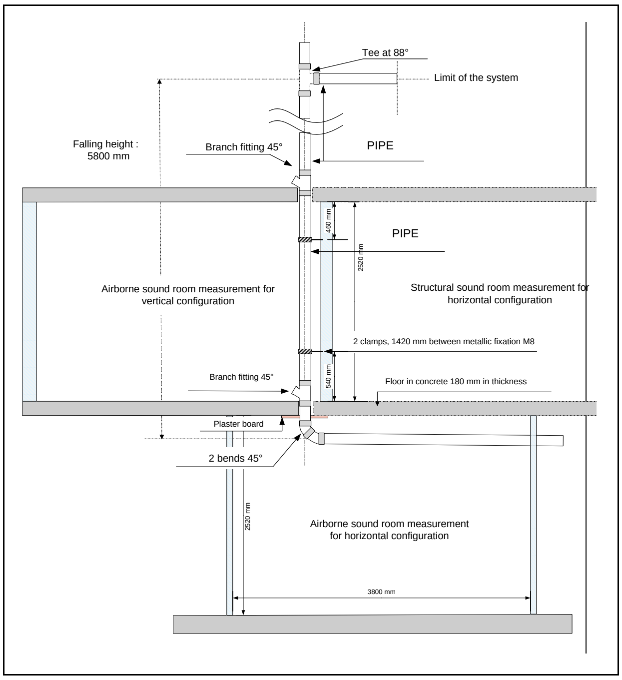

Figure 1. Schematic of the laboratory for constant water flow rate measurements.

3. Measurement Results and analysis

The complete set of collected results are not presented in this paper; only results for the vertical straight pipe and the horizontal pipe are discussed. The global indices associated to the measurements are given in Table I and II at the end of the paper for the pipe with a diameter of 110 mm and 58 mm respectively.

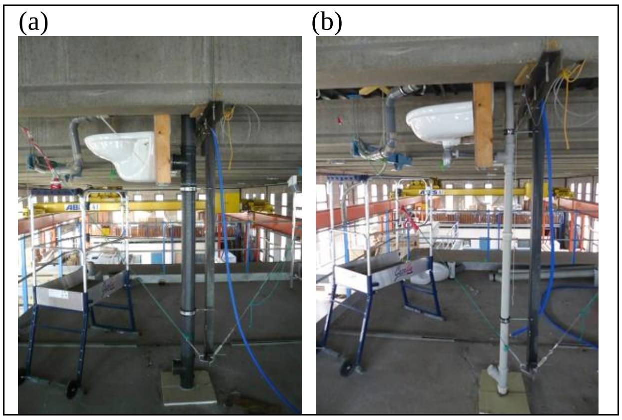

Figure 2. View of the water discharge systems; (a) toilet and (b) wash basin.

3.1. Pipes mounted with rigid standard connectors

The normalized airborne noise spectra for the different configurations are presented in Figures 3 and 4 for the 110 mm in diameter pipe and the 58 mm in diameter pipe, in the vertical and horizontal direction respectively. In a similar way, Figures 5 and 6 correspond to the characteristic structure-borne sound level.

3.1.1 Airborne noise

For the vertical 110 mm in diameter pipe, it can be observed that the spectra $L_{S,max,an}$ and $L_{F,max,an}$ obtained for the flushing toilet are globally between the measurements obtained for a stationary flow rate of 1 and 2 l/s. However, some values are closer to results for the 4 l/s (at the one third octave band of 160 and 200 Hz in particular). For the vertical 58 mm in diameter pipe, the spectra $L_{S,max,an}$ and $L_{F,max,an}$ obtained for the wash basin emptying are also globally between the measurements obtained for a stationary flow rate of 1 and 2 l/s; above 800 Hz, they are indeed very close to the 1 l/s spectrum. For the two different pipes, the difference between $L_{S,max,an}$ and $L_{F,max,an}$ is about 3 dB in the low frequency range and 2 dB in the high frequency range.

For the horizontal 110 mm in diameter pipe, the spectra $L_{S,max,an}$ and $L_{F,max,an}$ obtained for the flushing toilet are globally close to L_{an} spectrum for 2 l/s constant flow rate. However, up to 160 Hz, they are higher and even sometimes greater than those obtained for 4 l/s low rate. Concerning the vertical 58 mm in diameter pipe, the spectra $L_{S,max,an}$ and $L_{F,max,an}$ obtained for the wash basin emptying are higher in the low frequency range (250-315 Hz) than the spectra for any stationary flow rate investigated. However in the mid high frequency range they do fall globally between the 1 and 2 l/s flow rate. The difference between $L_{S,max,an}$ et $L_{F,max,an}$ is similar as the one observed for the vertical pipe of the same diameter.

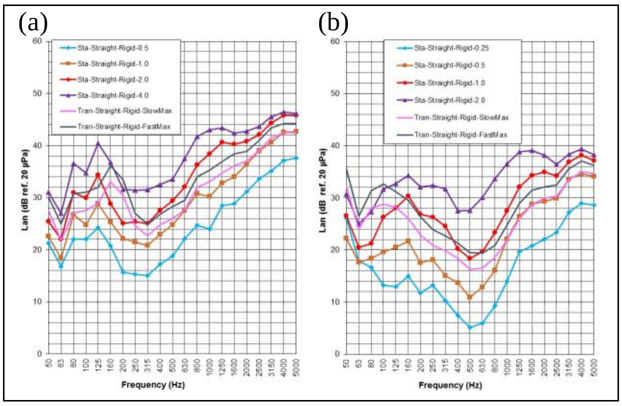

Figure 3. Normalized airborne noise L_{an} – Vertical pipe mounted with rigid connectors; (a) Ø 110 mm and (b) Ø 58 mm.

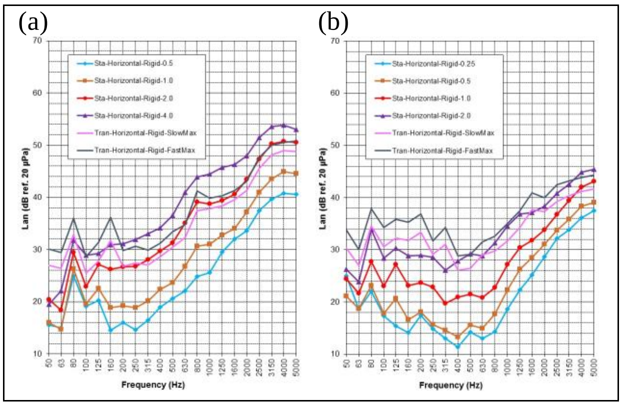

Figure 4. Normalized airborne noise L_{an} – Horizontal pipe mounted with rigid connectors; (a) Ø 110 mm and (b) Ø 58 mm.

3.1.2 Structure-borne noise

For the vertical 110 mm in diameter pipe, it can be observed that the spectra $L_{S,max,sc}$ et $L_{F,max,sc}$ obtained for the flushing toilet are close to L_{sc} spectrum evaluated for 2 l/s low rate. For the vertical 58 mm in diameter pipe, the spectra $L_{S,max,sc}$ et $L_{F,max,sc}$ obtained when emptying the wash basin are as for the airborne noise spectra close to the L_{sc} spectrum evaluated for 1 l/s in the mid high frequency range.

As for the airborne noise, the difference between $L_{S,max,sc}$ et $L_{F,max,sc}$ is about 3 dB in the low frequency range and 2 dB in the high frequency range, for the two different pipes.

For the horizontal 110 mm in diameter pipe, the spectra $L_{S,max,sc}$ et $L_{F,max,sc}$ obtained for the flushing toilet are comparable and even higher than L_{sc} spectrum for 4 l/s constant flow rate. They are indeed close to 2 l/s L_{sc} levels in the frequency range from 500 to 1600 Hz. For the 58 mm in diameter pipe, the spectra $L_{S,max,sc}$ et $L_{F,max,sc}$ are rather close to the L_{sc} for the 2 l/s flow rate except in the mid frequency range (250 to 630 Hz) for which it is close to the 1 l/s flow rate. For both pipe diameters, the difference between $L_{S,max,sc}$ et $L_{F,max,sc}$ is about 3 dB in the low frequency range and decreases to be below 1 dB in the high frequency range.

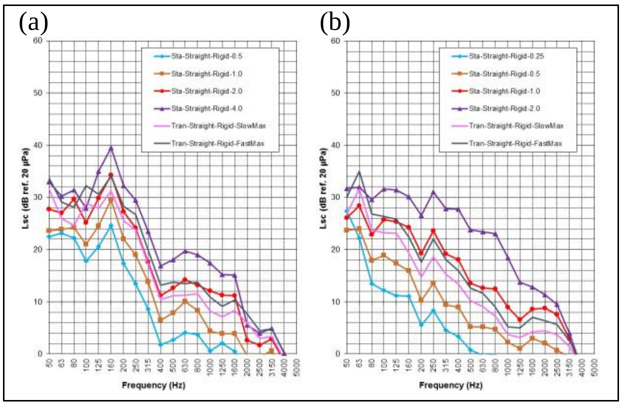

Figure 5. Structure-borne noise L_{sc} – Vertical pipe mounted with rigid connectors; (a) Ø 110 mm and (b) Ø 58 mm.

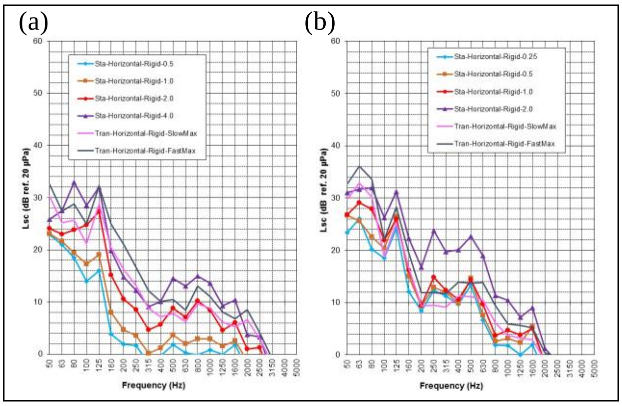

Figure 6. Structure-borne noise L_{sc} – Horizontal pipe mounted with rigid connectors; (a) Ø 110 mm and (b) Ø 58 mm

3.2. Effect of resilient anti-vibration connectors

In this section, the noise level reduction associated to the resilient anti-vibration connectors is presented in terms of insertion loss. The results obtained for the two types of water flow (stationary or transient) are compared.

The normalized airborne noise spectra for the different configurations are presented in Figures 7 and 8 for the 110 mm in diameter pipe and the 58 mm in diameter pipe respectively. In a similar way, Figures 9 and 10 correspond to the characteristic structure-borne sound level.

3.2.1 Airborne noise

For the largest diameter pipe, the insertion loss ΔL_{an} evaluated for a stationary water flow is close to 0 dB on average for all configurations. Variations of a few dBs are observed in the low frequency range. The results are relatively independent of the flow rate. The insertion loss is a little higher in the low and mid frequency range when evaluated based upon $L_{S,max,an}$ and $L_{F,max,an}$ for transient flow. For the smallest diameter pipe, the insertion low ΔL_{an} is similar for the 1 and 2 l/s flow rate; the very low flow rate presents a different behavior.

For both diameter pipes, the insertion loss does not depend on the Slow or Fast weighting.

Anyway as expected, the insertion loss associated to resilient anti-vibration connectors is almost zero in the high frequency range where the airborne noise level is maximum. Therefore, the global level in dB(A) remains almost the same for the systems mounted with the rigid and anti-vibration connectors.

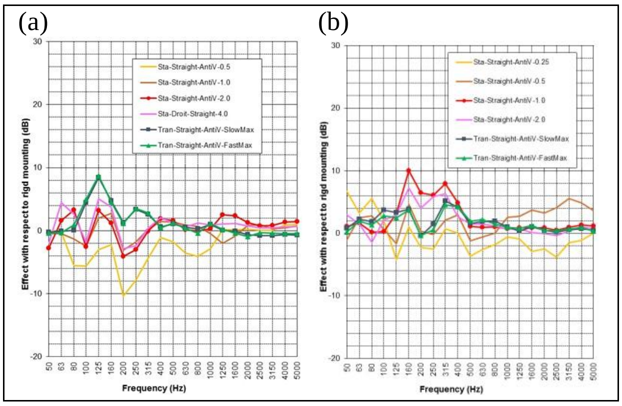

Figure 7. Insertion loss ΔL_{an} – Anti-vibration connectors – Vertical pipe; (a) Ø 110 mm and (b) Ø 58 mm.

3.2.2 Structure-borne noise

The insertion loss ΔL_{sc} is globally positive. For the largest diameter pipe; the insertion loss has a similar behavior if evaluated based on L_{sc} for stationary flow or on the $L_{S,max,sc}$ et $L_{F,max,sc}$ for the transient flow. It is even a little higher for the water discharge cases. For the smallest diameter pipe, the insertion loss evaluated based on $L_{S,max,sc}$ et $L_{F,max,sc}$ for the transient flow is higher in the low frequency range. The obtained insertion loss for the structure-borne noise level is more important for the vertical pipes than for the horizontal ones.

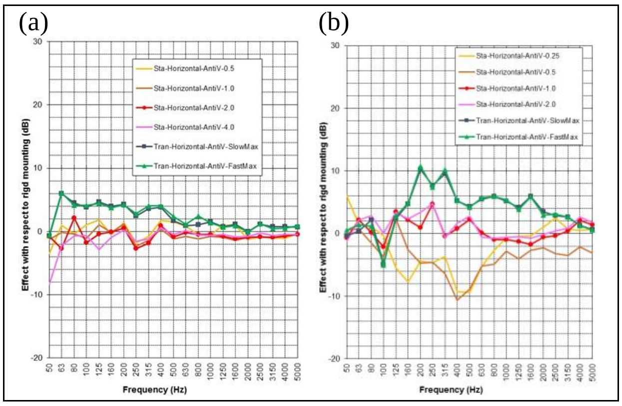

Figure 8. Insertion loss ΔL_{an} – Anti-vibration connectors – Horizontal pipe; (a) Ø 110 mm and (b) Ø 58 mm.

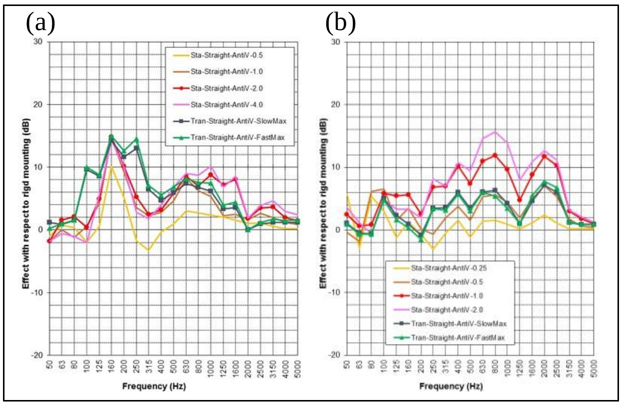

Figure 9. Insertion loss ΔL_{sc} – Anti-vibration connectors – Vertical pipe; (a) Ø 110 mm and (b) Ø 58 mm.

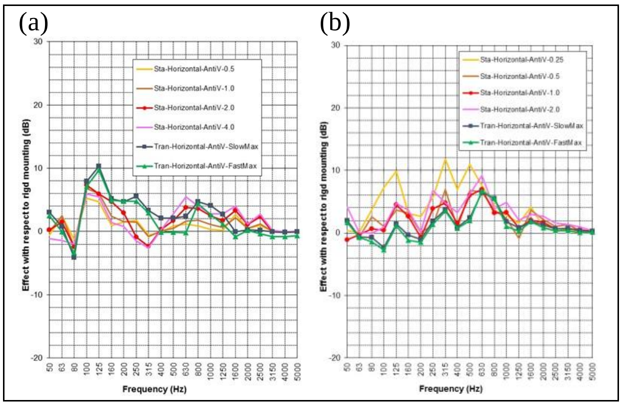

Figure 10. Insertion loss ΔL_{sc} – Anti-vibration connectors – Horizontal pipe; (a) Ø 110 mm and (b) Ø 58 mm.

3.3. Effect of an additional heavy mass type cladding

An additional heavy mass type cladding was placed on the pipes in order to reduce the airborne noise level, since the anti-vibration connectors only affected the structure-borne noise level. The heavy mass cladding covers 1 m of the vertical pipe starting at the laboratory floor (lower part of the pipe) while it covers either 1 or 3.2 m of the horizontal pipe starting from right under the laboratory floor (i.e. including the elbow). No difference was found between these two different covering lengths for the horizontal pipe (note that 3.2 m allowed to cover the entire pipe in the reception room).

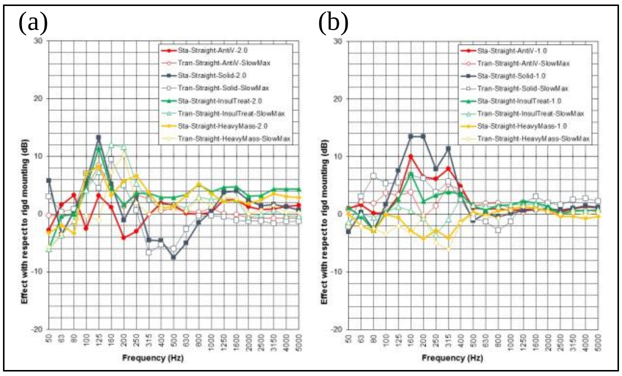

Figure 11. Insertion loss ΔL_{an} – Heavy mass cladding + anti-vibration connectors – Vertical pipe; (a) Ø 110 mm and (b) Ø 58 mm.

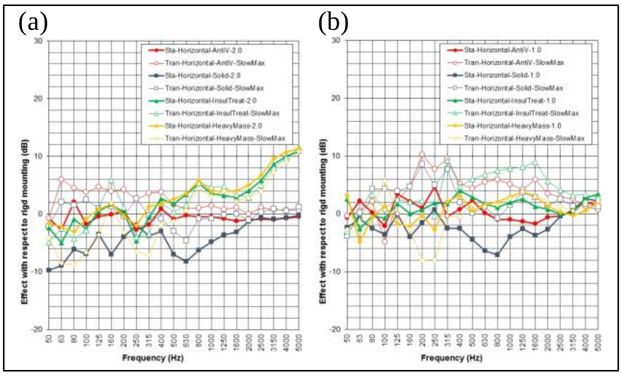

Figure 12. Insertion loss ΔL_{an} – Heavy mass cladding + anti-vibration connectors – Horizontal pipe; (a) Ø 110 mm and (b) Ø 58 mm.

3.4. Summary and discussion

Figure 13 presents the airborne and structure-borne noise level as a function of the stationary flow rate. In general, the noise level increases with the flow rate. The airborne noise level and the structure borne noise level appear to vary almost linearly as a function of flow rate logarithm; except for the low flow rate.

The airborne noise associated to the 110 mm in diameter pipe using regular or anti-vibration mounting is higher than the one for the 58 mm in diameter pipe; furthermore the airborne level is higher for the horizontal pipe than for the vertical pipe.

The structure-borne noise associated to the 110 mm in diameter pipe using regular or anti-vibration mounting is on the contrary lower than the one for the 58 mm in diameter pipe in general. Moreover the airborne level is lower for the horizontal pipe than for the vertical pipe.

One reason for this behavior could be that the smaller diameter pipe (58 mm) is stiffer than the larger one (110 mm) then injecting more structural power in the wall and therefore a higher structure-borne noise (for a same water flow). On the other hand, the smaller diameter pipe is associated to a smaller radiating surface than the larger diameter pipe resulting in a lower airborne noise (for a same water flow).

Figure 14 compares the noise level of different pipes (those tested in this investigation and some basic PVC pipes commonly used in France) as a function of the flow rate, for vertical straight configuration and horizontal configuration. The 100 mm in diameter PVC pipe is associated with a higher airborne noise level and a lower structure-borne noise level than the 110 mm in diameter PPI pipe tested in this work (made of polypropylene).

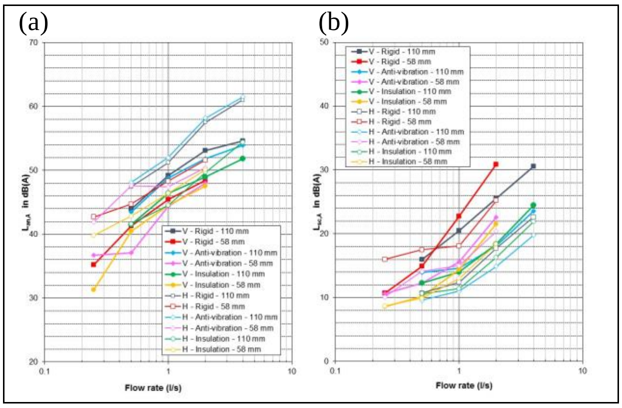

Figure 13. Noise level as a function of flow rate; (a) airborne ($L_{an,A}$) and structure-borne noise ($L_{sc,A}$).

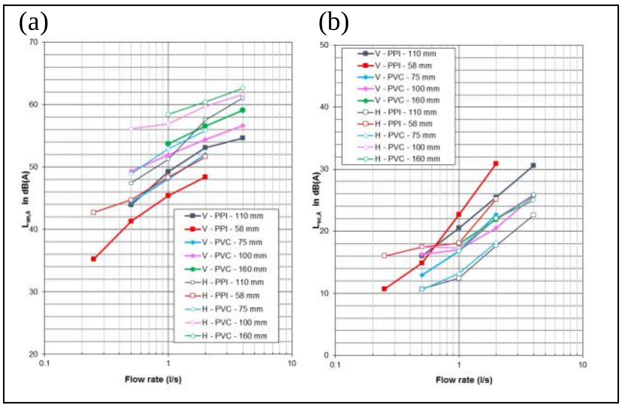

Figure 14. Noise level as a function of flow rate for rigid mounted pipes (standard connectors); (a) airborne ($L_{an,A}$) and structure-borne noise ($L_{sc,A}$).

4. Guidelines

In Korea, national regulations and recommendations for indoor noise levels with respect to water drainage pipe noise in multi-residential building are currently inexistent.

It is desired by LHI to achieve for the indoor noise level of drainage pipes Class B of service equipment noise defined in the ISO/DIS 19488 standard. Therefore for drainage pipe noise produced in the bathroom of a dwelling, a maximum of $L_{AF,max,nT}$ of 30 dB(A) should be obtained in a room of a different dwelling (adjacent or above or under).

It should be noted that in France service equipment noise associated to drainage pipe is limited to $L_{AS,max,nT}$ of 30 dB(A) in living rooms and bedrooms and 35 dB(A) in a kitchen of a different apartment. The limit level for living rooms and bedrooms of a different apartment corresponds to Class C the ISO/DIS 19488.

The collected laboratory data were used in the CSTB AcouBat software in order to evaluate air-borne and structure-borne noise levels associated with such waste water installation and assess different solutions in order to limit residents annoyance.

First of all, it is recommended to use a resilient envelope around a liquid carrying pipe when the pipe is going through a floor or a wall in order to limit vibration transmission to these structural elements. Indeed, any rigid connection between the pipe and the structural elements should be avoided. Furthermore, the resilient envelope should not be too rigid (so it does prevent vibration transmission); its dimensions should be adapted to the pipe dimensions: tight enough and not too thick. When installed its length should be larger than the thickness of the floor or wall being transpierced, then once the filler between the hole drilled in wall or floor and the resilient envelope has been applied and is dried up then the resilient enveloped can if necessary be cut shorter on each side of the wall/floor.

Since the effect of cladding was found limited for water discharge in the pipe, this sole solution cannot be recommended at this point. Therefore the proposed recommandations are based on service shaft, i.e. an enclosure around the pipe.

Since the standard EN 14366 is referring to stationary flow rates the recommendations have to be given for these characteristics evaluated at a flow rate of 1 l/s for pipes with interior diameter between

50 and 100 mm, 2 l/s between 100 and 125 mm and 4 l/s for 125 up to 150 mm ; however, the Fast max level is also indicated for information and it corresponds to a water discharge of 5 or 6 l.

The recommendations are presented in Table III and allow achieving the required level for straight vertical fixed to a supporting wall of at least 200 kg/m² and horizontal pipes fixed to a supporting floor of at least 350 kg/m². It should be mentioned that anti-vibration mounting connectors are necessary to reach the indicated structure-borne noise level. For horizontal pipes, a cladding with a certain mass can be used in order to reduce the airborne noise; this cladding needs to have a mass per unit area of at least 5 kg/m² and should cover the complete bend and the pipe over a length of approximately 2.5 m. In that case, it can be assumed that 5 dB(A) can be subtracted from the airborne noise level associated to the pipe. The use of such cladding allows to reduce the performance of the service shaft necessary in order to reach the chosen requirements.

The performance of a service shaft is defined by an insertion loss that is independent of the type and diameter of the pipe. It is assumed to affect only the airborne noise level; the global index ΔL_{an} is obtained with respect to a reference airborne noise level of 60 dB(A). It should be noticed that this measurement is not standardized as yet ; however, a procedure has been developped and used in CSTB for many years in order to evaluate and optimize their performance. Some examples of service shaft performance are given below:

- 24 dB ≤ ΔL_{an} < 27 dB : Masonry partition made of 50 mm thick brick or gypsum blocks; lining partition with 2 layers of gypsum boards 18 mm (fixed on the same side of the metallic frame) with no mineral wool
- 27 dB ≤ ΔL_{an} < 29 dB : Partition with 1 standard gypsum board 12.5 mm on each side of a metallic frame and 45 mm of mineral wool in cavity; sandwich panel with minimum thickness of 70 mm combining gypsum boards and 50 mm thick mineral wool core; lining partition with 3 layers of gypsum boards 18 mm (fixed on the same side of the metallic frame) with no mineral wool
- 29 dB ≤ ΔL_{an} < 34 dB: Masonry partition made of 50 mm thick brick or gypsum blocks with 50 mm thick mineral wool inside the service shaft; masonry partition made of 100 mm thick brick or gypsum blocks; sandwich panel with minimum thickness of 73 mm combining gypsum boards and 50 mm thick mineral wool core; lining partition with 2 layers of gypsum boards 12.5 mm in thickness each (fixed on the same side of the metallic frame) with 45 mm thick mineral wool
- 34 dB ≤ ΔL_{an} : sandwich panel with minimum thickness of 70 mm combining gypsum boards and 50 mm thick mineral wool core + 2 layers of 12.5 mm standard gypsum boards; sandwich panel with minimum thickness of 73 mm combining gypsum boards and 50 mm thick mineral wool core + 80 mm thick mineral wool inside the service shaft; 50 mm gypsum-board partition with honeycomb cardboard core + 30 mm thick mineral wool + 50 mm gypsum-board partition with honeycomb cardboard core.

5. Conclusions

Acoustic measurements were carried out on waste water pipes under different mounting configurations. Constant flow rates are taken into account, as well as a water discharge corresponding to a toilet flushing or a basin emptying depending on pipe diameter. The effects of the different configurations, mounting conditions, and water circulations were presented, analyzed and discussed. The collected laboratory data were then used in the CSTB AcouBat software in order to evaluate air-borne and structure-borne noise levels associated with such waste water installation and assess different solutions in order to limit residents annoyance. Recommendations in order to meet comfort level Class B of the ISO/DIS 19488 for service equipment noise were finally introduced.

Acknowledgement

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References

[1] H.-S. Yang, H.-M. Cho, M.-J. Kim, Field measurements for the water supply and drainage noises in the bathrooms of Korea's multi-residential buildings, Applied Sciences 6(11) 134-151, 2016.

[2] H.-M. Cho, H.-S. Yang, M.-J. Kim, Field measurements on propagation characteristics of water supply and drainage noise from the apartment bathroom to neighbouring space, Internoise 2017, 2017.

[3] EN 14366, Laboratory measurement of noise from waste water installations, 2005.

[4] EN 12354-5, Building acoustics — Estimation of acoustic performance of building from the performance of elements — Part 5: Sounds levels due to the service equipment, 2013.

[5] ISO/DIS 19488, Acoustics – Acoustic classification of dwellings, 2017.

Table I. Global indices for the Ø110 mm pipe configurations

	Water flow	Rigid mounting		Anti-vibration mounting		Additional cladding	
		Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal
Air-borne noise ($L_{a,A}$) in dB(A) – 50-5000 Hz							
L_{an}	0.5 l/s	43.9	47.4	43.5	48.1	41.5	41.6
L_{an}	1.0 l/s	49.2	51.2	48.8	52.0	46.4	44.5
L_{an}	2.0 l/s	53.1	57.5	51.8	58.2	49.0	49.7
L_{an}	4.0 l/s	54.6	61.0	53.9	61.5	51.8	54.4
$L_{Smax,an}$	Discharge	49.6	55.7	50.2	54.9	49.4	48.3
$L_{Fmax,an}$	Discharge	51.5	57.6	51.8	56.8	51.3	50.4
Structure-borne noise ($L_{sc,A}$) in dB(A) – 50-5000 Hz							
L_{sc}	0.5 l/s	16.0	10.7	13.9	9.6	12.3	10.6
L_{sc}	1.0 l/s	20.5	12.4	14.6	11.0	14.0	11.4
L_{sc}	2.0 l/s	25.5	17.7	18.1	14.9	18.4	16.3
L_{sc}	4.0 l/s	30.6	22.6	23.6	19.8	24.5	21.9
$L_{Smax,sc}$	Discharge	23.6	19.0	16.0	15.9	15.9	15.0
$L_{Fmax,sc}$	Discharge	26.2	22.0	17.8	19.2	18.6	17.6

Table II. Global indices for the Ø58 mm pipe configurations

	Water flow	Rigid mounting		Anti-vibration mounting		Additional cladding	
		Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal
Air-borne noise ($L_{a,A}$) in dB(A) – 50-5000 Hz							
L_{an}	0.25 l/s	35.2	42.7	36.7	41.9	31.3	39.8
L_{an}	0.5 l/s	41.3	44.7	37.1	47.6	40.5	42.8
L_{an}	1.0 l/s	45.4	48.3	44.4	47.4	44.5	46.4
L_{an}	2.0 l/s	48.4	51.6	48.0	50.4	47.5	50.1
$L_{Smax,an}$	Discharge	41.6	49.0	41.1	46.7	40.9	45.0
$L_{Fmax,an}$	Discharge	43.8	51.9	43.1	49.6	42.5	47.4
Structure-borne noise ($L_{sc,A}$) in dB(A) – 50-5000 Hz							
L_{sc}	0.25 l/s	10.7	16.0	10.6	10.1	8.6	8.7
L_{sc}	0.5 l/s	14.9	17.5	12.3	14.1	10.2	9.9
L_{sc}	1.0 l/s	22.7	18.1	15.6	15.0	14.4	13.0
L_{sc}	2.0 l/s	30.9	25.2	22.6	20.4	21.5	18.4
$L_{Smax,sc}$	Discharge	18.8	17.6	15.8	16.3	16.1	15.9
$L_{Fmax,sc}$	Discharge	21.5	20.5	18.8	19.5	18.9	19.1

Table III. Recommendations to limit waste water pipe noise in dwellings.

Pipe	Service shaft
$L_{an,A}$ or $L_{Fmax,an,A} \leq 58$ dB(A) $L_{sc,A}$ or $L_{Fmax,sc,A} \leq 20$ dB(A)	$\Delta L_{an} \geq 34$ dB
$L_{an,A}$ or $L_{Fmax,an,A} \leq 53$ dB(A) $L_{sc,A}$ or $L_{Fmax,sc,A} \leq 20$ dB(A)	$\Delta L_{an} \geq 29$ dB
$L_{an,A}$ or $L_{Fmax,an,A} \leq 49$ dB(A) $L_{sc,A}$ or $L_{Fmax,sc,A} \leq 20$ dB(A)	$\Delta L_{an} \geq 27$ dB
$L_{an,A}$ or $L_{Fmax,an,A} \leq 46$ dB(A) $L_{sc,A}$ or $L_{Fmax,sc,A} \leq 20$ dB(A)	$\Delta L_{an} \geq 24$ dB