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Revision of acoustic and vibration classification standards in Norway

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Norwegian standards for classification of sound and vibration conditions are revised. The revision of the vibration classification, NS 8176, was finalised in December 2017, and an English version was finished in January 2018. The acoustic classification, NS 8175, is under revision in the standardization committee. NS 8176 is based on studies made during preparation of the standard in 1990's. At that time, a basic socio-vibrational survey on people's annoyance on vibrations from transport, was conducted. This resulted in dose-response curves for vibration annoyance. During the revision work, a control of these survey data from the study was done, and it resulted in slightly revised dose-response curves. The measurement method was also improved, especially for the road traffic. Unclear description of the selection of vehicle passings was one of the main reasons for the revision. The aim of the work was also to check if other types of buildings and vibration sources could be included. The main changes in the revised document will be presented. The revision of acoustic classification standard, NS 8175 from 2012, started partly due to a need for better sound insulation in dwellings at the low frequencies and, partly due to the updates in ISO standards and European discussions on framework of the acoustic classification. A Norwegian study on sound conditions for dwellings was conducted in 2015 due to the complaints on sound conditions. The study was commissioned by the building authorities, and the results have been used in this revision work. The results from the study were published in 2016. The standard is referred to in the building regulations, and updates are also connected to the revised requirements in regulations. Main changes in the draft proposal from the revision work will be presented.

1 Introduction

1.1 Vibration from transport

NS 8176 [1] was originally prepared to establish a measurement method and base criteria for evaluating vibration limits from transport. Accordingly, exposure-effect curves were prepared for the relationship between vibration annoyance and measured or calculated vibration values for dwellings. The last years, complaints on unclear description of the selection of vehicle passings started a discussion on revision of this Norwegian standard that contains both vibration measurement method for transport sources and vibration classification for dwellings. One of the aims of the work was to check if other types of buildings and vibration sources could be included, e.g. noise-induced vibration due to air traffic.

NS 8176 [1] is based on studies made during preparation of the standard in 1990's. At that time, a basic socio-vibrational survey on people's annoyance on vibrations from transport, was conducted [2, 3]. During the revision work, it was found that a control of these survey data from the basic study was needed. Better knowledge on the factors for amplification of vibration in buildings was considered to have an influence on the results in the earlier study. A check of the basic data for dose-response curves was conducted [4]. Also, harmonization with the acoustic classes was reconsidered.

1.2 Sound insulation limits for dwellings

In the Europe and internationally, common acoustic classification of dwellings has been discussed during the latest years. Updates of ISO standards and European discussions on framework of the acoustic classification have been in focus [5, 6, 7]. In Norway, the discussion has been going on in parallel during these years. Complaints on sound insulation and noise at low frequencies has been an issue. There has been a great need for documentation on how sound insulation and noise conditions are experienced by inhabitants. During 2010 to 2011, a socio-acoustic study was conducted on universal design and experience of sound conditions by vision and hearing disabled [8, 9, 10]. In 2015-2016, the low-frequency sound insulation came in focus. Documentation and better knowledge on human experience of acoustic conditions was desirable. Therefore, the Norwegian authorities conducted a new national socio-acoustical study [11, 12]. This study with the new knowledge, together with requirements on regulations on universal design and accessibility to all in buildings, resulted in revision of NS 8175 [13].

2 Determination of vibrations in dwellings

2.1 Vibrations from rail and road traffic

The weighted vibration velocity is determined in buildings in accordance with a standardized procedure [1]. The vibration shall be measured at the position and in the direction on the floor in a bedroom or living room where the highest values of weighted velocity occur. Alternatively, vibration values for weighted acceleration can be determined and converted to weighted velocity. Then, the statistical maximum value of weighted velocity, $v_{w,95}$, is determined from measurements of weighted velocity.

The measurements are carried out when the rail or road conditions (e.g. track or road quality, seasonal changes), traffic pattern and driving speed at the time of passing are representative of the relevant vibration situation at the location, i.e. with normal traffic situation. For rail roads, the standard defines for measurement of vibration from railway vehicles (trains, including underground or tram), at least 15 individual passings at each measurement position. At least 30 % of these passings shall be of the train type that produces the highest values of weighted velocity.

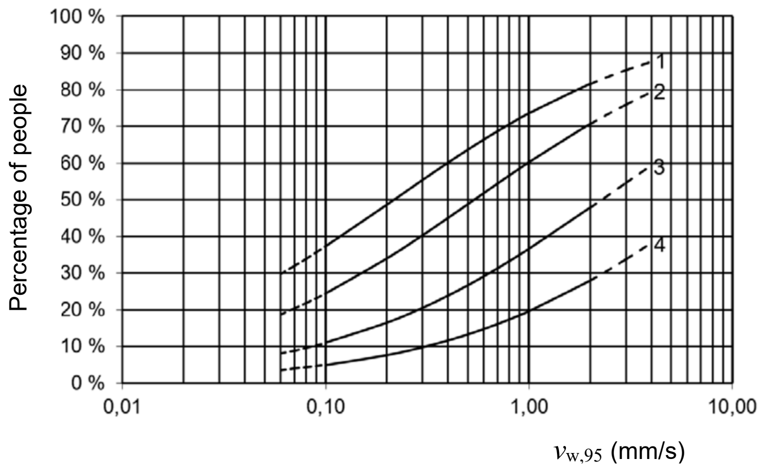
For road vehicles, the determination of passings was previously not specified as detailed as for rail vehicles. Additional measurements on vibration from passing road vehicles were therefore made in order to clarify the number of passings needed [14]. For ordinary road traffic, only vibration values from heavy road vehicles greater than 7500 kg, such as semi-articulated lorries, buses, lorries with trailers, construction machinery and similar transport units, are included in the calculation of the statistical maximum value.

The measurement time for ordinary road traffic was set to at least four hours in each measurement position and until at least 15 passings of the correct type of vehicles have been measured. In cases where the highest vibration events are caused by special conditions, for example irregularities in parts of the traffic lane where the traffic regularly passes (manhole covers, speed bumps etc.), passings where these conditions are present are included in the calculation. These detailed specifications were included for clarifications of the procedures, as was the aim of the revision.

2.2 Vibration annoyance at dwellings

As mentioned in 1.1, during the revision work a reconsideration of the basic dose-response data was found to be necessary [4]. Almost 20 years' experience from determination of vibration values for dwellings and other buildings has given a better knowledge of the factors for amplification of vibration in buildings. The factors seem to be less than expected previously. The calculated input data were therefore individually reconsidered and adjusted in accordance with this knowledge. Exposure-effect curves have been updated based on new analyses [14, 15], and the resulting curves are shown in Figure 1.

The results showed a slightly higher percentage of annoyed people than in the earlier study [15]. From Figure 1, one may read for example that approximately 15 % of people are highly annoyed by vibration in the dwelling at a vibration exposure $v_{w,95}$ of 0,6 mm/s that corresponds to class D in Table 1. In total, approximately 30 % will be highly and moderately annoyed at this vibration value. The curves are dotted below $v_{w,95}$ = 0,1 mm/s and above $v_{w,95}$ = 2,0 mm/s because there is uncertainty in the population response at very low and very high vibration values.



Key
1 Perceives vibration
2 Highly, moderately and slightly annoyed by vibration
3 Highly annoyed and moderately annoyed by vibration
4 Highly annoyed by vibration

Figure 1: Cumulative exposure-effect curves with percentages of annoyed people in dwellings, related to statistical maximum values of weighted velocity, $v_{w,95}$. Figure from annex to NS 8176 [1]

2.3 Vibration classes for dwellings

In Table 1, the present vibration classes are shown. As it may be read from Figure 1, percentage of highly annoyed people in dwellings of class C, may be around 10 %. In the studies from 1990's [4], the percentage of highly annoyed was found to be about 7 %. Compared to later studies from other countries, the new Norwegian dose-response curves fit better with their results [16].

Table 1: Vibration classes for dwellings. Upper limit values for statistical maximum value of weighted velocity. Table modified from NS 8176 [1]

Vibration value	Class A	Class B	Class C	Class D
$v_{w,95}$ (mm/s)	0,1	0,2	0,3	0,6

The standard allows measurements of both vibration acceleration and velocity. The values may be converted from weighted acceleration to weighted velocity, v_w, by using the Equation (1):

$$v_w = a_w \cdot k \tag{1}$$

where v_w is weighted *velocity*, in mm/s; a_w is weighted acceleration, in mm/s^2, and k is a constant equal to 0,028 s.

2.4 Consideration of other types of buildings and vibration sources

One of the tasks in this revision work was to study if there is sufficient documentation for applying vibration limits for other types of buildings. Vibration regulations and standards have been checked by Elias and Villot [17] for the European countries. We did not find enough scientific background data and documented studies to provide vibration limits or classes for other types of buildings. There was however a strong wish to give some advice. Guideline ranges for vibration from land-based transport were therefore provided for offices and some other buildings. The limit values for vibration in new buildings were based on national experience and the limit values used in some European countries [17]. By experience, vibration exceeding $v_{w,95}$ = 0,4 mm/s – 0,5 mm/s for land-based transport, can give rise to complaints and vibration annoyance in new office buildings. In buildings such as museums, hospitals, churches and concert halls, where vibration values exceed $v_{w,95}$ = 0,1 mm/s – 0,2 mm/s can, by experience, complaints and vibration annoyance appear. Other vibrations sources and noise-induced vibrations from air traffic were not included due to lack of scientific documentation.

3 Sound insulation in dwellings

3.1 Changes to the acoustic conditions for dwellings

It was decided to revise the Norwegian standard NS 8175 [13] as explained in 1.2. The revision is ongoing in this writing moment. Details in the standard may still be changed and all matters are therefore not presented here. The future use of the revised standard will also depend on whether the authorities connect the revised edition to the regulations or not [18].

As a consequence of the Norwegian study on human annoyance on sound conditions in dwellings, the airborne and impact sound insulation in dwellings are proposed to be changed [11, 12]. The limits for extended frequency range (the spectrum adaptation term $C_{50\text{-}3150}$) are proposed to be used for airborne sound insulation between dwellings. In many cases, the limit values are in the same time adjusted ± 1 dB not to increase the requirements too much, and to adjust to 4 dB steps between classes for dwellings. The use of 4 dB steps have been introduced in some other building types, too. Sound insulation between outdoor stairwells/gallery and dwellings have been proposed to be reduced by 5 dB from the present situation, see Table 2.

For impact sound insulation, no connection was found between annoyance and impact sound insulation without the extension to low frequencies [11, 12]. This resulted in a proposal for including the low frequency adaptation term ($C_{I,50\text{-}2500}$) for dwellings in all situations except for impact sound insulation from toilet, bathroom, balcony and similar.

For A-weighted sound pressure levels from service equipment, the limit values at low frequencies have been included in a different way that previously. The present edition refers to RC-curves (Room Criteria curves). The determination was complicated and the RC- values are now proposed replaced by tabled low frequency level limits at 1/1-octave bands 31,5 Hz, 63 Hz and 125 Hz. These limits are based on the values of RC-curves at these low frequencies.

3.2 Acoustic classification

The Norwegian acoustic classification is historically based the acoustic requirements in building regulations, i.e. class C origins from the regulations in 1987. The change came in 1997, after that the EU Directive on construction products [19] was implemented in the Norwegian regulations. The class limits have been changed somewhat in 2005, 2008 and 2012 [13].

The Norwegian standard defines four acoustic classes for buildings which differ from the international draft standard [7] that has defined six classes. Also, the limits in various classes in the Norwegian standard are given so that you can consider one class with requirements for a building, not choosing between different classes for various parts of a building. The latter is also possible, but the minimum requirements for regulations must be fulfilled.

The present draft has the following definitions of classes:

Class A: Corresponds to very good acoustic conditions in which exposed people will only exceptionally be able to notice sound and noise.

Class B: Corresponds to good sound conditions, but exposed people may be disturbed by sound and noise to a certain extent.

Class C: Corresponds to satisfactory sound conditions for a large proportion of exposed people.

Class D: Corresponds to sound conditions in which a majority of exposed people can be expected to be disturbed by sound and noise.

In table 2, some proposed classification of airborne and impact sound insulation conditions for dwellings are shown. The limits for extended frequency range (the spectrum adaptation terms $C_{50\text{-}3150}$ and $C_{I,50\text{-}2500}$) are proposed to be used.

Compared to the Norwegian study on annoyance of sound conditions in dwellings [11, 12], the proposed limits in class C entail that about 70 % of the inhabitants are a little or not at all annoyed by the airborne sound insulation. For impact sound insulation, the same percentage will be between 60 % and 65 %. In class B, it may be expected that about 80 % of the inhabitants will be a little or not at all annoyed by the airborne and impact sound insulation.

Table 2: Draft acoustic classes for dwellings. Some of the proposed airborne and impact sound insulation limits

Type of space	Measure	Class A dB	Class B dB	Class C dB	Class D dB
Airborne sound insulation					
Between dwellings	$R'_{\mathrm{w}} + C_{50\text{-}3150}$	62	58	54	
	R'_{w}				50
Between a dwelling and a common areal/communication road such as common corridor, stairwell, stairs etc.	R'_{w}	62	58	54	50
Between a dwelling and gallery /external stairs From garage/ car parking and external storage to a living room in a neighbouring dwelling	R'_{w}	58	54	50	46
Impact sound insulation					
Between dwellings In a dwelling from a common areal/communication road such as common gallery/external stairs, stairwells/stairs etc.	$L'_{\mathrm{n,w}} + C_{\mathrm{I,50\text{-}2500}}$	44	48	52	
	$L'_{\mathrm{n,w}}$				56
In a dwelling and business and service premises, garage, common roof terrace etc.	$L'_{\mathrm{n,w}} + C_{\mathrm{I,50\text{-}2500}}$	40	44	48	
	$L'_{\mathrm{n,w}}$				52

4 Summary

If we compare the acoustic and vibration classes, we can see that the class C is similar when the highly annoyed are considered [1, 4]. At vibration class C for dwellings, about 10 % of the inhabitants are expected to be highly annoyed. With the proposed limit values for impact sound insulation, including the low frequency consideration in class C for dwellings, about 10 % of inhabitants may be expected to be very annoyed. For airborne sound insulation, less than 5 % may be expected to be very annoyed [11, 12].

In the regulations from 1997 and earlier, the intention was that about 80 % of inhabitants may be expected to consider the sound conditions satisfactory. The requirements at that time did not differ very much from those of today, and at that time the low frequencies were not considered at all [20, 21]. However, in the early considerations the uncertainty was higher due to lack of extensive studies on human annoyance on the sound conditions. If the percentage of satisfied people would be about 80 %, then application of class B would be appropriate.

The revision is ongoing at the writing moment, and the tabled values and text quoted to the acoustic limits in this paper, may differ from those in the final edition of revised NS 8175.

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