Transformation into dwellings an acoustical problem?

Wim Beentjes

LBP|SIGHT BV, POBox 1475, 3430 BL, Nieuwegein, The Netherlands

ABSTRACT

In the Netherlands is a need for dwellings especially for starters because they were not built during the last 20 years. Also because of the crisis many office buildings, old factories, old service flats etc. are not in use any more, waiting for a new destination. In many cases transformation into dwellings is a good solution for all, so it cuts both ways. The praxis for these transformations gives birth to new acoustic solutions for a good sound insulation between dwellings and low sound levels for noise of service equipment. Special problems occur in offices that are lying in the direct neighborhood of traffic high ways. Sometimes special constructions are needed to lower the sound level on the façades. A few examples will be given to show the solutions and the restrictions for an old school, an old factory with a construction out of steel and a more recent office. The assumptions were treated: Not the legally obtained level (it is not allowed to make it worse) but a good acoustic dwelling with a sound insulation level of newly built dwellings high ($L_{nT;A} \leq 54$ dB and $R'_A \geq 52$ dB) or even better.

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1. INTRODUCTION

At the moment two things we have to meet in the Netherlands:

1. There is a shortage of dwellings especially for starters, students and for the middle class. During the last 15 years and especially during the economic crisis of 2008 less (small) dwellings were built;
2. Also because of the economic crisis, many office buildings, old factories, old service flats and hospitals are out of use and are waiting for a new destination or for removal.

After some research of architects and developers most of the buildings which are not in use any more can be transformed into dwellings for various people: from starters till the upper market for residences.

In this paper the acoustical consequences and possibilities of these transformations into of real estate will be discussed:

In chapter 2 the typical legal aspects of the acoustical requirements are discussed. In chapter 3 two general schemes were given reaching the requirements for newly build dwellings and for situations with requirements for 5 dB better (for luxury class). In chapter 4 some examples will be given of transformations. In chapter 5 conclusions are given.

2. REQUIREMENTS

2.1 Legal requirements

In the Netherlands the requirements for building are in the Dutch Building Code(1)

For new dwellings the requirements are given in table 1

<table>
<thead>
<tr>
<th>Situations</th>
<th>Airborne sound insulation $R'_A$ dB</th>
<th>Impact sound insulation $L_{nT;A}$ dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living area</td>
<td>$\geq 52$</td>
<td>$\leq 54$</td>
</tr>
<tr>
<td>Non-living area.</td>
<td>$\geq 47$</td>
<td>$\leq 59$</td>
</tr>
<tr>
<td>Living/bedrooms in the same</td>
<td>$\geq 32$</td>
<td>$\leq 79$</td>
</tr>
</tbody>
</table>
The living area consists mostly of adjacent living rooms and/or bedrooms, without bearing constructions and on the same floor. Rooms as the bathroom, toilet, attic and common rooms as corridors and staircases are no part of a living area. Between these rooms the requirements are 5 dB lower. For the exact definition of $R'_A$ is referred to NEN 5077:2006.

\[ L_{nT;A} = L'_w + C \] according to ISO 717-part 2:2013
\[ R'_A = R'_w + C \] according to ISO 717-part 1:2013

In case of renovation the requirement level is the legally obtained level as stated in the last planning permission. These levels are summarized in table 2. If the actual level is higher than the requirements for newly built dwellings, than it is even allowed to lower the quality to the level for newly built dwellings.

In case of transformation into dwellings, there is no legally obtained level because the existing level has no connection with dwellings: in principal everything is allowed, even very low quality. (There are always requirements for fire-protection so not everything is allowed).

Table 2 — Requirements airborne and impact sound insulation during the last 50 years

<table>
<thead>
<tr>
<th>Period</th>
<th>Airborne sound</th>
<th>Impact sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1962</td>
<td>No requirements</td>
<td>No requirements</td>
</tr>
<tr>
<td>1962 – 1976</td>
<td>$R'_w + C \geq 51$ dB</td>
<td>$L'_{nw} \leq 65$ dB</td>
</tr>
<tr>
<td>1992 – 2003</td>
<td>$R'_A \approx R'_w + C \geq 52$ dB</td>
<td>$L_{nA,T} \leq 59$ dB</td>
</tr>
<tr>
<td>2003 – now</td>
<td>$R'_A \approx R'_w + C \geq 52$ dB</td>
<td>$L_{nA,T} \leq 54$ dB</td>
</tr>
</tbody>
</table>

2.2 Requirements in practice

In practice the principle is to meet the requirements for newly built dwellings, but sometimes it is not possible, mostly because of monumental structures that have to be respected or there are other difficulties with some building parts. Sometimes the requirements, that can be reached, will be 5 dB higher than the legal requirements. If the developer wants to reach this level and the building has a good quality and appearance, the transformed building is also suitable the upper class of the market.

The legal level and the 5 dB (mostly called “comfort”) level will be treated furthermore in this paper.

3. Transformation

Most buildings that have to be transformed into dwellings, have more than one floors and will be transformed in apartments. The buildings are:
- Old factories, with wooden or concrete floors
- Offices with concrete floors (after 1965) or wooden floors (before 1965)
- Schools, from primary schools to university buildings
- Old hospitals, not up-to-date anymore
- Homes for aged persons not up to date anymore

At first we give some characteristics of the original buildings, then we show two general schemes to solve the problem of sound insulation, depending on the type of separating walls and floors. One scheme to reach the newly built level and one scheme to reach a 5 dB better sound insulation (the so called comfort level or class 2 according to the Dutch classification scheme of NEN 1070:1999. These

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schemes are based on investigations in renovation situations, in laboratories and field measurements and extended to transformation.

3.1 Characteristics of transformation buildings

In originally built dwellings the typical situation is that the separating walls mostly are bearing stony or concrete walls. In transformation buildings this is usually not the case. The area of the whole building must be as open as possible. For that reason the bearing constructions are concrete columns or columns made of steel. The concrete floors of industrial buildings built before 1940 are less thick (80 mm to 140 mm) and are strengthened by concrete beams in both directions (see figure 1). Sometimes steel constructions are also carrying the floor, see figure 2. In that case there is no need to place columns in the middle of the building. In most buildings there are a few bearing walls for the overall stability of the building, mostly near elevators or other central provisions.

![Figure 1 — Bearing construction of an old factory, (left) with concrete columns and concrete floors with concrete beams. (right) with steel columns and beams and a wooden floor](image)

After 1970 thicker concrete floors (180 to 250 mm) were used without strengthened beams in offices, hospitals and homes for aged persons. Bearing beams under the floor are not necessary anymore, only the columns and the floors itself are needed as bearing constructions. The separating walls in this types of buildings were replaceable light weight walls mostly made with gypsum board panels or metal stud systems especially for offices, hospitals etc.

In schools the number and types of floors is as in dwellings: before 1960 mostly wooden floors and after 1960 concrete. Especially in primary schools there is only one floor and mostly stony walls of 100 mm bricks are present. Secondary schools, High schools and universities have multi-story buildings with concrete floors and light weight or brick or concrete walls.

3.2 Schemes to improve sound insulation

In 2005 Gyproc Netherlands presented the Gypbox(2,3), with solutions for renovation of dwellings based on investigations on the influence of floating floors, acoustical linings and suspended ceilings. It handles on laboratory measurements and measurements in the field on wooden and stony floors, brick and concrete walls. The basics are also useful for transformation. But it is not suited for light weight walls. Therefor the system is enlarged with light weight walls. Sources for this enlargement are the code of practice NPR 5086:2006 (4) that gives solutions for light weight walls in various flanking conditions and several measurement results in the field. The results of this are given in the two next tables for the level of the Dutch requirements ($R'_{A} \geq 52 \text{ dB}$ and $R'_{A} \geq 57 \text{ dB}$ in combination with $L_{nT;A} \leq 54 \text{ dB}$ respectively 49 dB).

3.3 Explanation of the schemes

In every row | column combination the measures are given for the floating floor (F), the acoustical
lining (W) and the suspended ceiling (C) for a category of floors (horizontal) and walls (vertical). The measures have to be taken in the send- as well as the receiving room, except for the acoustical linings for walls: Only when ‘2x’ is stated, the acoustical linings have to be placed on both sides of the separating wall.

For the acoustical linings and the suspended ceilings the descriptions of Gyproc are used. The dry floating floor is characterised by $\Delta L_{\text{lin}}$ conform ISO 717 part 2:2013

- $\Delta L_{\text{lin}} = 10$ dB: E30MF or 2x 10 mm gypsum fibre board and 10 mm rockwool
- $\Delta L_{\text{lin}} = 13$ dB: E30MF + E20 = 2x 10 mm gypsum fibre board (1250 kg/m³) or a wet (screed or anhydrite) floating floor, if the bearing construction is strong enough.
- $\Delta L_{\text{lin}} = 16$ dB: as 13 dB only with a layer of screed of ca 100 mm, instead of 50 mm.

The use of the tables can be as follows: Sometimes it is not allowed to use suspended ceilings because of monumental considerations. In that case it has to be investigated to increase the weight of the floor.: If the floor has a weight of 325 kg/m², the scheme in table 3 shows that the minimum mass for the floor is 400 kg/m², when a suspended ceiling will not be applied. Enlarging the weight of the floor to that level makes it also possible to meet the requirements for newly built dwellings. A design engineer has to check that the construction can bear this extra weight.

In Dutch acoustic design in case of lightweight walls it is common use that the wall has to have a measured sound insulation in the laboratory ($R_A$ or $R_{w+C}$) that is 5 dB better than the requirements.

Typical lightweight walls used in the Netherlands, are

- metal stud walls with double or single C-profiles;
- panels consisting of gypsum board and flax-waste;
- panels or blocks of gypsum or blocks of panels of aerated concrete with special acoustical linings: 25 mm mineral wool with 12.5 mm gypsum board with metal Z-profiles

The description of the products is according to Gyproc products. Compatible products can also be used.

Table 3 — Design scheme for sound insulation in case of transforming buildings into apartments.

<table>
<thead>
<tr>
<th>Existing wall</th>
<th>Mass ≤ 500 kg/m²</th>
<th>Mass ≥ 500 kg/m²</th>
<th>Mass ≥ 600 kg/m²</th>
<th>New Light weight wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>$\Delta L_{\text{lin}} \geq 13$ dB</td>
<td>$\Delta L_{\text{lin}} \geq 13$ dB</td>
<td>$\Delta L_{\text{lin}} \geq 13$ dB</td>
<td>$\Delta L_{\text{lin}} \geq 13$ dB</td>
</tr>
<tr>
<td>Wooden floor W</td>
<td>MS 70V/45.2.A.10</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>C</td>
<td>MS 75P/50 2.A.10</td>
<td>MS 75P/50 2.A.10</td>
<td>MS 75P/50 2.A.10</td>
<td>MS 75P/50 2A 10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stony or concrete floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 250 kg/m²</td>
</tr>
<tr>
<td>F</td>
</tr>
<tr>
<td>W</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>≥ 350 kg/m²</td>
</tr>
<tr>
<td>F</td>
</tr>
<tr>
<td>W</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>≥ 400 kg/m²</td>
</tr>
<tr>
<td>F</td>
</tr>
<tr>
<td>W</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>≥ 500 kg/m²</td>
</tr>
<tr>
<td>F</td>
</tr>
</tbody>
</table>
### Table 4: Design scheme for sound insulation in case of transforming buildings into apartments.

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Existing wall} & \text{Mass} \leq 500 \text{ kg/m}^2 & \text{Mass} \geq 500 \text{ kg/m}^2 & \text{Mass} \geq 600 \text{ kg/m}^2 \\
\hline
\text{New Light weight wall} & \text{R}_w+C \geq 57 \text{ dB} & \text{R}_w+C \geq 62 \text{ dB} \\
\hline
\end{array}
\]

#### 4. SOME EXAMPLES OF TRANSFORMATION

Out of our various work in transformation we give some examples in the next subparagraphs.

- A Technical high school with concrete floors with a weight of 500 kg/m² and an concrete column structure. Originally built in the fifties of the last century
- An old chocolate factory with concrete floors, beams and columns
- An office with wooden floors, built in several periods in the first half of the 20th century
- The Ministry of home affairs with concrete floors beams and iron columns
- Office buildings with separating walls in connection with old monumental windows.

#### 4.1 Technical High school with floors ca 500 kg/m² and concrete columns

In this situation the main construction is as follows:

- Concrete floors of 190 mm and 30 mm screed (513 kg/m²)
- Concrete columns, rectangular and circular
- Inner façade wall, made of TBB 100 or 200 mm thick

In this project the proprietor wants to meet the legal requirements.
This is possible with a MS-wall at every separating with a laboratory $R_w + C$ value of 58 dB. That is enough for the newly built requirements ($\geq 52$ dB) in the horizontal direction.

On the 500 kg/m² floor is planned a wet floating floor of 40 mm Rockwool and 100 mm screed (with a heating floor inside). The acoustical performance is enough for the newly built requirements. But, because of the height (3.50 m) and because of the fact that the service equipment must have a place directly under the concrete floor, a suspended ceiling of 12.5 mm gypsum board on a cavity of 250 mm is applied. With this constructions even the comfort class will be reached in the vertical direction. In the horizontal direction only the newly built level will be reached because of the light weight wall.

The transformation starts at the end of 2016.

The designed floor and wall construction are given in figure 3.

Figure 3 — Designed floor construction for transformation of a technical high school into dwellings

4.2 Chocolate factory

In this factory the floors are made of 80 mm concrete with concrete beams in both directions, see figure 4. The vertical bearing constructions are concrete columns. See also figure 1 left. At first we try a floating floor and a suspended ceiling to improve the sound insulation. However the sight on the concrete beams must be respected, because of the monumental structure of the factory: So the suspended ceiling was not possible. The solution is to make the floor heavier: in cooperation with the concrete designer the mass of the floor is increased from 340 to 430 kg/m² and with a wet floating floor with an heavy screed (190 kg/m²) the sound insulation meets the legal requirements. see figure 5 for the floor and wall construction.
4.3 Office building with wooden floors

This office is placed in an old dwelling and after a few enlargements expanded to an office for a broadcasting company. At the moment the office will be transformed back into dwellings. In the design process solutions for the newly built requirements as well as for the comfort class are considered and it was decided to meet the legal requirements. For the wooden floor the design was given in figure 6.
The façade construction has flexible connections to the separating wall. The new ceiling, the mineral wool in the cavity and the dry floating floor with floor heating improve the sound insulation.

This floor can reach the comfort class but only in the living room (55 m²), because of the impact sound insulation depends on the surface of the floor. In the bedroom (15 m²) the LnT;A value is ca 6 dB lower, but meets the legal requirements. The solution for the separating wall is an existing 120 mm brick wall with an acoustical lining with a $R'_A \geq 52$ dB.

4.4 Office with a strip of glazing

In this relative recent office building there are strips of glass of 1.70 m high at every story. (see figure 7) Dividing the office into dwellings is only possible at window frames, which limits the achievable sound insulation. Not because of the glazing that is fitted in rubber, but because of the wooden window frame. The effect will be a 2 dB lower sound insulation due to flanking transmission. The 100 mm thick metal stud wall gives an $R_A$ just below the legal requirements for newly built dwellings. Because of the connection with the window frame the expected $R'_A$ value is 49 dB.

Another problem is the 120 mm limestone inner façade wall that is also present over the whole façade. A dilatation is necessary at the connection with the separating wall.
The connection of the window frame to the separating wall diminish the sound insulation of the wall with ca 2 dB, resulting in $R'A$.

4.5 Old factory with wooden floors and steel beams and columns

In an old flour factory some parts are built with a steel bearing structure of columns and beams, see figure 9.

The bearing construction made of steel columns and beams. The floor construction consists of 80 mm of wood supported by horizontal steel beams.

The problem in this situation was the contribution of the steel-construction to the sound propagation in vertical direction. The steel construction has to be visible in the room because of the monumental aspect. Because it is difficult to calculate the sound insulation of the steel columns and beams, it was decided to measure it. With an airborne sound source the sound level in the send room is measured and with velocity measurements on the steel construction in the receiving room. This way was chosen because of the low sound insulation of the 80 mm wooden floor. The radiation efficiency was calculated according to Maidanek(5). A $R_A$-value of ca 50 dB is derived from the measured $L_v$-levels. Because of this value it was decided to leave the steel construction visible. The concrete designer calculated that the mass of the floor can have a maximum weight of 600 kg/m² with a floor of 500 kg/m² and the load by the inhabitant is 100 kg/m² so the load of the floor must be maximum of 400 kg/m² a standard floating floor (340 kg/m² basic concrete floor and a floating floor of 144 kg/m²) for a $L_{NT,A}$-value of ca 49 dB for the relatively large rooms.

In this project extra measures have to be done to be for the connections of the window frames with the lightweight separating walls and to keep the floating floor free from all the vertical constructions. The building process is (may 2016) at the end of the design process. The new floor construction consists of: 80 mm existing wood, a waterproof foil, 180 mm concrete in a steel profile.
(400 kg/m²), and a floating floor of 90 mm (20 mm mineral wool and 70 mm screed. Here also some measures have to be taken for the connection of the wall with the window frame, see in fig. 10.

![Figure 10 — Connection of separating wall with window frame and building the separating wall around the vertical steel frame](image)

4.6 Old department of home affairs

At the moment the old department building is transformed partly in dwellings and partly in a university building. The main construction is of steel and the floors are made of concrete on concrete beams. In this situation it was allowed to design a suspended ceiling under the concrete floor. Also a wet floating floor was programmed.

![Figure 11 — The steel strips connect the balconies to the concrete floor. How to make a floating floor without connections between the concrete floor and the screed](image)

Problems appeared because of the balconies are strongly connected to the concrete floor with steel strips and thick screws. See figure 11. Special measures were taken to avoid connections between the screed of the floating floor and the concrete of the existing floor. The floating layer at the steel strips was made of fonofloor (8 mm thick dynamic stiffness = 17 MN/m³). The floating layer of the other the lower part was made of 20 mm elasticized EPS with a dynamic stiffness of the class under 20 MN/m³.

Measurements between bedrooms and living rooms were done in a mock-up. They showed that the $R'\Delta$-value was 58 dB in the horizontal direction and 63 – 71 dB in the vertical direction. The measured
$L_{TN}$A values are 43 dB respectively 33-43 dB. High values are also possible in buildings that will be transformed into dwellings.

5. CONCLUSION

Our consulting praxis shows that it is possible to achieve a sound insulation in dwellings in transformed buildings that meet the requirements for newly built dwellings or even 5 dB better, despite the low requirements in the Dutch building code for transformation. (legally obtained level according to the last planning permission or no requirements at all). The needs of the inhabitants show that a good sound insulation is needed. Sometimes a little lower sound insulation is unavoidable, because of the existing (monumental) constructions. but in that case it is to look for best able solution. Several examples illustrate the various aspects, so that transformation does not have to be an acoustical problem.

REFERENCES

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