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Stage acoustic requirements extended to orchestra rehearsal rooms

Margriet Lautenbach[a], Martijn Vercammen[b]

[a] Peutz BV, The Netherlands, m.lautenbach@peutz.nl
[b] Peutz BV, The Netherlands, m.vercammen@peutz.nl

Abstract

In the last 8 years a lot of research has been carried out in the field of stage acoustics. The inducement for the investigations originally was initiated by the direct question concerning the improvement of the stage acoustics for a renovation. But the topic continually had our attention for new concert halls, other renovations and not at least: orchestra rehearsal halls.

In order to rehearse on sound quality, balance and playing in time, the acoustical conditions in the rehearsal hall should not differ too much from the conditions on stage in a concert hall. This means that the rehearsal halls should not be too loud, have a decent frequency response, early reflections and reverberation time.

The best place to have the rehearsal is mostly the concert hall. But the purpose of a separate rehearsal room is usually to have the maximum possibility to exploit the concert hall, and the economics desire a cheap and therefore small rehearsal room. With a lot of small (ca 2000 m³) orchestra rehearsal rooms as a reference, the acoustical reasons for investing in a much larger orchestra rehearsal room should be very strong.

In this paper the demands for good stage acoustics and the European requirements on sound exposure are extended to orchestra rehearsal rooms. Measurements in several (and very different) orchestra rehearsal rooms are provided to substantiate the maximum allowed differences between the performance environment and the rehearsal environment.

Keywords: Stage acoustics, orchestra rehearsal room

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1 Introduction

For an orchestra that needs to rehearse on sound quality, balance and playing in time, the acoustical conditions in an (symphonic) orchestra rehearsal hall should logically not differ too much from the conditions on stage in a concert hall. This means that the rehearsal hall should not be too loud, have a decent frequency response, early reflections and reverberation time.

The best place to have the rehearsal is mostly the concert hall. But the purpose of a separate rehearsal room is usually to have the maximum possibility to exploit the concert hall for other clients, and the economics desire a cheap and therefore small rehearsal room. With a lot of small (ca 2000 m³) orchestra rehearsal rooms as a reference (especially in Germany), the acoustical reasons for investing in a much larger orchestra rehearsal room should be very strong.

In this paper, the demands for orchestra rehearsal rooms are reviewed from different angles:

- literature and standards;

- "noise" exposure;

- with respect to the "average" concert hall;

- with respect to stage acoustics;

- a few recent examples on orchestra rehearsal rooms.

2 Literature on orchestra rehearsal rooms

According to Beranek [2]: If a seperate rehearsal space is to be provided, the optimum RT should probably 0.2 to 0.4 s lower than the concert hall, provided that the conductor and orchestra agree. Goal is a better intelligibility and definition for the rehearsal.

Tennhardt & Winkler wrote a paper in 1995 [3] in which they state that in a few years, they experienced a fundamental change in acoustic requirements for orchestra practice rooms. Whereas practice conditions very close to performance conditions had to be realised up to then, a critical analyses of the musicians and singers became more important, leading to the demand for shorter reverberation times, higher clarity and less mixing of the sound picture. This statement is difficult to verify, as they do not write for which orchestra's they got this "new" requirements as a goal for a rehearsal room. But it is a fact that especially in Germany a lot of relatively small orchestra rehearsal rooms exist, which are now used to substantiate the idea that orchestra rehearsal rooms may in volume be reduced until about 2.000 or 3.000 m³.

Tennhardt & Winkler recommend an average RT between 0,8 and 1,1 s. They also state that the Loudness should not substantially differ from concert hall conditions, in order to reduce hearing loss and to support critical listening. From there they conclude that for an orchestra of 60 to 80 musicians, the volume should not be less than 2.000 m³. In order to reduce the loudness, the RT should be reduced to the given range, or the volume of the hall should be at least 5.000 m³.

Pompoli [4] proposes a geometrical approach from which he concludes that in order to attain a suitable ST_{Early} of -12 dB (+/- 2 dB) and a height in the range of 5 to 7 m, the room volume ranges from 750 to 2.500 m². For larger volumes and heights, ceiling reflectors can be installed in order to increase the ST_{Early}. He nevertheless concludes with the statement that in order to reduce the sound level, it is important to increase the volume per musician as much as possible.

Rindel describes in his paper about the new Norwegian Standard for rehearsal rooms [5] a method to estimate the optimum strength for a music rehearsal room. The total sound power at *forte* (L_w(f)) of an ensemble can be estimated from the sum of the number of instruments multiplied by the k-factor for those instruments. From several studies it was concluded that the optimum range for the sound pressure level at forte L_p(f) shoud be in the range of 85-90 dB, which is the basis in the new Norwegian Standard. Here it is noticed that Meyer (see also [5]) found 90 dB to be the optimum for *forte* sound level.

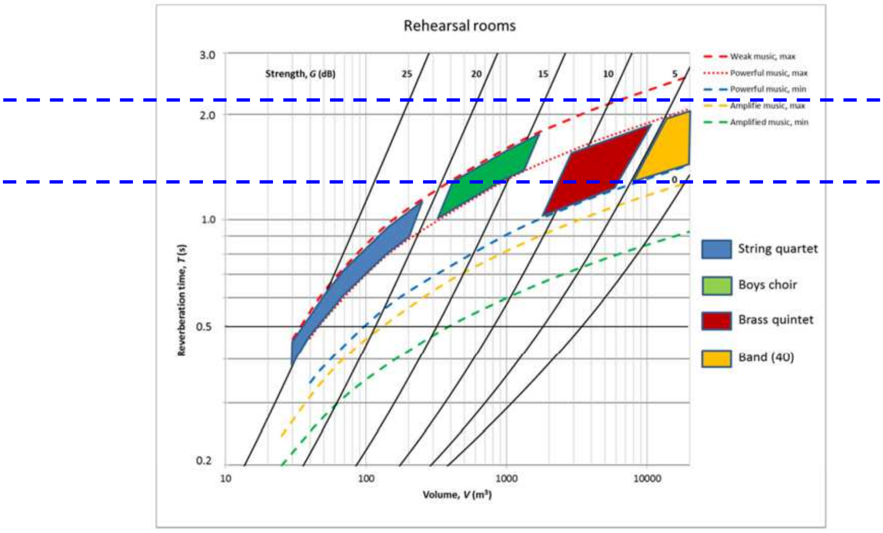
Rindle also refers to an example described by Meyer, in which it was found that the dynamic range of a piano piece by the same musician was clearly bigger in a room with optimum reverberation time, than in rooms with a too short RT (dry) or a too long RT (over-acoustic).

The Norwegian standard gives two graphs, one for performance spaces and one for rehearsal rooms, for three types of music, from which a range can be selected for Volume and RT, based on the type of music and the optimum range for the loudness. Although a symphonic orchestra rehearsal room seems (just) out of scope for the Norwegian Standard, it is an interesting method to check the outcome for an orchestra rehearsal room. As for an example, the sound power level of a 90 musician orchestra is about 116 dB. This means that according to [6]:

$$L_p(f) = L_w(f) + G - 31\,dB \tag{1}$$

the Strength G should be 5 dB in order to have an optimum L_p(f) of 90 dB. This is not a very surprising outcome, as the average measured and theoretical G is 4 to 5 dB for the concert halls with good critics (see chapter 4).

According to the new Norwegian Standard, the Strength G for an orchestra rehearsal room should be in the range of 0 and 5 dB. If this is expanded to the graph for rehearsal rooms, the minimum requirements for an orchestra rehearsal room would be a volume of 8.000 m³ and an RT of 1,2 s. The maximum cannot be read from the graph, but would be about 12.000 m³ and an RT of 2,1 s. See figure 1 on the next page.



Source: (Rindel, 2014) [4]

Figure 1: Upper and lower limits of RT and Volume for a specific range of G for rehearsal rooms according to the Norwegian Standard. The orchestra rehearsal room would be the yellow range.

3 European legislation on noise

Also for (orchestra) musicians, the European Directive 2003/10/EC applies, which means that they should be protected from noise levels that may cause hearing damage. For symphonic orchestra's with a lot of late romantic works on their agenda, the noise exposure is critical to this standard. As technical solutions are preferred above organizational solutions (like changing the repertoire), it is important that the levels in the rehearsal room, do not add up to the level exposure (technical measure). Although the real exposure level due to the musicians own instrument and all the other instruments is very difficult to analyse or to predict (see for instance [8] and [9], it is easy to calculate that the Strength G should be limited in order not to significantly contribute to the total sound level.

For distances of 1 m or less (sound level of the own instrument), the Strength G is of little influence. Only if the Strength G is larger than +10 dB, it may have influence.

But for sound sources at distances, especially larger than 2 m, the influence of Strength G becomes more important. For a Q of 1 and distance of 2 m, a Strength G of + 5 dB already increases the sound level with 0,5 dB. Therefore, the Strength G of the orchestra rehearsal room is an important acoustic factor for the sound exposure of musicians.

4 The "average" concert hall

Following the idea that the acoustical conditions in an orchestra rehearsal room should not deviate too much from the performance conditions in the concert hall, it is important to know what the "average" conditions in the concert hall are. Though it is quite clear that the average concert hall does not exist, it is known that the well known and liked concert halls share some basic properties. From the Beranek overview [1] the average values of 24 concert halls larger than 12.000 m³, good critics and in which the strength has been measured we find the following averages:

Volume:	ca. 20.500 m³	Seats:	ca. 2.100
RT occupied:	1,9 s	G5-80 on stage:	2,3 s
G,mid,unocc.:	+3,6 dB	G,theoretical, unocc*	+5,4 / +4,5 dB
Hall radius r**:	5,4 / 9,4 m (Q = 1 / Q = 3)		

* the calculated strength G in the reverberant field according to:

$$G = 31 - 10\log\left(\frac{V}{24T}\right) dB \tag{2}$$

$$G = 10\log\left(\frac{100}{r^2} + \frac{1600\pi^2(1-\alpha)}{A}\right) dB \tag{3}$$

with V being the volume and T the reverberation time, at a source-receiver-distance r = 20 m and an average absorption/m² α of 0,25.

** The calculated hall radius for Q = 1 and 3 respectively according to:

$$r = \sqrt{\frac{QA}{16\pi}}\ m \tag{4}$$

With the amount of absorption (A) calculated from the RT and the hall volume, and Q being the directivity index of the source.

So if the rehearsal room conditions should not differ too much from the performance conditions, limits have to be set as a possible deviations from the average RT, G and hall radius of the "average" concert hall, or a specific concert hall.

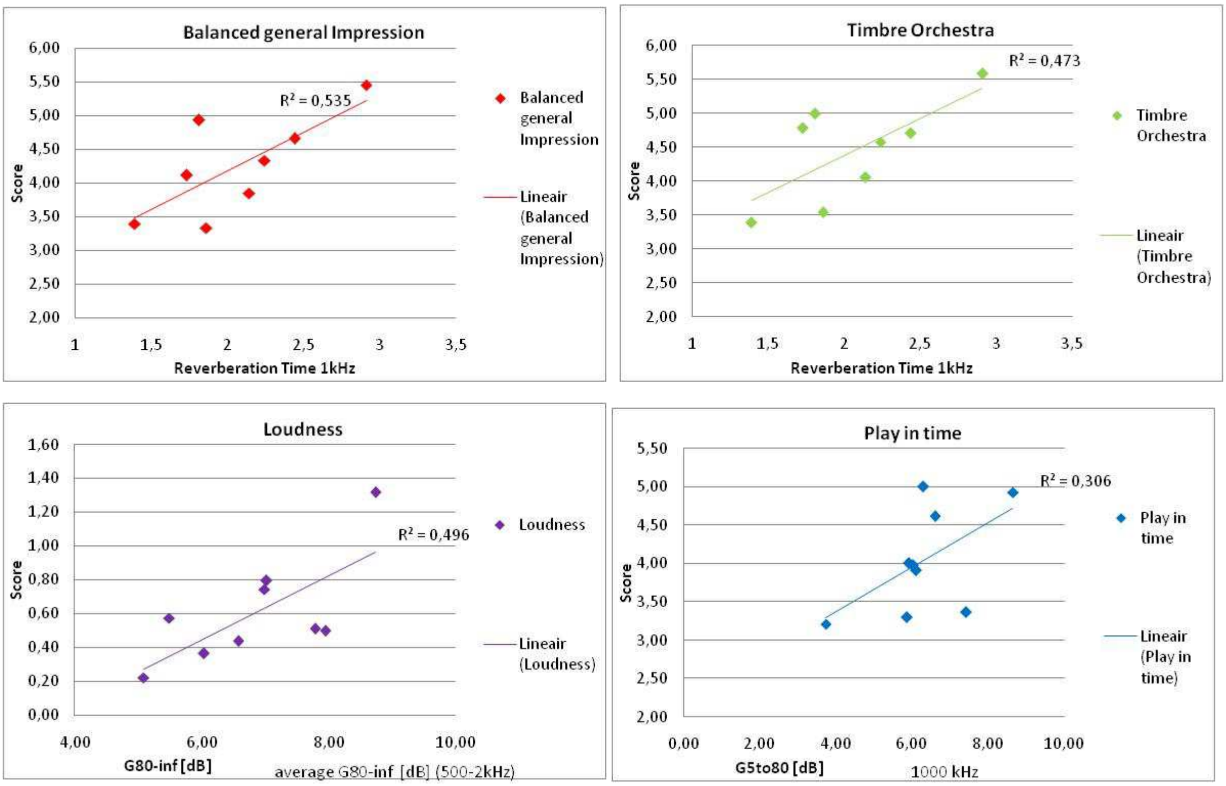
From [6] we know that the just noticeable difference (JND) for the RT is 5%, and for the G it is 1 dB. If we'd assume a 2*JND would be acceptable, this would mean an RT of 1,7 s and a G of 6,5 dB. To realise this, the volume needs to be at least 10.000 m³ (according to (3)). But it has to be noticed, that the hall radius already decreases with 1 m for a Q of 1, also it decreases more for larger Q's (which is the case for a lot of musical instruments). This means that the sound from other instruments has more reverberant energy in it. From that, it is concluded that with half the volume of the concert hall, and 2*JND difference in RT and G, the balance within the orchestra already changes. Only if we reduce the RT further, the hall radius could be maintained.

A further reduction of the RT on the other hand, will influence the players behaviour. In a dry room, musicians tend to play louder. Apart from that, especially the string and woodwind instruments need the reverberation for a rich sound quality.

Although a higher Strength G is already not favourable related to the "noise exposure", a higher Strength will also influence the musicians behaviour. As the Strength G mainly influences the sound level of other instruments, they will hear their own instrument less good, from which they will have the tendency to play louder, which disturbs the balance, relative to the performance hall.

5 Musician's Preferences for stage acoustics

From our ongoing stage acoustics investigation [10] in which measurments on different stages are compared to the individual opinions of the musicians, we find a correlation between the musicians opinion and the measured RT at 1kHz when it comes to the "balanced general impression of the hall and the timbre of the orchestra, see figure 2.



Figures 2a to d: Correlation graphs between the measured parameters and the subjective musicians opinion [10].

There is also correlation between the measured late loudness ($G_{80\text{-}inf}$) and the perceived loudness. The early reflections ($G_{5\text{-}80}$) are important in order to play in time.

6 A few examples

The NedPhO-Koepel Amsterdam (realised in 2012 in a monumental church), for the Dutch Philharmonic Orchestra, which plays in the Amsterdam Concertgebouw and in the Amsterdam Opera.

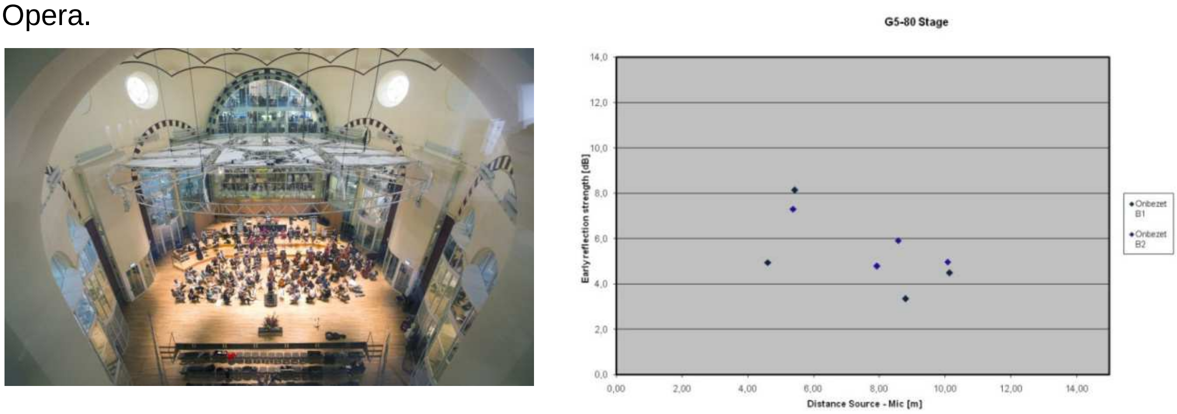


Figure 3a and b: The NedPhO-Koepel and the measured strength of the early reflections $G_{5\text{-}80}$.

Volume:	12.000 m³	RT unocc:	1,9 s
Strength G ≥ 5m, unocc:	+5,0 to +9 dB	$G_{5\text{-}80}$ on stage ≥ 5m:	+3,3 to + 8,1 dB
ST_{Early}:	-12 to -14 dB	C_{80}:	0,1 dB

The musicians are very, very happy with their rehearsal room, it is never too loud.

Der Grosse Sendesaal NDR Hannover, for the Radiophilharmonie NDR, which rehearses and performs in this hall.

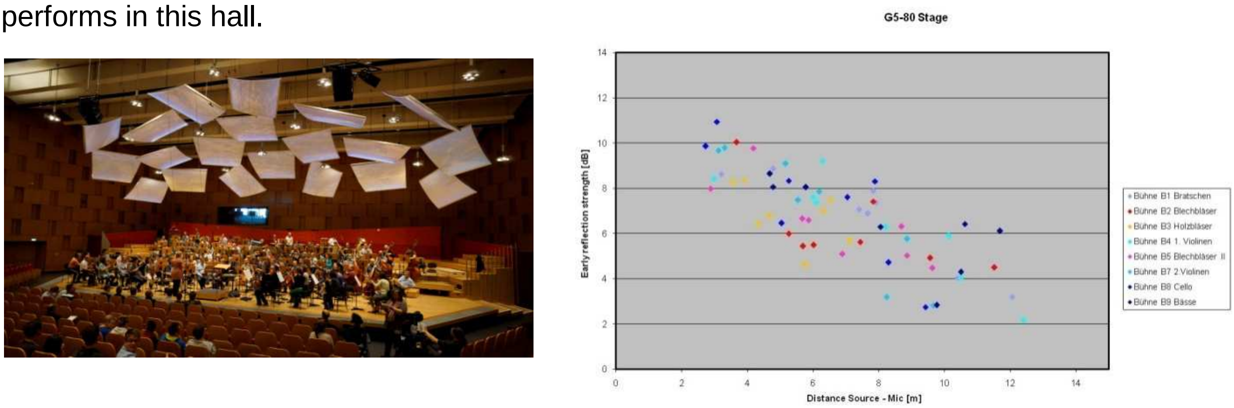


Figure 4a and b: The Gr. Sendesaal and the measured strength of the early reflections $G_{5\text{-}80}$.

Volume:	12.000 m³	RT unocc:	1,9 s
Strength G ≥ 5m, unocc:	+2,5 to +9 dB	$G_{5\text{-}80}$ on stage ≥ 5m:	+2,0 to + 9,0 dB
ST_{Early}:	-9,7 to -14,3 dB		

The musicians can hear themselves quite good, but have difficulty hearing the other instruments, they complain on the harsh sound. The first might be explained by the large differences on stage for the strength of the early reflections and support. The latter might be explained by the extremely low height of the reflectors.

Orchesterprobezentrum Stolbergerstrasse, Köln, before renovation, Gürzenich Orchester, which performs in the Köln opera house.

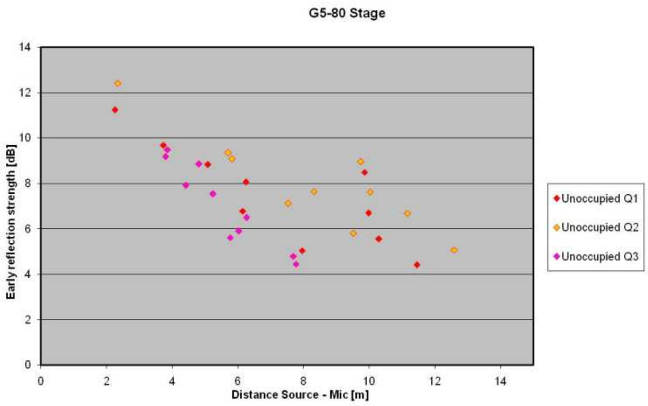


Figure 5a and b: The Stolbergerstrasse and the measured strength of the early reflections $G_{5\text{-}80}$.

Volume:	5.100 m³	RT unocc:	1,9 s
Strength G ≥ 5m, unocc:	+6,0 to +13 dB	$G_{5\text{-}80}$ on stage ≥ 5m:	+4 to + 9,5 dB
ST_{Early}:	-8 to -12 dB	C_{80}:	-2,1 to + 4,0 dB

The musicians found it too loud for the orchestra, difficult playing together, and a harsh sound. The found it too loud below the orchestra reflector, therefore their position was before the reflector. This, the ceiling T-beams and the low amount of diffusion caused a very poor sound distribution in the room, the loudness was high.

Orchesterprobezentrum Stolbergerstrasse, Köln, after renovation, Gürzenich Orchester, which performs in the opera house.

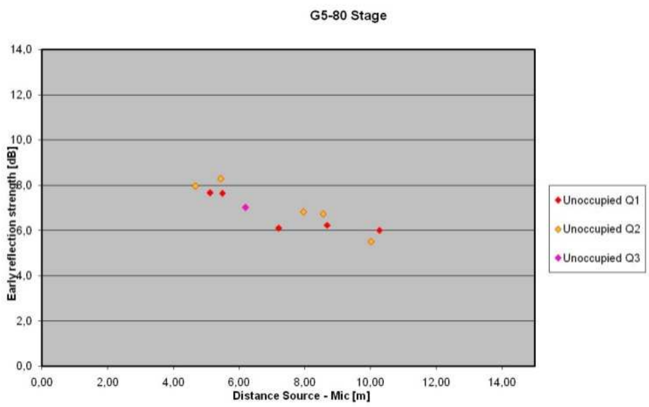


Figure 6a and b: The Stolbergerstrasse and the measured strength of the early reflections $G_{5\text{-}80}$.

Volume:	5.100 m³	RT unocc:	1,3 s (var. to 2,0 s)
Strength G ≥ 5m, unocc:	+8,0 to +10 dB	$G_{5\text{-}80}$ on stage ≥ 5m:	+4,8 to + 8,1 dB
ST_{Early}:	-11,1 to -12,8 dB	C_{80}:	-0,5 to + 2,5 dB

The musicians are very happy with the sound quality, but are still anxious that the loudness is too high.

Kranenburgweg Den Haag, het Residentieorkest, which used to play in the Concert Hall in the Hague (destroyed) and now performes in a temporary theatre they share with the Dutch Dance Theatre.

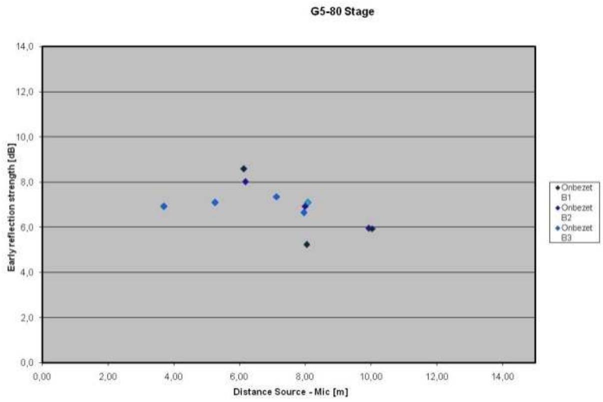


Figure 7a and b: The Kranenburgweg and the measured strength of the early reflections $G_{5\text{-}80}$.

Volume:	4.050 m³	RT unocc:	1,3 s (3,9 s at 63 Hz)
Strength G ≥ 5m, unocc:	+7,5 to +11,5 dB	$G_{5\text{-}80}$ on stage ≥ 5m:	+5,2 to 8,6 dB
ST_{Early}:	-11,2 to -13,7 dB		

The musicians refuse to enter the room again, they find it way too loud. Three musicians claim to have hearing damage due to the rehearsal room. We have moved the orchestra to a temporary location, an old school atrium with a volume of 8.000 m³.

7 Discussion and conclusion

From literature study we find very different requirements for orchestra rehearsal rooms. As for the smaller rooms, Tennhardt & Winkler are the only ones that try to substantiate a reason or a goal for smaller orchestra rehearsal rooms. And it is a fact that especially in Germany a lot of relatively small orchestra rehearsal rooms exist, which are now used to substantiate the idea that orchestra rehearsal rooms may in volume be reduced until about 2.000 or 3.000 m³.

But as often being the case, the fact that something exist, does not mean that it is good, or that the musicians are happy. It is often difficult to get a good opinion from the orchestra, as being the average of all musicians. The manager stating that all musicians are very happy might not be drawing the right conclusion. In addition to that, Germany has several specialised opera orchestra's. As the conditions in the orchestra pit severely differ from a concert hall stage, their demands for an orchestra rehearsal room may severely differ from an orchestra that has a core business on the concert hall stage. Therefore, the smaller orchestra rehearsal room for an opera orchestra might not be a good reference for the average symphonic orchestra rehearsal room.

From the several approaches it is quite clear that the loudness is important, for a symphonic orchestra rehearsal room. A good requirement might be to reduce the Strength G to + 7 dB at average.

The RT seems of lesser importance, at least not as important as the loudness, but the larger the deviation from the concert hall, the less good the orchestra can rehearse, on sound quality and balance. Musicians are sensitive to the RT as is described in [5] and is to be found in the correlation between the RT and the musicians opinions on balance and timbre (chapter 5). So there is good reason to set a goal for the RT that is not too short.

From the examples we see that the musicians complain about hearing the other musicians when there is a large spread in sound levels (large spread in G, $G_{5\text{-}80}$, C_{80}, ST_{Early}). Diffusive reflective surfaces are needed to realise an even distribution of sound and strength of early reflections. But if the reflective elements come very close (ie. at low height), they realise the opposite: an uneven sound distribution. Apart from that, musicians complain about a harsh sound if the reflectors are very close. In order to realise an even sound distribution, it is proposed to set limits to the spread for parameters like G, $G_{5\text{-}80}$, C_{80}, $ST_{Early.}$

All these aspects plead in favour for a large volume for the orchestra rehearsal room. The NedPhO-Koepel is a good example which shows that the described goals can be attained.

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