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The applicability of DIN 18041 in Brazilian offices

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ABSTRACT

German standard DIN 18041 – "Acoustic quality in rooms – Specification and instructions for the room acoustic design" is a relevant document, which establishes requirements, recommendations and instructions to guarantee acoustic quality according to the use of each room. Taking this into account, the Room Acoustics WG from CEE 196 of Brazilian Technical Standard Association (ABNT) is considering the possibility of implementing a new Brazilian standard based on the requirements from DIN 18041. To support this project, this study evaluates the applicability of the mentioned standard in Brazil for office spaces and provides guidelines on how it can be adopted. In order to verify how far the German standard can be incorporated, several study cases of office rooms were analysed. For this purpose, first, they were designed following DIN 18041 recommendations and then subjected to in situ measurements to verify the compliance with the proposed criteria

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1. INTRODUCTION

According to de World Health Organization, excessive noise seriously harms human health and interferes with people's ability and their activities at school, at work, at home and during leisure time. It can disturb sleep, cause cardiovascular problems and psychophysiological effect, reduce performance and provoke annoyance responses and changes in social behavior[1].

Beside these side effects, the presence of noise in offices can cause distractions and productivity loss [2]. Studies have shown that one of the most disturbing noise sources at work environment is the conversation speech on the phone or between colleagues[3].

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For this reason, to guarantee a proper acoustic quality for workspaces, a specific study is needed [4].

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In Brazil, there is only one standard which indicates acoustic criteria to design offices. The ABNT NBR 10152:2017 establishes sound pressure levels reference values, according to the usage of each indoor environment, pursuing the health preservation and human well-being[5].

The following table presents the reference values for offices according to the Brazilian standard.

Table 1. Sound pressure levels reference values according to each type of usage.[5]

Type of Use	**Reference Values**		
Office	**L_{Aeq}** (dB)	**L_{ASmax}** (dB)	**NC** (dB)
Call Center	50	55	45
Hallways	50	55	45
Enclosed Office	40	45	35
Open Plan	45	50	40
Reception	45	50	40
Waiting Room	45	50	40
Meeting Room	35	40	30
Videoconference Room	40	45	35

In addition to ABNT NBR 10152, the international standard ISO 3382-3 was adopted in Brazil as ABNT NBR ISO 3382-3. However, this standard does not show acoustic criteria or appropriated parameter that enable designing an acoustic environment [4]. In the international panorama, it is believed that this gap will be closed by the standard that is being prepared by ISO/TC43/SC1/WG65 about Acoustic quality of open plan offices.

In many countries, national building codes specifies acoustical requirements. In Germany, DIN 18041:2016 give some recommendations and basis for planning and design well-established knowledge acoustics in everyday rooms. The scope of this standard does not include “acoustic criteria for rooms with specific requirements”, for example, concert halls, churches and recording studios [6][7].

The German standard defines acoustic quality as a property of a room according to the its suitability for specific acoustical performance, for speech communication and musical performance according to the room’s usage[6]. Taking this into account, this standard presents two distinguished applications, one the audibility occurs at medium and long distances, which is characterized by category A, such as classrooms and meeting rooms. The other application, the audibility occurs at short distances, characterized as Category B, such as open plan offices, showrooms, lobby and halls.

Therefore, the rooms from **Category A**, the acoustic quality is ensured through Reverberation Time (RT) and directivity of the sound source. The RT requirements depends on the room volumes and each room usage and this RT value refers to the occupied state with an occupancy rate of 80% of the regular occupation. In case of measurement of unoccupied rooms, the standard establishes an RT correction. There are five usage types for this category, and it is described at *Table 2*.

In advance, the rooms from **Category B**, the acoustic quality for spoken communication is ensured through the ratio between the room's sound absorption area and the room's volume (A/V) and noise control. The ratio A/V values are given depending on the ceiling height of the rooms and on its type of usage. This category is dived into five main types as shown in *Table 3.*

The orientations given in DIN 18041 for the minimum required A/V ratio are applied at octaves bands from 250Hz to 2000 Hz (on category B), and the reverberation time tolerance are applied in octaves bands from 125Hz to 4000Hz (on category A), frequencies important to speech.

Table 2. DIN 18041 Criteria – Category A[6]

Category A
Usage types
A1 – Music
A2 – Speech/presentation
A3 – Education/communication
A4 Education/communication inclusive
A5 – Sports

Table 3. DIN 18041 Criteria – Category B[6]

Category B
Usage types
B1 – Spaces without amenity values. Non-habitable rooms and circulation areas where people will seldom congregate
B2 – Spaces intended for short-term use. Non-habitable rooms where there is a need for people to congregate or wait for short periods and spoken communication may be important
B3 – Spaces intended for long term use. Non-habitable rooms where people may be expected to congregate or wait for longer periods and good conditions for spoken communication it is important
B4 – Rooms with a need for reduced noise levels and room comfort
B5 – Rooms with special need for reduced noise levels and room comfort

Being an easy-to-apply standard, DIN 18041 has called the attention of the Room Acoustics Working Group 10 from CEE 196 of Brazilian Technical Standard Association (ABNT) and it is being evaluated the possibility of preparing a Brazilian room acoustics standard based on its procedures.

Analyzing the German standard's categories, it is possible to determine which usages are applicable to Brazilian offices scenario. The more frequent usage types are meeting rooms, conferences rooms and video-conference rooms from Category A, and open plan office spaces and call-centers from Category B.

Nevertheless, a very frequent room type in Brazilian offices is not contemplated by DIN 8041 due to its volume: i.e., voice booths or small meeting rooms. Because its average room volume, usually under 30m³, this usage types are out of DIN's application. The standard only considers room volumes from 30m³ to 5000m³, except for sports and pool areas, where the volume could be up to 30.000m³.

This room volume range can be explained by the difficulty in dealing with the acoustic performance of such small rooms. Voice booths have an remarkably different acoustic field and some studies [8][9] and a standard project [10] are being developed in order to simplify diverse aspects of the acoustic design and characterization of this type of rooms.

Considering all the previous information, it is observed that the prescriptions given at DIN 18041 are clear, unambiguous and that the requirements can be easily measured and evaluated. Due to the lack of room acoustics prescription guides or national standards in Brazil, which can provide a reference to architects and acoustic consultants when design a room for everyday usages, *e.g.* offices, classrooms or hospital rooms, the motivation of this study is to evaluate the applicability of DIN 18041 in Brazil.

2. OBJECTIVE

The main objective is to give input to WG 10 from ABNT CEE 196 to verify to what extent the adoption of DIN 18041 requirements and recommendations can be used as a reference to create a similar standard in Brazil.

For the purposes of this study, only office spaces were evaluated by comparing field measurements and DIN 18041 software simulation results.

3. METHODOLOGY

3.1 Study cases

To evaluate representative spaces of Brazilian offices scenario, 48 study cases were selected, where 41 are meeting or conference rooms (Category A) and 7 of them are open plan offices (Category B). Considering room volumes, the group of rooms from Category A were classified as small, medium and large rooms. The rooms with volumes from 30m³ to 70m³ were classified as small, those from 71m³ to 120m³ were classified as medium and the large rooms presented volumes varying from 121m³ to 5000m³.

Following DIN 18041categorization, the 41 room samples from Category A were all classified as usage type A3, which is characterized by intensive communication and usage with several simultaneous speakers spread throughout the room. All the 7 room samples from Category B, were classified as B4 and besides were grouped by its type of activity: six rooms are offices of collaborative work and one of non-collaborative work.

Tables 4 and *5* summarizes the study cases characteristics considering their occupation, absorbent surfaces and volume.

3.2 Field Measurements

Field measurements were carried out on the 48 study cases, according to ABNT NBR ISO 3382-2, to obtain the reverberation time and ISO 3382-3 to obtain open plan offices parameters. All equipment used in the measurements are certificated and calibrated according to IEC 61672 and IEC 61260.

As all field measurements were performed in non-occupied conditions, the obtained reverberation time results were corrected for the required 80% occupation required by DIN 18041.

3.3 Room Acoustics Simulations

Room acoustics simulations were performed for each sample room using Acoustics software Sarooma®, an acoustics calculator that uses Sabine's statistic methods to design enclosed rooms based on DIN 18041 criteria. Therefore, for Category A rooms, reverberation time (RT) was obtained, and for Category B rooms, the ratio between absorption/volume (A/V ratio).

4. RESULTS

In *Tables 4* and *5* are presented the outcomes of the field measurements and the room acoustic simulations.

Table 4. Study cases classified by each usage.

Category A								
Case	**Size**	**Occupation (number of people)**	**Acoustic Ceiling lining**	**Absorbent Wall lining**	**Carpet**	**Volume (m^3)**	**Attendance**	
							Simulated	**Measured**
1	Large	16	x	x	-	189,95	✓	✓
2	Medium	9	x	x	x	73	✓	×
3	Medium	8	-	-	x	105	×	×
4	Large	14	x	-	x	265	×	✓
5	Medium	16	x	x	x	107,7	✓	✓
6	Large	9	-	x	x	127,37	✓	✓
7	Large	26	-	-	x	337,46	✓	×
8	Small	6	-	-	x	33,66	✓	×
9	Large	11	x	-	x	135,02	✓	✓
10	Small	12	x	-	x	54,51	✓	×
11	Small	12	x	-	x	54,22	✓	×
12	Small	12	x	-	x	54,52	✓	×
13	Small	8	-	-	x	51,19	✓	×
14	Small	5	-	-	x	37,8	×	×
15	Medium	26	-	-	x	115,34	✓	×
16	Small	7	-	-	x	39,53	×	×
17	Small	9	-	-	x	55,81	×	×
18	Small	6	-	-	x	49,73	×	×
19	Large	20	x	-	x	264,6	×	×
20	Large	20	x	-	x	284,2	×	✓
21	Small	4	-	-	x	32,02	×	×
22	Small	6	-	-	x	46,09	×	×
23	Small	4	-	-	x	32,29	×	×
24	Small	7	-	-	x	42,09	×	×
25	Large	20	-	-	x	179,8	×	✓
26	Medium	12	-	-	x	103,82	×	×
27	Small	6	x	-	x	58	✓	×
28	Medium	10	x	-	x	119,19	×	✓
29	Large	8	-	-	x	165,59	×	×
30	Large	8	-	-	x	159,79	×	×
31	Medium	8	x	x	x	100,33	✓	✓
32	Small	7	-	-	x	45,9	×	×
33	Small	8	-	-	x	58,7	×	×
34	Medium	10	-	-	x	96,2	×	×
35	Medium	8	x	-	-	73,14	✓	✓
36	Small	8	-	-	x	57,43	×	×
37	Small	7	-	-	x	51,3	×	×
38	Small	6	x	-	x	37	×	✓
39	Medium	12	x	-	x	79,82	✓	✓
40	Small	7	x	-	x	41	✓	×
41	Small	12	x	-	x	54,19	✓	×

Table 5. Study cases classified by each usage.

Category B								
Case	**Type of work**	**Occupation (nº of people)**	**Acoustic Ceiling lining**	**Absorbent Wall lining**	**Carpet**	**Room's Hight**	**Attendance**	
							Simulated	**Measured**
1	Collaborative	95	x	-	x	2,95	✓	✓
2	Collaborative	19	x	-	-	2,85	✓	✓
3	Non-Collaborative	44	x	x	x	2,78	✓	✓
4	Collaborative	74	x	x	x	3,55	✓	✓
5	Non-Collaborative	17	x	-	x	4,2	✓	✓
6	Collaborative	15	x	-	x	2,7	✓	✓
7	Collaborative	25	x	x	-	3,3	✓	✓

4.1 Category A samples analysis

Table 6 presents the correlation between predicted and measured RT for the 41 Category A samples to evaluate if they converge. It is possible to observe that there is a low correlation for almost all frequencies under evaluation. From the linear regression of both variables (not presented in this paper), it was not possible to obtain any conclusive observation or trend due to the high dispersion. The reasons for this divergence will be further discussed in section 5.

Table 6. Correlation between the data from Category A samples.

Correlation RT (s)	Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
	0,52	0,44	0,45	0,60	0,59	0,50

Although the obtained correlations were not the expected, when evaluating if DIN 18041 requirements and recommendations can be used as a reference for meeting or conference rooms in Brazil, it was observed from field data results that, for the great majority of cases with adequate acoustic treatment application, the requirements were met (Figure 1).

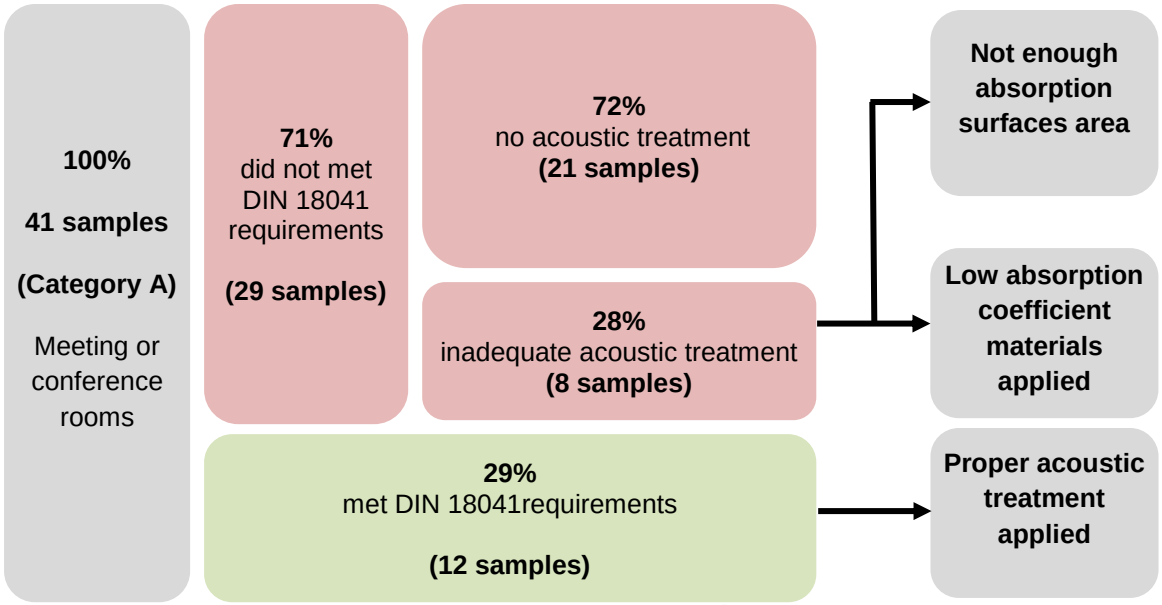

Figure 1. Category A analysis

In the preponderant cases, where the requirements were not met, it was possible to identify at least one or more issues related to acoustic treatment inefficiency:

- Insufficient absorption surfaces areas for the considered room volumes
- Use of absorption linings with low absorption performance

4.2 Category B samples analysis

Table 7 presents the correlation between predicted and measured A/V ratio for the 7 Category B samples to evaluate if they converge. It is possible to observe that there is a low correlation for medium and high frequencies and a better correlation for low frequencies. From the linear regression of both variables (not presented in this paper), it was not possible to obtain any conclusive observation or trend due to reduced number of samples and the high dispersion. The reasons for this divergence will be further discussed in section 5.

Table 7. Correlation between the data from Category B samples.

Correlation A/V ratio	Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
	0,71	0,76	0,42	0,26	0,12	-0,14

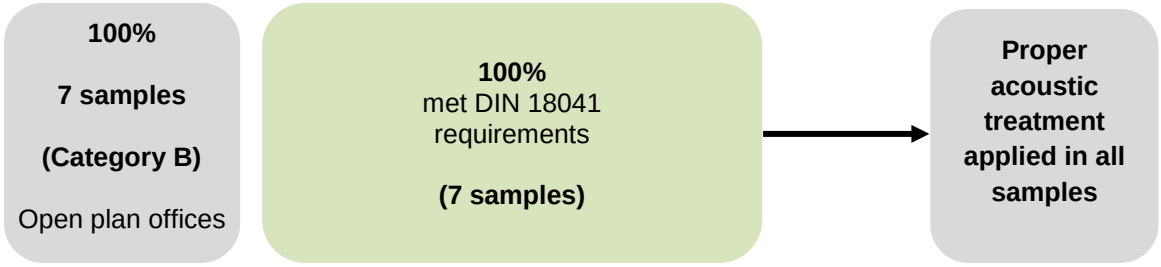

Figure 2. Category B analysis.

Despite the low correlations, when evaluating if DIN 18041 requirements and recommendations can be used as a reference for open plan offices in Brazil, it was observed that, as for the all cases adequate acoustic treatment was incorporated, all the requirements were met when field measurements were performed (Figure 2). Despite the few samples in Category B, it is noticeable that there is more concern about the acoustic quality of open plan offices, and that the acoustic design project is executed in its entirety.

5. DISCUSSIONS AND CONCLUSIONS

From the results of this preliminary study it is possible to recommend the adoption of DIN 18041 criteria and requirements as a reference to elaborate a Brazilian standard for Offices Acoustic Quality.

Both for Category A and Category B spaces, when proper acoustic treatment was executed, the requirements were achieved due to the adequate dimensioning of absorbent ceiling lining and/or walls absorbent linings.

The unexpected side outcome of the study was the awareness that there is a low correlation when simulation data from room acoustics software Sarooma® were compared to field measurements. In fact, there were even few cases from **Category A** (highlighted in grey in Table 4), in which the RT requirement have not been met in the

simulations but have done so when field measurements were performed. In those 5 cases, it was possible to identify a higher simulated RT values between the bands of 125Hz and 500Hz, as the reason for the not attendance on the calculations.

Additionally, for the results from Category B, it was observed a better correlation in low frequencies for A/V ratio obtained from simulated and from measured data, than for medium and high frequencies. Specific studies need to be performed, but one of the reasons for the better correlation in low frequencies might be the larger room volume of open plan offices that result in a better RT prediction in those frequencies. Due to the low absorption coefficients of the lining materials and furniture in this range, it is not expected a strong influence on the field performance of the room, resulting in more stable decay results. This is not the case for Category A samples, which can present a more variable performance in low frequencies because their reduced room volumes.

In general, the more feasible reason for the divergence between the simulated and measured results is the lack of accuracy of the input data in the simulation software. In Brazil, there are few acoustic products manufactures that present absorption laboratory test performed for different set ups, more related to real life applications. In field, acoustics ceilings are frequently placed with different heights and in most of cases, the available input data was obtained from a standard absorption coefficient test, and the plenum effect cannot be considered on the simulations.

Furthermore, another input problem that might be part of the lack of accuracy on the simulations is the furniture data. The prediction software applies the corrections presented in EN 12354-6 [11]that considers typical values of the equivalent absorbance area and sound absorption coefficient for objects that maybe differs considerably from Brazilian offices furniture.

7. FURTHER WORK

In order to verify how far the DIN 18041 requirements can be suitable to the cultural aspects of Brazilian offices, a subjective evaluation will be carried out through a listening test campaign. This evaluation will be used to analyze the applicability of the criteria by comparing the subjective responses obtained from rooms that comply with the requirements of the German standard versus those that do not.

In addition to DIN 18041 subjective evaluation, a comparative study could be carry out with German document VDI 2569: 2016, which establishes three classes A, B and C with different noise levels of input for different open plan offices and single person offices acoustic conditions[12].

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