

LIGHTWEIGHT PLASTERBOARD WALLS, EMPIRICAL SUPPORT OF THE SOUND INSULATION PREDICTION METHODS

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ABSTRACT

Great variety of building partitions with different structure can be created within lightweight plasterboard wall system. The sound insulation index R_w ranges from 27 dB for single gypsum plate to over 70 dB in case of special walls used in auditoria. Many technical factors influence actual sound insulation of such walls and the precise theoretical prediction is rather complicated. During last few years a number of laboratory tests was carried out on lightweight walls of different type and structure made of different materials. Some dependences were observed, and some empirical relationship can be derived based on the tests results. They can be useful for prediction methods development and their empirical support.

INTRODUCTION

When discussing acoustical performances of lightweight plasterboard partitions three main elements should be taken into consideration; frame, external leaves made of plasterboard panels and cavity with absorbing material inserted or not inserted into it. Each of these elements influence the sound insulation of wall and each of them could be solved in different way for a different type of partition. Great variety of structures can be created within plasterboard walls system so a large variety of sound insulation curves affected by number of technical factors can be obtained. Thus precise theoretical prediction of acoustic properties of particular structure is rather complicated, even laboratory tests taken on semi identical samples of walls show significant differences in results. Description of effects which were observed during sound insulation measurements while changing chosen technical parameters of wall frame, gypsum plates or cavity can be useful for preparing theoretical models or prediction methods.

Another problem is transferring laboratory test results to the real conditions that exist in a specific building. Flanking transmission, influence of solutions of details and connections with another members of building structures, reduction of power transmission over junctions or simply workmanship quality are still rather poorly recognised but are not discussed in the paper.

FRAME

Type and structure of frame is of crucial importance for sound insulation of lightweight plasterboard walls. In the case of single partitions members of frame i.e. studs and horizontal metal channels connect leaves of gypsum plates screwed on both sides of it. Such a joint form direct path of sound transmission through the wall. The effect can be observed in figure 1 where two sound insulation curves for single and double walls of near the same total thickness (150 and 155 mm), with identical absorbing material inserted into cavity (100 mm glass wool) and the same gypsum plates (2x12,5 mm screwed on each side) are compared. For double wall single number values R_w (R_{A1} , R_{A2}) are higher respectively by 6 (6; 3) dB. Another six couples of similar walls were analysed, the differences were on average 5 (6; 4) dB. However such an advantageous effect of double structure was observed only in case of walls with absorbing material used as a filler. Figure 2 shows analogical comparison for "empty" walls with no material in the cavity. The difference in sound insulation is not so evident and single number values R_{A1} and R_{A2} were even lower for double wall while R_w was the same in both cases. It can suggest that in practice the direct path of sound transmission through studs is not dominant when "empty" walls are considered and starts to be important for walls filled with absorbing material which increase the sound insulation of plate-cavity-plate path of transmission.

Dimension of metal channels section, which determines the total thickness of partition, also influence its sound insulation. In the case of single wall with typically used 12,5 mm plates taking profile 100 mm instead of 50 mm usually causes the increase of sound insulation indices by about ΔR_w (ΔR_{A1} , ΔR_{A2}) = 5 (5; 6) dB. There are mean values calculated based on results of measurements taken on six couples of walls when comparing samples with the same sound absorbing material and the same gypsum plates but different dimensions of channels (50/100 mm).

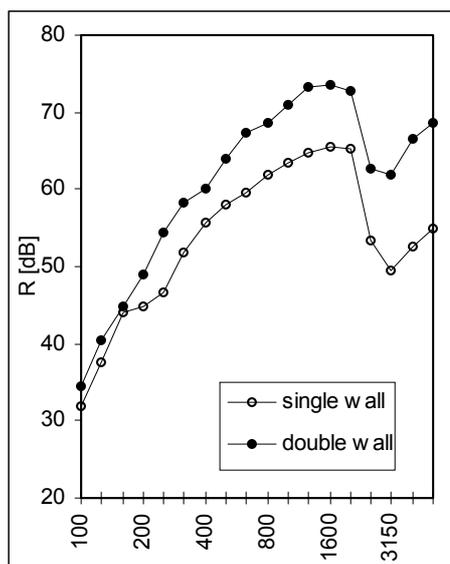


Fig. 1

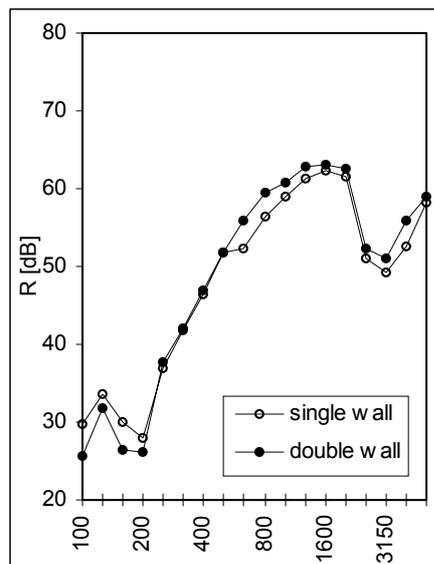


Fig. 2

Using bigger profiles as a frame members of single wall not always results in its higher sound insulation. For some structures the effect can be even opposite; walls with frame made of 50 mm channels can obtain higher values of single number indices than thicker walls build with 100 mm sections. This is the case of walls with thick 20-25 mm gypsum plates screwed horizontally to studs which are in a distance of 1000 mm. Such walls have slightly different structure than regular single lightweight partitions. Studs span is greater than 600 mm used typically. Joints of gypsum panels run horizontally and are not supported or connected with metal channels. Figure 3 shows comparison of sound insulation curves obtained for walls with 20 mm plates fastened singly on each side of 50 and 100 mm frame with no absorbing material

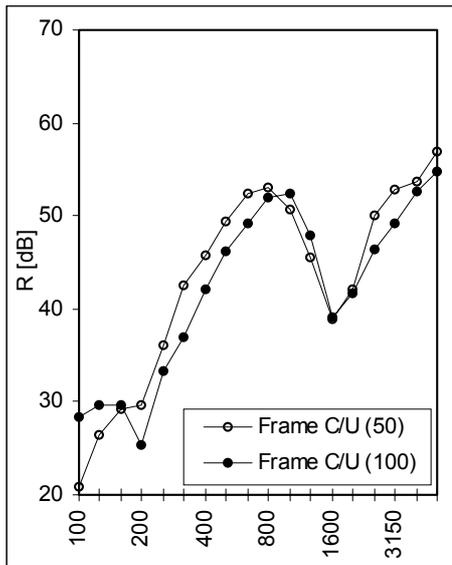


Fig. 3

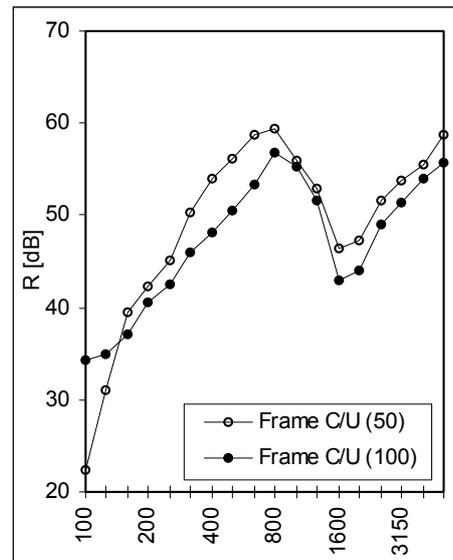


Fig. 4

in the cavity. Figure 4 illustrates behaviour of the same walls filled with 50 mm glass wool. The tendency is similar in both cases; thinner walls shows significantly better sound insulation in the range of middle and high frequency.

Metal channels dimensions (50, 75 or 100 mm) used for frame construction influence the geometry of chambers closed by studs and gypsum boards and determine the distance between plates. But the stiffness of studs depends also on channel section. It means that the support rigidity of gypsum plates and stiffness of the whole wall structure change according to profiles used. Thus from the acoustic point of view the dimension of channels gives combined effect on structure of a wall and in different way influences its sound insulation. The effect of stud stiffness alone was observed while testing walls with regular studs made of C channels and then the same structure supported by studs made of two coupled C channels designated for additional load.

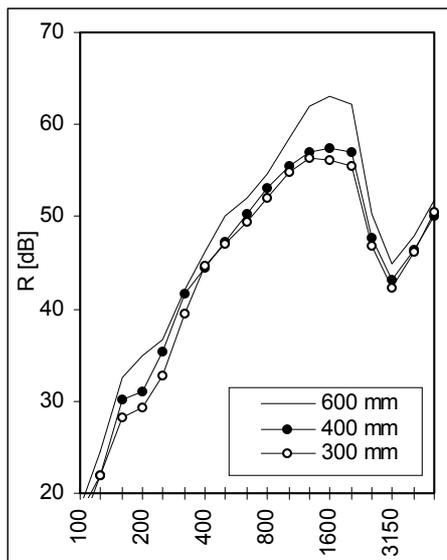


Fig. 5

Different distance between studs can be used for walls designated for different purpose. Usually the distance is 600 mm, but in practice can be also 300 or 400 mm as a fraction of total width of typical gypsum board (1200 mm). Reduction of studs span is used to increase resistance of wall structure while additional load is expected, or to obtain more rigid surface of wall required for further finishing. Smaller distance between studs usually results in lower sound insulation, particularly in case of walls with thick gypsum boards [3]. Exemplary sound insulation curves obtained for single walls build of 100 mm channels with 50 mm of glass wool inside and studs distance respectively 300, 400, and 600 mm is shown in figure 5. The distance between studs determine the stiffness of wall structure but also the number of linear junctions between both gypsum leaves, the geometry of caves and dimensions of sub plates so the effect observed is combined.

Another factor that influence the sound insulation of lightweight plasterboard wall is the connection of metal channels to the surrounding partitions. This path of transmission is of rising importance in case of double wall where both leaves of gypsum plates are connected to each other only on perimeter by surrounding structures [1]. In prediction models such influence should be taken into consideration as the flanking path of transmission depending on specific structure of building.

GYPSUM PLATES

Different kind of plasterboard can be used as the external leaves of a frame wall. Common gypsum panels, fire resistant or bathroom plates are taken for different purpose depending on requirements and conditions existing in particular building. From an acoustic point of view “common” and “fire” plates should be distinguished. Gypsum material used for “fire” palates is reinforced with glass fibres and is of greater density ($850 - 950\text{kg/m}^3$) than in case of “common” plates. It results in higher surface mass while comparing plates of the same thickness. Walls made with “fire” panels usually reveal better sound insulation in the middle frequency bands and usually have the coincidence frequency moved one third octave towards low frequency. Fifteen couples of walls constructed with the same elements but plates of different types were investigated. Among them were partitions of single or double structure but in nearly each case walls with “fire” plates showed better acoustic performance. Values of R_w and R_{A1} indices were higher by (1 – 3)dB. The differences in R_{A2} values in three cases out of fifteen analysed were out of above limits. On average R_{A2} was by 2 dB higher for walls with “fire” plates.

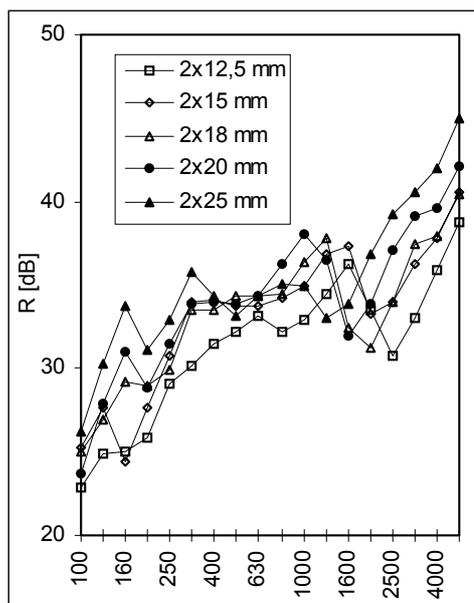


Fig. 6

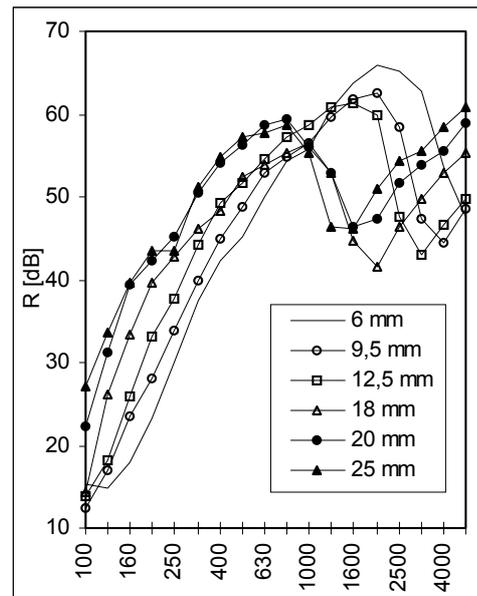


Fig. 7

Next factor that affects the sound insulation of gypsum panels themselves and then the acoustic properties of the whole wall is board thickness. In practice for different structures plates of 6 to 25 mm thickness can be used. They are fastened in one, two or three layers on each side of frame, or different number of plates can be put on each side. Thickness of plate determine its mass per unit area and the position of coincidence frequency. However the number of plates screwed to the frame do not influence coincidence frequency location. It means that plasterboard layers act as a separate plates even if there is two or three of them fastened together on one side of frame. Coincidence frequency lays between 1250-1600 Hz for 25 mm boards and 5000 Hz in case of 6 mm plates. (In the same range coincidence frequency of glass panes with thickness typically used in glazing can be found, some more analogy can be observed between behaviour of glazing units and lightweight plasterboard walls). Figure 6

presents the results of measurements that illustrate displacement of coincidence frequency according to change of plate thickness. In each case two plates were assembled to only one side of frame. Resonance of single plate is reflected in sound insulation characteristics of wall. In figure 7 sound insulation curves for single walls with frame made of 50 mm channels are collected. Single gypsum plates of different thickness (6 – 25) mm were used on both sides of a frame. The drop of sound insulation in the coincidence frequency region affected the R_w value particularly in case of walls with thick plasterboard panels. For such a partition the location of f_c causes that in the range of 1250-2500 Hz essential part of sound insulation characteristics is beneath the reference curve and it greatly influences R_w value.

Also plasterboard plates support conditions affects acoustic performance of partition. For example in case of single walls the increase of distance between screws that fasten plates to the frame cause the increase of sound insulation in the range of medium and high frequency. There are probably two main reasons causing such behaviour; different ratio of energy transmitted via studs connecting both leafs of plaster in each case and different rigidity of edges of plasterboard plates. Other result of enlarged distance between screws was observed in case of double walls. The increase of screw span resulted in reduction of sound insulation in low frequency area. For double walls metal studs are separated and do not connect the panels fixed on both sides of the frame. Hence the screw distance does not influence this path of transmission (via studs). Reduced screw span restricted modal behaviour across the surface of panels in low frequency bands and resulted in increasing sound insulation in this range [3].

CAVITY

Gypsum plates enclose space inside the wall and form chambers filled with air or some kind of absorbing material. Such configuration reveals mass-spring-mass resonance in low frequency range. Figure 8 show the comparison of sound insulation curves obtained for two partitions. The first one consist of two 12,5 mm gypsum plates screwed on only one side of frame made of 50 mm channels. The second is a typical single wall with singular 12,5 mm gypsum plates on both sides of 50 mm frame. No absorbing material was used in each case. In the low frequency area simple leaf of two 12,5 mm gypsum panels have better sound insulation than single wall in which these two panels are separated by 50 mm space of air. The same tendency can be observed in each case of partition with 6-18 mm plates regardless of presence or absence of absorbing material in the cavity. It is the effect of resonance frequency which occurred between 63 and 100 Hz depending of wall structure. (Similar effect can be observed while comparing the

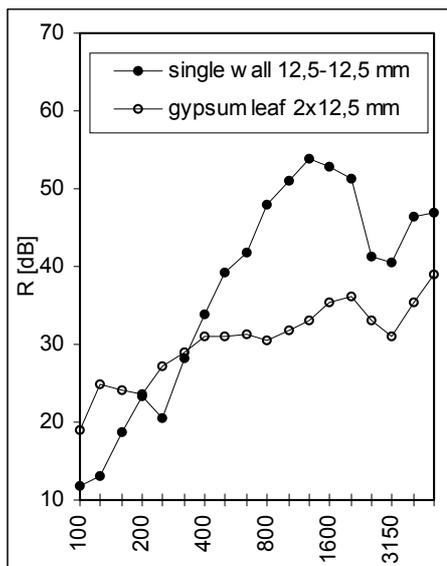


Fig. 8

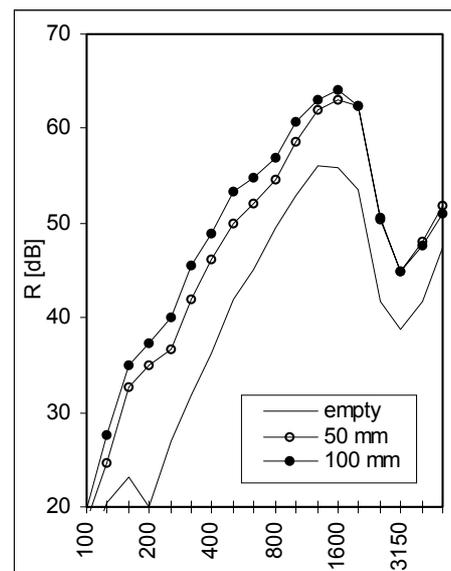


Fig. 9

sound insulation curves obtained for single pane of glass and glazing unit consisted of two such panes with the same thickness. Although in case of glazing we have two panes instead of one and they are separated by several millimetres of air space the single pane have higher sound insulation in the range of low frequency).

Presence of absorbing material within the cavity is of great importance for the sound insulation of partition. Several couples of walls of identical structure but with or without absorption were analysed. Decrease of sound reduction index caused by absence of absorbing material expressed by R_w value was usually between (6 – 9) dB. Total thickness of material used has also its contribution to acoustic performance of wall. In figure 9 there are three curves obtained for the same single partition (100 mm channels, 12,5 mm single leaves of plasterboards) without any absorption, and respectively with 50 and 100 mm of glass wool. Similar tendency was observed in the case of another corresponding couples of walls regardless of frame type or number of plates fastened to it.

The influence of absorbing material type was also investigated. Different kind of glass and mineral wool was used in the cavity of the same wall. Changing of material affected mainly the high frequency range of sound insulation curves which is of less influence on single number quantities. Weighted sound reduction index values varied by ± 1 dB.

CONCLUSIONS

Sound insulation prediction methods designated for lightweight frame partitions should take into consideration a number of technical factors that influence acoustic performance of such walls. Analysis of laboratory tests results can indicate factors that are actually important and allow to describe degree to which they affect sound insulation of a specific structure. Effects that were observed during laboratory measurements while changing chosen technical parameters of frame, gypsum plates or cavity can be useful for preparing theoretical models or prediction methods. However the laboratory samples are only patterns of real partitions in specific building. Another task is to transfer laboratory results to particular building and to link prediction models to real structures.

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