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Noise Control Stratagies in Reinforced Concrete Buildings

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ABSTRACT: This study is aimed at bringing out the salient aspects of building noise control. An analysis has been carried out with respect to the noise transmission as well as the characteristics of noise inside buildings. The key issues on building noise control have been included and discussed. A comprehensive study on building noise and on acoustically divisible spaces has been made. It has been observed that a sound insulation of the order of 30 to 35 dB is possible in a given building. Further, the noise propagation parameters in an exhibition hall have been theoretically estimated. The data so obtained has been compared with actual SPL measurements and recorded. Variations in noise levels observed have been explained. Before the partition is made, the SPL drop is faster inside the building but after the partition the drop falls at the rate of 3dB for doubling the distance. The cost of the acoustically divisible partition wall is found to be very high, but the advantage of this partition seems to be creating acoustically divisible spaces where in one can conduct two programs simultaneously, without any disturbance to each other. Prior to the selection and design of control measures, noise sources must be identified and the noise produced must be carefully evaluated.
Key Words / Phrases: Sound Pollution; Concrete Buildings; Noise Control; Sound Pressure Level; Sound Level Meter; Transmission of Sound;

I. Introduction

Noise is generally considered to be unwanted sound and sound can be considered unwanted due to reasons of volume, type of noise, the time of day, or any factor making sound unpleasant or annoying [1]. As this is often subjective noise pollution can be controversial. Noise pollution impacts upon health and wellbeing by causing disturbances that create poor quality environments. Noise pollution in residential environments can cause physical and mental health deterioration [2, 3]. In the workplace and educational environments, these symptoms can accompany reduced productivity and quality of work.

Noise pollution is the disturbing or excessive noise that may harm the activity or balance of human or animal life. The source of most outdoor noise worldwide is mainly caused by machines and transportation system, motor vehicles, aircraft, and trains. Outdoor noise is summarized by the word environmental noise. Due to poor urban planning may give rise to noise pollution, since side-by-side industrial and residential building can result in noise pollution in the residential areas [4, 5].

Indoor noise can be caused by machines, building activities, and music performances, especially in some workplaces. There is no great difference whether noise-induced hearing loss is brought about by outside (e.g trains) or inside (e.g music) noise [6].

High noise levels can contribute to cardiovascular effects in humans, a rise in blood pressure, and in increase in stress and vasoconstriction, and an increased incidence of coronary artery disease. In animals, noise can increase the risk of death by altering predator or prey detection and avoidance, interfere with reproduction and navigation, and contribute to permanent hearing loss.

The reverberation time of room is focused by [7]. The measurement of the reverberation time has been carried out, the RT measured is quite similar, and decreases fairly uniformly as the frequency increases. Moreover, in each frequency band the greater the volume of the room, the greater the RT observed.

The design of the barrier shape (1) gives a better sound absorption at the total frequencies of interest (2) protects the inside absorption layer from deterioration due to harsh weather [8, 9]**.** For a lightly damped thin-walled barrier, the absorption treatment not only absorbs acoustical energy but also damps the barrier structure resulting in a negligible energy transmission. The results demonstrated that for total noises the proposed barrier is more effective than reflecting and absorbent barriers [10].

The Planning and Development Regulations [11, 12] provide planning exemptions for renewable technologies for commercial, public, industrial and agricultural buildings where noise levels do not exceed 43 dB (A) during normal operations as measured from the nearest party boundary.

Sound pollution: Sound is a form of energy and is defined as any disturbance of air, ground or water that produces a sensation of hearing. Transmission of sound facilitates enjoyable experiences such as listening to music; spoken communication with family and friends Sound is generated by creating a disturbance of the air, which sets up a series of pressure waves fluctuating above and below the normal atmospheric pressure, such as a stone that falls in water generates expanding ripples on the surface [13]. Unlike the water waves, however, these pressure waves propagate in all directions from the source of the sound. Our ears sense these pressure fluctuations, convert them to electrical impulses, and send them to our brain, where they are interpreted as sound.

There are different sources of sound in building, i.e. communication, human activates, fluorescent light, fans, air-conditions, furniture movement noise, clocks and fish tanks etc. apart this some of the external noise in the building such as traffic movement, noisy streets, entertainment devices and machinery. These are all generating small rapid variation in the pressure about the static atmospheric pressure. Any sound not occurring in the natural environment, such as sounds generating from aircraft, highways, industrial, commercial and residential sources may be called as noise, it is called unwanted sound.

The main source of noise is transportation, industries and equipments, any other modes that produce pressure variation in the frequency range audible to ear. The sources may be point, line or plane. Noise in building may propagate through air, and various structural members, that are air conditioning ducts, and water supply pipes etc. both direct sound and reverberated sound reach to the listener. The reverberated sound interface with listening of the direct sound thus even wanted sound, when reverberates becomes noisy.

Normal ranges of sound level: The central pollution control board (CPCB) recommended the sound pressure level (SPL) for different areas as follows:

S.No	Area	SPL Leq (dBA)	
		Day Time	Night Time
1	Industrial	75	70
2	Commercial	65	60
3	Residential	55	50
4	Silence zones	50	40

Table 1 Central pollution control board recommendation for noise level

Effect of Noise pollution: The effect of noise on human health indicates a variety of health effects, noise can affects human health in various forms such as Irritation reaction, sleep disturbance, interference with communication, performance effects, effects on social behavior and hearing loss, and also it increased number of headaches, greater susceptibility to minor accidents and increased mental hospital admission rates etc. the health hazards due to noise based on the intensity are described below: Here and in what follows dB stands for 'decibel', dBA stands for 'sound when A-weighted' and NRC stands for 'Noise Reduction Coefficient'.

Type of Sound	Range of SPL	Hazard
Sounds of Normal Conversations	40-60 dB	Orchestra is about 70 dB and is safe for ear upto 80 dB
Sounds of Heavy Traffic	90 dB	Constant hearing of sound, greater than 80 dB, causes temporary hearing loss and if they are not treated immediately, causes permanent impairment
Sounds of Pneumatic Drills and other machines	100 dB	Constant hearing causes temporary hearing loss and if they are not treated immediately, causes permanent impairment
Sounds of Aircraft Engine	100 – 200 dB	Higher noise level of 160 dB cause total deafness, rupturing eardrums, damaging inner ear. It also causes high blood pressure, ulcer in stomach, palpitation, nervous problems, irritation, anger, and affects pregnant women's embryo
Sounds of Rockets during Take Off	200 dB	It is dangerously causing total deafness by rupturing the eardrums and damaging the inner ear. It also causes high blood pressure, ulcer in stomach, palpitation, nervous problems, irritation, anger and affects pregnant women's embryo

Table 2. Health hazards due to noise based on the intensity

In Section 2, we have presented the building structure acoustical treatment for different elements of building components. In Section 3, the analysis of observations has been made before and after introduction of partition wall in the exhibition hall. In Section 4, Sound Power Level is computed from the data obtained through sound level meter, and the paper ends with concluding remarks in Section 5.

II. Building Structure Considered for the present Experiment

Acoustical design for buildings requires quantitative information about acoustical products, materials and systems so that recommended design criteria can be met. A number of acoustical test procedures are used in the laboratory and in buildings to obtain this kind of information and to verify that the building is performing as the designer intended For most noise control work in buildings, the most important acoustical properties of the materials and systems used for sound reduction through different elements of building like walls, flooring, ceiling and stage arrangement in a building.

Considering an experimental study in a exhibition hall with a seating capacity of 1000 persons is selected. The dimension of exhibition hall is 50mx40.5mx8.5m with gypsum board and daikan ceiling at a height of 7.5m from plinth level.

Arrangement of Sound Absorption: The ceiling of exhibition building is false ceiling type. Wall paneling is only for multipurpose hall and some other important locations of the building. Different type of false ceiling is recommended for different areas. Wall paneling is recommended only for important places of the building to reduce the echo effects.

Arrangement of false ceiling: Supporting system for execution of false ceiling construction was done through the slab with nut and bolt system. GI frames were attached to the supporting system to support the gypsum boards. The joints in gypsum board were filled with joint filler material. Tiles were fixed to the gypsum board; these tiles were coated with different colours.

Arrangement of wall paneling: The frame system for wall panels was done with mild steel frame pipes. These pipes were arranged in both horizontal and vertical direction with equal spacing of 600mm × 600 mm. The area between the pipe grids was covered with sound reduction material, called glass wool. To hold the glass wool in position wire mesh is added to the system. On this system cemented wood wool slab is attached which is about19 mm thick. For appearance as well as to reduce the sound, carpet is attached to final finished system

Partition Wall: It is a 45m x 7.5m wall, comprising of a number of segments, 1.2m in width, made of glass wool, laminated of both sides with wooden panels. The overall thickness of the wall is 7.5 cm. Each segment is provided with locking system to secure it with adjoining segment, as well as the roof and floor. A rubber beeding is provided at all joints to ensure sound proof and secure interlocking, the overall cost of the partition wall was about Rs 45 lakhs.

Seating Layout: Cushioned sofa type seating is provided on a flat floor covered with dense vinyl wall to wall carpet.

Walls and Openings: The walls have openings in the forms of doors measuring a total of about 25% of wall area. The walls are treated with wooden paneling which is again covered by teak wood beeding material.

Cost Analysis of different materials: The breakdown costs of different materials used in the hall are as shown in the following table:

Here and in what follows 'Sqm' stands for 'Square Meter', 'Cum' stands for 'Cubic Meter' and 'Kg' stands for 'Kilo Grams'.

S.No	Item no	Area in Sqm	Rates	Amount
1	VT-15 tiles(aluminum coil coated tiles)	1037.5	1675	1737846
2	Gyp-Board- 25mm thickness	1020.9	668	681948
3	Wall carpet	840	400	336000
4	GI Frame in Kgs	8500	58	493000
5	Wood wool slabs	800	304	243200
6	Carpet on floor	1919	700	1343300
7	Glass wool	800	178	142400
8	Stage area wooden flooring	438	3185	139500
			Total Amount	**6372724**

Table 4. Overall Cost Analysis of Exhibition Hall

S. No.	Description	Availability	Units	Rates
1.	Daikan ceiling (mineral fiber)	Imported	Sqm	660
2.	Cemented wood wool (19mm thick)	Local	Sqm	563
3.	GYP board material	Local	Sqm	668
4.	T.W for sound reducing doors & windows	Local	Cum	40445
5.	Carpet	Imported	Sqm	1014
6.	Steel clip for false ceiling	Imported	Sqm	1450
7.	Aluminum work for wall paneling	Local	Kg	212
8.	Glass wool	Local	Sqm	240
9.	Aluminum frame work for partition	Local	Kg	250
10.	8mm thick water proof marine ply wood	Local	Sqm	392
11.	1.5mm thick Lamination	Local	Sqm	372
12.	"Nova fine" over ply surface circular column	Local	Sqm	360
13.	Aluminum Coil coated tiles "boxer – VT-24"	Imported	Sqm	2475
14.	G.I coil coated tiles "boxer-VT-15"	Imported	Sqm	1672
15.	Fire fissured mineral acoustic ceiling tiles	Local	Sqm	789
16.	Aluminum composite panel in ceiling	Local	Sqm	3500
17.	Gypsum board for false ceiling (Regular)	Local	Sqm	668
18.	Perforated tiles	Local	Sqm	1450
19.	Plain tiles	Imported	Sqm	1254
20.	Metal screen LA 150 false ceiling	Local	Sqm	1450
21.	19mm thick ply in cat walk	Local	Sqm	654
22.	Wood wool cemented slab	Local	Sqm	568
23.	Water proof marine ply wood(12mm)	Local	Sqm	492
24.	Glass panel 8mm thick	Local	Sqm	711
25.	Loop pile carper 20 OZ over 12mm	Local	Sqm	1100
26.	Light wt. partition (cyclorama)	Local	Sqm	1254
27.	T.W frame for SRD (second class)	Local	Cum	40445
28.	100*200mm T.Wood skirting	Imported	Cum	102
29.	Operable glass window	Imported	Sqm	1895
30.	Double glazed observation window	Imported	Sqm	2750
31.	T.W plank flooring (stage area)	Imported	Cum	40445
32.	Sound barrier over foldable partition with Gyp board	Local	Sqm	10000

Table 3. Breakdown rates of Materials

III. Analysis of the observations

The analysis of observation has been made before and after introduction of partition wall in the exhibition hall, the noise propagation in a building was studied by measuring SPL at different locations in the exhibition hall and the data obtained has been tabulated. Based on these readings the sound power levels were calculated.
To study the effect of the partition wall in the exhibition hall a noise generating source is placed at a location at a fixed place along one edge of the hall as shown in Fig. 1. The level was measured at six different location namely A, B, C, D, E, F before introducing the partition. The measurement of noise level was again repeated after introducing the partition wall. The SPL at different points has been plotted against distance from the source and frequencies (See Figures 2, 3, 4 and 5)

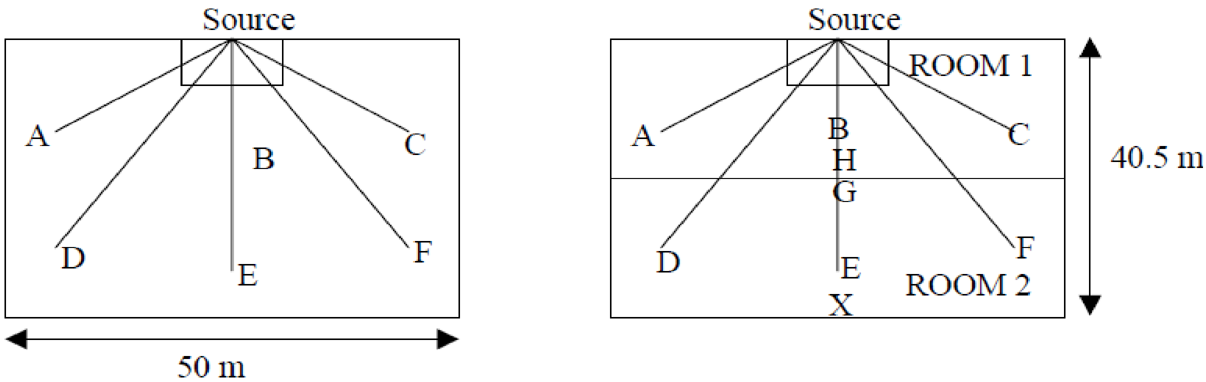

Figure 1. Observation points in the exhibition hall before and after the partition

Points	Distance	A-Weighted	Linear	31.5	63	250	500	1k	2k	4k	Over-all frequency
A	18.5	72.2	77.4	53.5	61.2	72.7	71.5	67.1	63.9	58.2	83.04
B	12	81	84.6	53.5	61.3	80.8	79.6	76.2	73.8	68.3	88.6
C	20	71.9	77.1	53.8	53.9	73.4	70.9	66.3	63.6	58	81.2
D	38	69.5	76.1	53.3	58.5	70.3	66.6	63.5	63.4	55.4	79.2
E	35	74.3	77.4	54.7	56.7	71.1	71.1	68.9	69.1	60.2	81.46
F	38.15	69	74.3	51	56.8	69.3	66.9	62.9	63.8	57.8	78.42

Table 5. SPL measurements at different locations (Without partition wall)

Location Of Observation	**Distance from source**	**SPL**	**Octave Band Center Frequencies, Hz**								
			31.5	**63**	**125**	**250**	**500**	**1K**	**2K**	**4K**	**8K**
A	20.8m	78.3	53.5	61.8	73.3	72.4	70.6	66.3	63.8	57.8	39.9
B	15.3m	81.5	50.4	62.9	74.5	75.4	75.3	75.3	73.8	68.3	54.5
C	20.8m	77.3	48.5	60.3	71.7	72.8	70.8	68.4	66.9	60.9	43.3
D	38.7m	58.2	49.1	50.9	46.1	39.2	35.2	34.1	32.7	31.4	30.1
E	36.1m	57.2	48.9	50.5	45	38.5	34.9	34.7	32.8	32.3	30.2
F	38.8m	59.7	48.4	49.2	45	38.2	35.3	35.1	33.2	32.5	30.4
G	24.5m	58.2	51.5	51	46.7	41.5	36.3	36	33.4	31.2	30.4
H	22.5m	81.1	54.1	57.9	71.4	77	76.6	73.2	70.6	64.9	49.4
X	50m	57.4	50.9	48.9	42.2	38.4	33	32.1	31.2	31	30.1

Table 6. SPL measurements at different locations (With partition wall)

The salient points that emanate from this study include (i) Before the introduction of the partition wall the SPL drop from source to receiver location averages 3dB, (ii**)** After introduction of partition, the sound pressure level dropped by 30 dB at all the observation points in room 2. At this level, the sound no longer remains audible in the receiver room, and (iii) The Sound pressure levels were recorded in the receiving room keeping all the openings (doors) closed. It is apparent that the sound insulation capability of doors and partition is of a high order.

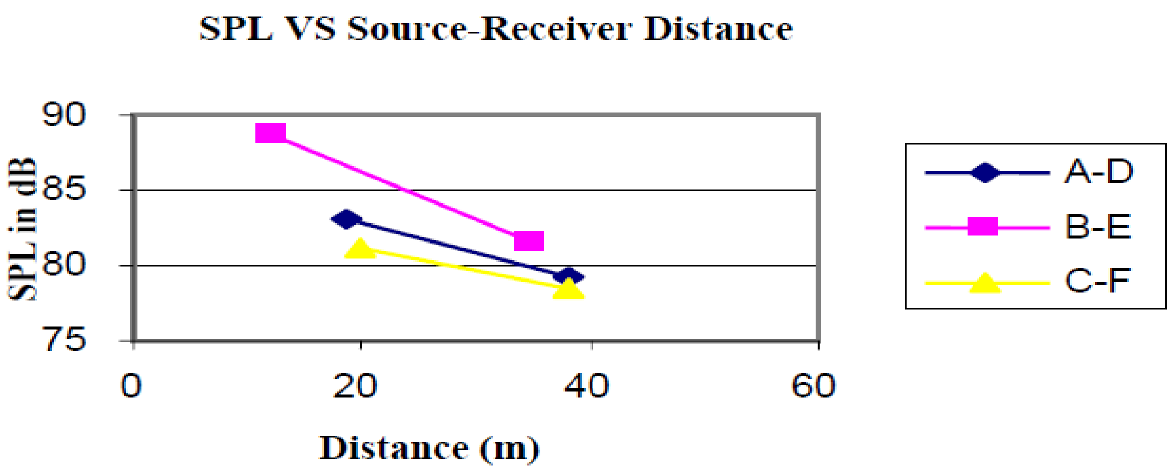

Figure 2. SPL vs Distance before introducing a partition wall

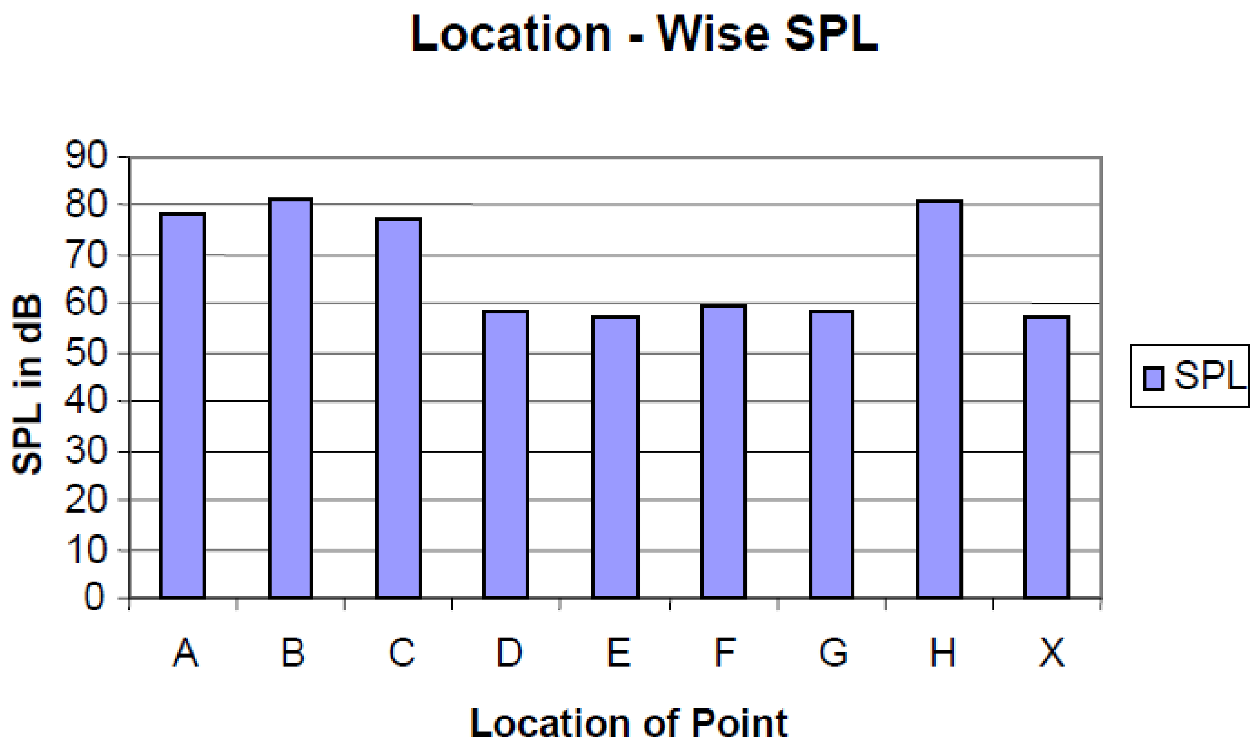

Figure 3. SPL vs Distance after introducing a partition wall

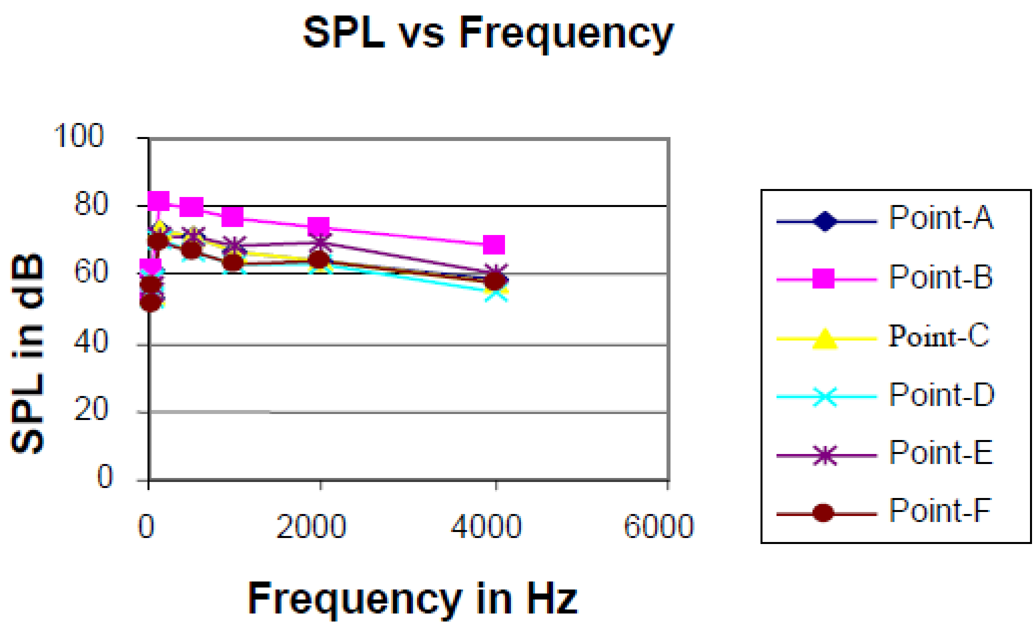

Figure 4. SPL vs. Frequency before introducing a partition wall

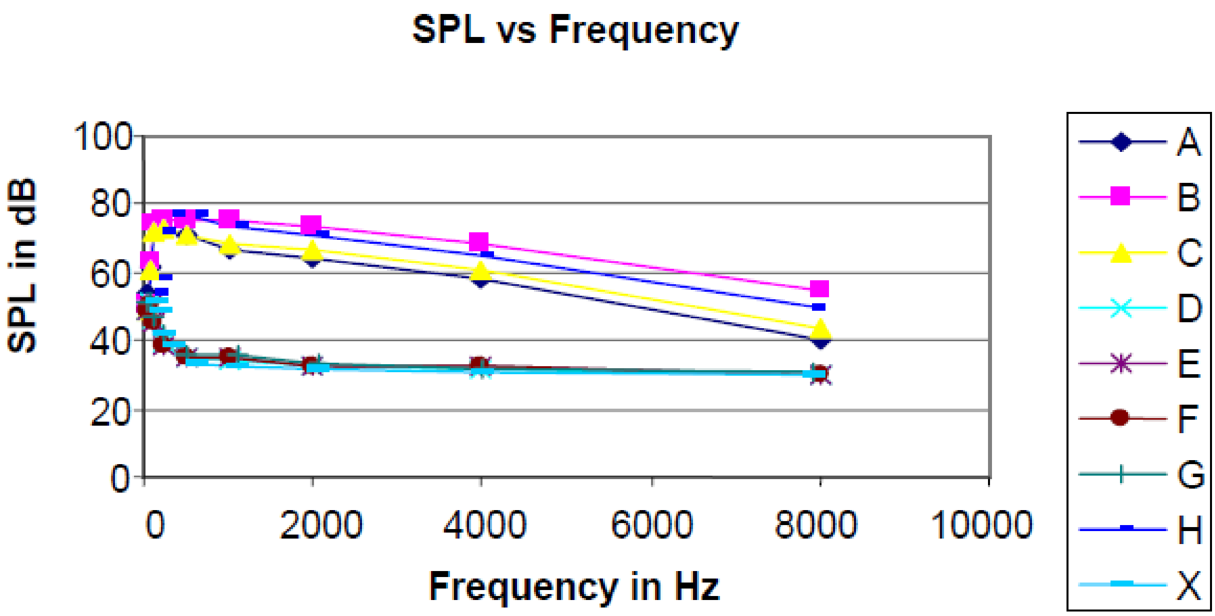

Figure 5. SPL vs. Frequency after introducing a partition wall

IV. Results and Discussions

Computation of Sound Power Level: Based on the measured sound pressure level at different locations at different frequency ranges, the sound power levels at these points have been worked out using the following formula:

$$L_p = L_w + 10\ \log_{10}\left((Q_\theta / 4\pi r^2) + (4/R)\right) \quad (1)$$

where the parameters denote and take the following values:

L_p = Sound pressure level in dB

L_w = Sound power level in watts

Q_θ = Directivity factor =2

R= Room constant

r= Radius

Calculation of Sound Power Level at Point "B" (See Figure 1.):

$$L_p = L_w + 10\ \log_{10}\left((Q\theta/4\pi r^2) + (4/R)\right)$$

Distance from source (B) = 12m

R = Room constant = $s\alpha/(1-\alpha)$

α = Absorption coefficients = 0.05 (for octave band center frequency, Hz)

S_1 = Wall area ((40.5x7.5x2) + (50x7.5x2)) = 1356m^2

S_2 = Floor area (50x40.5) = 2020m^2

S_3= Ceiling area (50x40.5) = 2020m^2

Frequency (Hz)	A-Weighed	Linear	31.5	63	125	250	500	1K	2K	4K
SPL in dB	81	84.6	53.5	61.2	76.6	80.8	79.6	76.2	73.8	68.3
S_1	1356	1356	1356	1356	1356	1356	1356	1356	1356	1356
$ά_1$	0.088	0.089	0.09	0.09	0.1	0.12	0.12	0.16	0.2	0.2
S_1*$ά_1$	119.328	120.684	122.04	122.04	135.6	162.72	162.72	216.96	271.2	271.2
S_2	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
$ά_2$	0.08	0.089	0.09	0.01	0.01	0.01	0.02	0.02	0.02	0.03
S_2*$ά_2$	161.6	179.78	181.8	20.2	20.2	20.2	40.4	40.4	40.4	60.6
S_3	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
$ά_3$	0.09	0.098	0.1	0.1	0.2	0.12	0.1	0.1	0.08	0.08
S_3*$ά_3$	181.8	197.96	202	202	404	242.4	202	202	161.6	161.6

S*ά	462.728	498.424	505.84	344.24	559.8	425.32	405.12	459.36	473.2	493.4
(1-ά)	0.93	0.93	0.93	0.93	0.9	0.91	0.91	0.89	0.87	0.87
$Q_\theta/(4*3.142*r^2)$	0.0011	0.00111	0.00111	0.0011	0.0011	0.00111	0.00111	0.0011	0.0011	0.0011
R = Sά/(1-ά)	497.556	535.94	543.914	370.15	622	467.385	445.187	516.13	543.91	567.13
4/R	0.00803928	0.00746	0.00735	0.0108	0.0064	0.00856	0.00898	0.0077	0.0074	0.0071
L_w	101.39	105.27	74.23	80.44	97.83	100.95	99.56	96.73	94.53	89.18

Table 7. Sound Power Level Calculation at a point "B"

V. Conclusions

A comprehensive study on building noise and on acoustically divisible spaces has been made. It has been observed that a sound insulation of the order of 30 to 35 dB is possible in a given building.

The devisable partition is made up of glass wool, laminate of both sides with wooden panels. Initially the SPL drop is faster inside the building and later on drop falls at the rate of 3dB for doubling the distance. The cost of the acoustically divisible partition wall is found to be very high; even though it has one advantage of this partition wall seem to be creating acoustically divisible spaces where in one can conduct two programs simultaneously, without any disturbance to each other.

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