K A D U N A M U S I C I N D U S T R Y

(ACOUSTICS AND INTERIORS)

A THESIS PRESENTED TO THE POST GRADUATE SCHOOL AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ARCHITECTURE.

BY

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D E D I C A T I O N

This thesis is dedicated to my Mother for bearing the pain of bringing me up.

"Sweet Mother I no go forget you". Nico Nbarga.

D E C L A R A T I O N

I, Caleb Moses Gaiya, declare that this thesis has been written by my person and it is a record of my research work. It has not been accepted in any previous application for a higher degree unless footnoted.

All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.

Signed:.....

C E R T I F I C A T I O N

This thesis entitled Kaduna Music Industry (Acoustics and Interiors) by Caleb Moses Gaiya meets the regulations governing the award of the degree of Master of Science (Architecture) of Ahmadu Bello University, and is approved for its contribution to knowledge and literacy presentation.

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A C K N O W L E D G E M E N T

The completion of this thesis would have been an impossible task without the contributions of other p people in one way or the other.

I am grateful to my Mentor Arch. M. Onoba and the other members of my supervisory committee for their criticisms and guidance through out the thesis period.

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A B S T R A C T

A Music Industry is a controlled Environment used for the Production and Recording of Music. Music is a properly organised sound with a definite tone and a pitch running between a low and high scale, or a noisy sound with no perceptible pitch at all.

The perceived quality of Music depends on two major factors; an Administrative factor on the one hand and an acoustical one *on* the other. The producer's and Artiste's wish, industry's recording system, and the condition of the Recording Instruments falls under the Administrative factors while the Acoustical factors comprise of the geometry of the room, its construction method and materials used, finishes, services incorporated into the buildings, and its position on site in relation to other activities around it. It is not on exageration when one says that the quality of music produced in a space depends on the Architectural solution employed on the site as a whole and on the space itself, this is to say it depends on the acoustical quality of the space.

This thesis will delve into the Architectural factors that affect the quality of music, This is to say that I am goin to research into the area of Architectural Acoustics and noise \ control viz - a - viz the buildings used for Recording Music.

Creation of ideal Acoustical Environments needed for the recording of Music is an Architectural problem, it is envisaged that this thesis will show us how to solve the biggest problem facing the listening and production of Music.

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I N T R O D U C T I O N

We are living in an age of high technological knowhow with everything revolving around mechanization and the economic use of materials, this can be seen in the buildings we build nowadays, with prefabricated materials and their interiors filled with electronics and other electrical gadgets. These gadgets produce noise, while the thin building materials transmit this noise to other rooms, thereby bringing up problems of noise control for Architects to solve. This problem is that of providing quite environments needed by people for their physiological well being on the one hand and for them to carry out some of their activities that require quite environments, for example the recording of Music. In order to be able to provide this quite environments, a good knowledge of Acoustics is needed by the Architects and planners.

Music is synonymous with organized sounds, For sounds to be properly perceived and understood, conditions that favour their production, transmission and reception are needed, in other words a good acoustical environment is a pre-requisite for a sound communication in a space. This requirement can be met by designing surfaces that can reinforce sound reflections on the one hand, and suppress unwanted sounds from interfering with the activity going on. The former falls under room acoustics, it is a major area in the field of Architectural sound control, while the latter is in the field of Noise control in buildings.

In this thesis I am going to limit my study into the areas of Noise and Architectural sound control as it affects a Music Industry. The areas of Interior design, materials and finishes and space Acoustics, Fall under Architectural sound control while mechanical noise and vibrations due to services incorporated

into the building and noise infiltration from the external sources all under noise control.

It is hoped that this thesis will help in raising the standards of the Nigerian Produced Music by providing knowledge on how to create studios which can respond to the different Acoustical situations needed for producing the different types of Music available in this country.

CHAPTER ONE

SOUND

For a successful study in Acoustics, the nature and properties of sound has to be known.

1.1 What is Sound

Sound can be defined in two ways, either by taking its physical nature, or its effect on a subject into consideration Physically, sound is a pressure fluctuation in the air, a particle displacement in an elastic medium. Physiologically it is an auditory sensation brought up by particle displacement in an elastic medium.

Sound is produced by vibrating elements, modulated flow of fluid or a turbulent flow of air and it needs a medium to propagate.

1.1.1 Kinds of Sounds (Figure 1.1)

Sounds can be divided into three kinds. A pure tone is the simplest kind of sound composed of a waves with a single frequency. A pure tone is produced by striking a tuning fork. A musical tone is the other kind of sound, it is produced by a combination of many pure tones. The last group is that of common sounds, these are the speech, music and noise. They are composed of complex tones with varied frequency and loudness.

1.2 Properties of Sound

1.2.1 Velocity (v)

The velocity of sound is the speed at which it travels measured in metres per second (m/sec).

$$V = f \lambda$$

Where f = frequency in H_z

λ = Wave lenght in m.

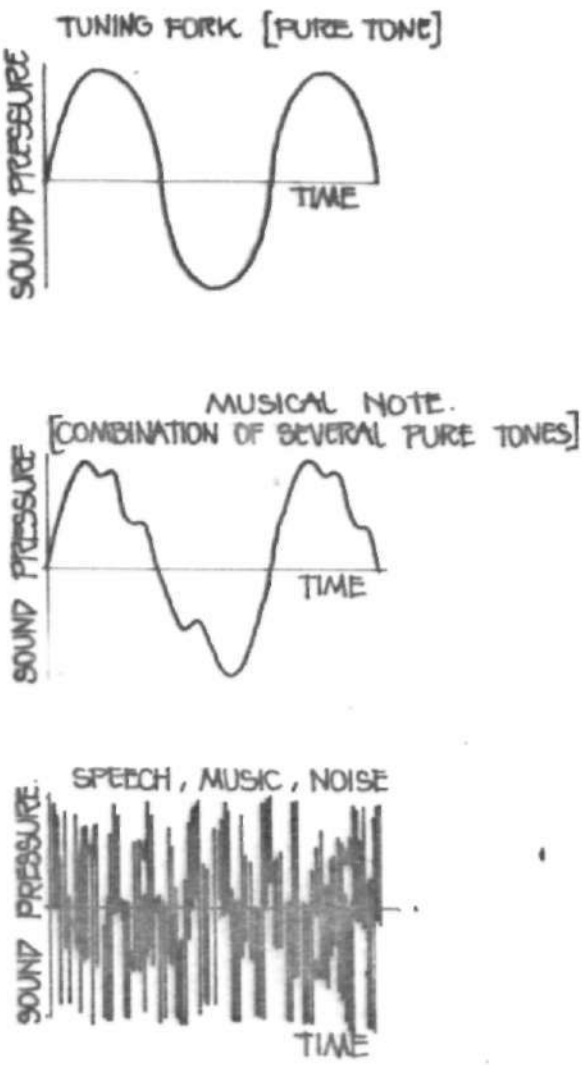


FIGURE 1·1 KINDS OF SOUND.

The velocity of sound waves depends on the degree of elasticity and the density of the medium. The velocity of sound waves in air at $20^{o}C$ is 344m/sec, this low speed of sound brought about the problem of echo.

1.2.2 Frequency (f)

This is the number of complete oscillations that occur every second. $f = 1/T$

where T = period of oscillation in seconds.

The audio frequency is between $20H_z$ and 20,000 H_z. This is the region within which the ear is sensitive. The human voice has a frequency range of about 80Hz for a low bass upto $1100H_z$ for a high soprano. The lowest frequency present in a complex tone is called the fundamental, the components of higher frequencies are called partials, if they are multiples of the fundamentals then they are termed harmonics.

An octave is a succession of eight notes, where the eighth has a frequency double that of the first, for example in do,re,mi,fa,soh,la,ti, do.

1.2.3 Intensity and Loudness

It is a measure of the energy of sound. The ear can detect a small change in loudness. The smallest change normally heard is the phon . The loudness level of a sound in phons is equal to the intensity level in dB at $1000H_z$ (figure 1.2). There is also a relationship between sound pressure level and relative loudness. An increase of 10dB in intensity will double the loudness (figure 1.3). The sone is a unit of assessing loudness. By doubling its number the intensity will increase by 10 phons

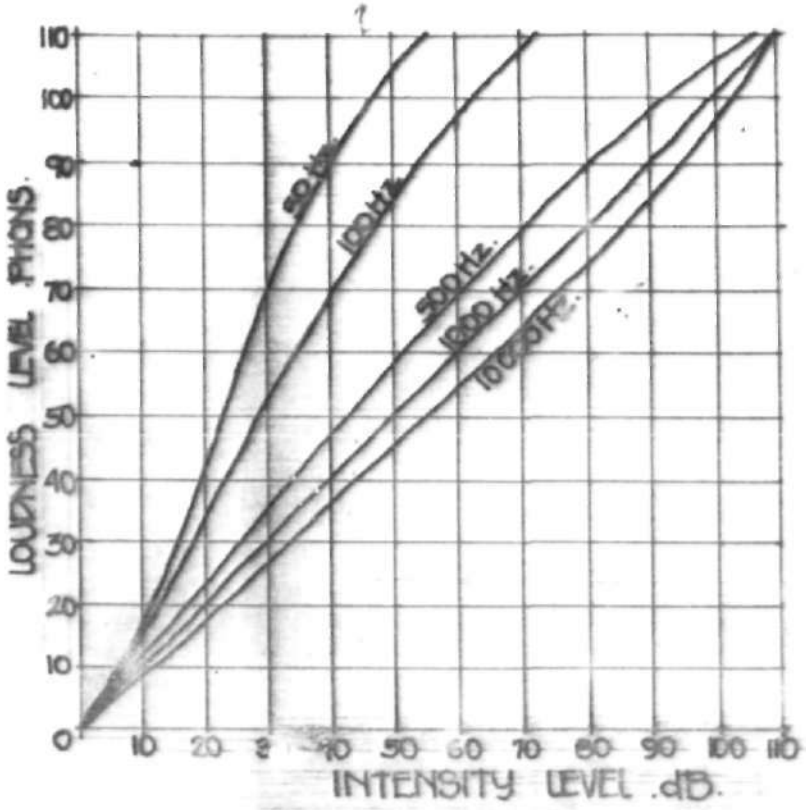


FIGURE 1·2 COMPARISON BETWEEN LOUDNESS AND INTENSITY LEVELS.

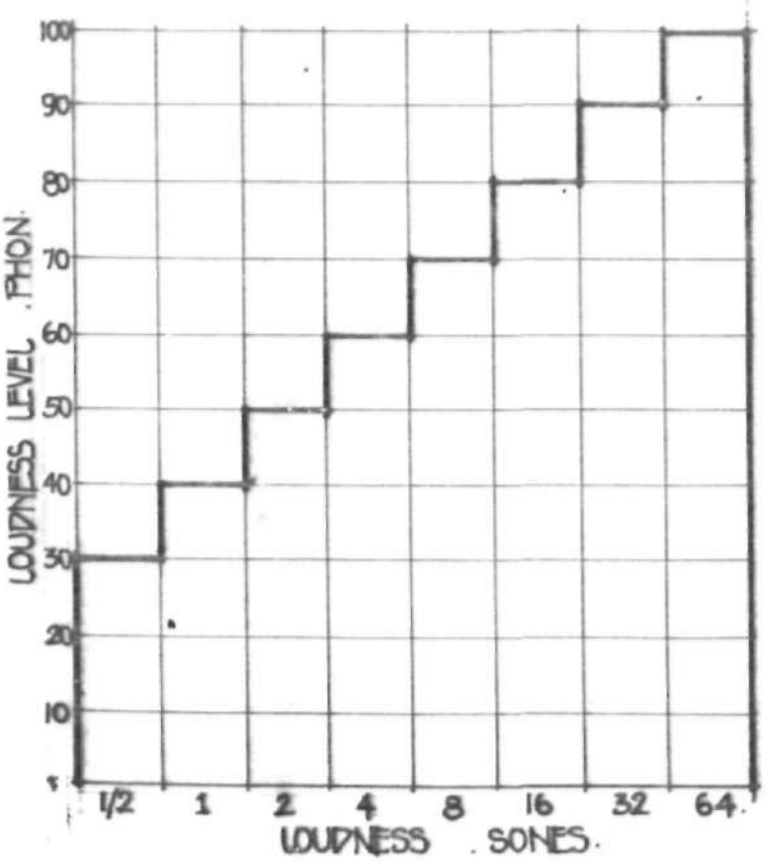


FIGURE 1·3 COMPARISON BETWEEN LOUDNESS IN PHONS AND SONES.

1.2.4 Pitch

This is the subjective measure of the frequency of the sound. The ear can detect doubling in sound frequency much more than in case of loudness. Pitch acuity is the ability to detect differences in pitch. (Figure 1.4)

1.2.5 Timbre (Quality)

It is that subjective characteristics of sound which enables one to distinguish it from other sounds of the same pitch and loudness. The quality of the sound is determined by the harmonics that a particular source adds to a note.

1.2.6 Directionality of Sound Sources

In a space free from reflecting surfaces the intensity of the emitted sound may be more pronounced in a given direction, although sound sources radiate waves in all directions. This phenomenon is noticeable with most musical instruments such as the human voice, loud speakers and so on.

The radiation of a high frequency sound is more directional than that of sounds within the medium and low frequency ranges within the medium and low frequency ranges which tend to be more uniform in all directions (figure 1.5).

1.2.7 Masking

The masking of a sound is defined as the number of decibels the sound has to be raised above its normal threshold in order to be perceived in the presence of another sound. The amount of masking depends on the time and frequency. Upto 300 milliseconds may elapse before a second sound is perceived particularly at threshold levels. A low frequency sound is more likely to mask a high frequency one. The

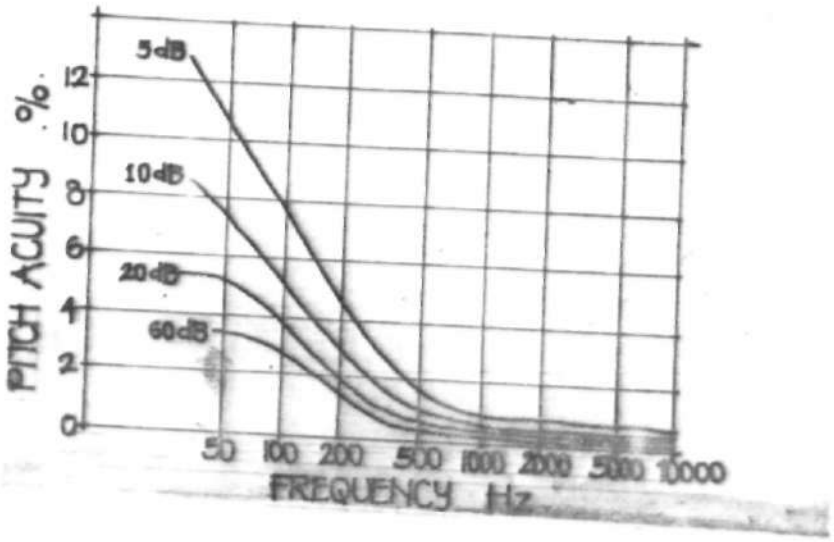


Figure 1·4 PITCH ACUITY AT VARIOUS FREQUENCIES.

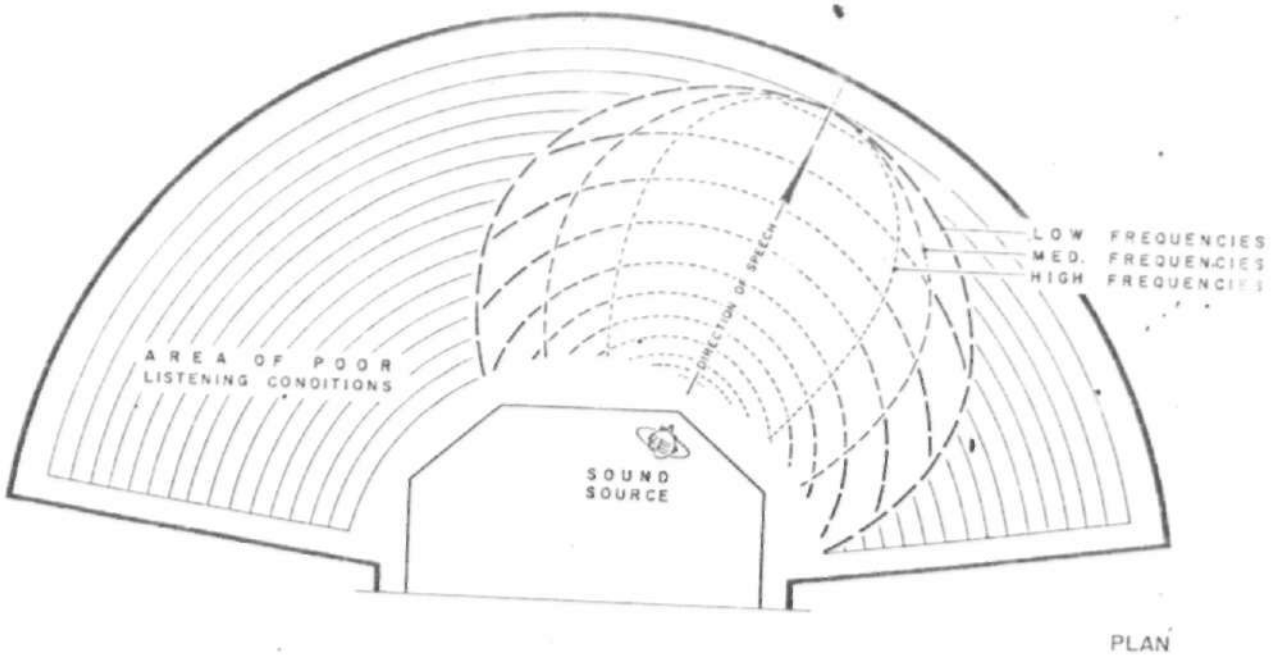


Figure 1·5 DIRECTIONALITY OF THE HUMAN VOICE.

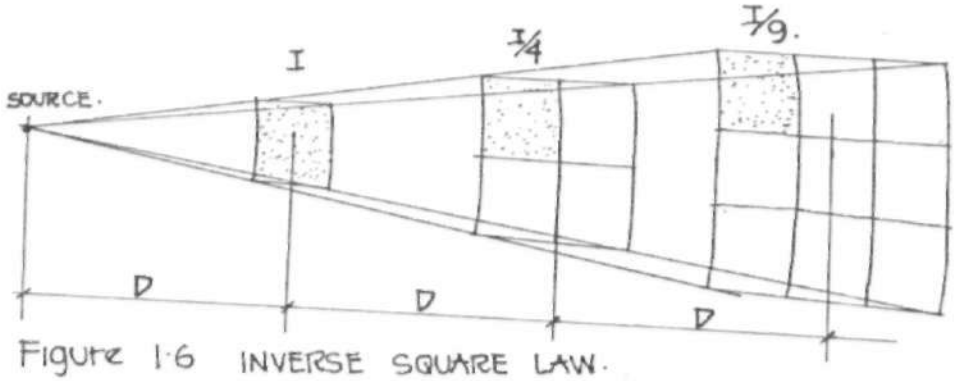


Figure 1·6 INVERSE SQUARE LAW.

phenomenon of masking is more exploited in environmental noise control.

1.2.8 Sound and direction

The reduction in sound intensity is regarded as 6dB each time the distance from the source is doubled. It should be noted that this does not happen if the surface is a hard one. In a free field the intensity of sound at any point is universely proportional to the square of the distance from the source point. This is the inverse sequare law (figure 1.6) in architectural acoustics. This phenomenon explains why there is inadequate loudness at the remote seats of large auditoriums.

1.2.9 Reflection

Sound is reflected from plane and curved surfaces in the same way as light is. Reflection occurs if the angle of incidence (i) is equal to the angle of reflection(r). Figure 1.7 shpw the reflections of sound from different boundaries. The reflected sounds from a concave surface converge at a point, while on a diffuse surface a diffused reflection is noticed.

1.2.10 Refraction

This is the change in the speed and direction of a sound wave when it passes from one medium to another (figure 1.8). Refraction of sound can happen in the same material if the temperature is different at different points. Figure 1.9 illustrates this point, the velocity of sound increases with temperature and so does the wavelength. Such a situation occurs over a calm lake in the evening after a hot day, the air at the surface is cooler and warmer above.

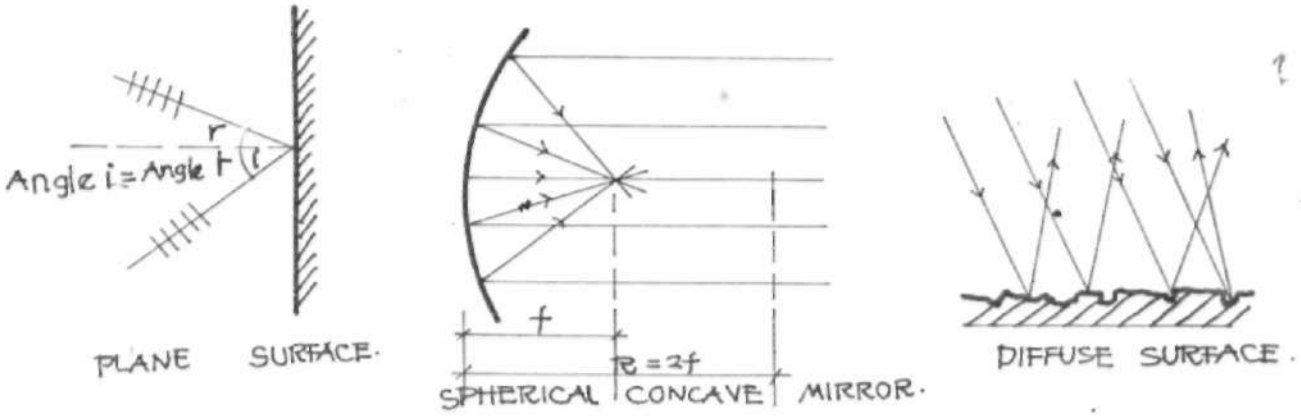


Figure 1.7 Sound REFLECTIONS FROM DIFFERENT BOUNDARIES

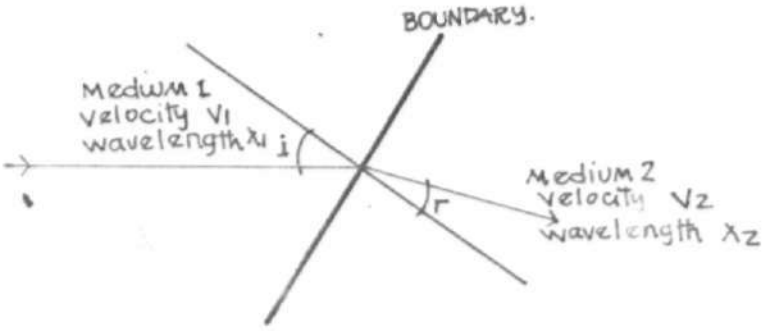


Figure 1.8 REFRACTION OF SOUND AT A BOUNDARY BETWEEN TWO DIFFERENT MEDIA.

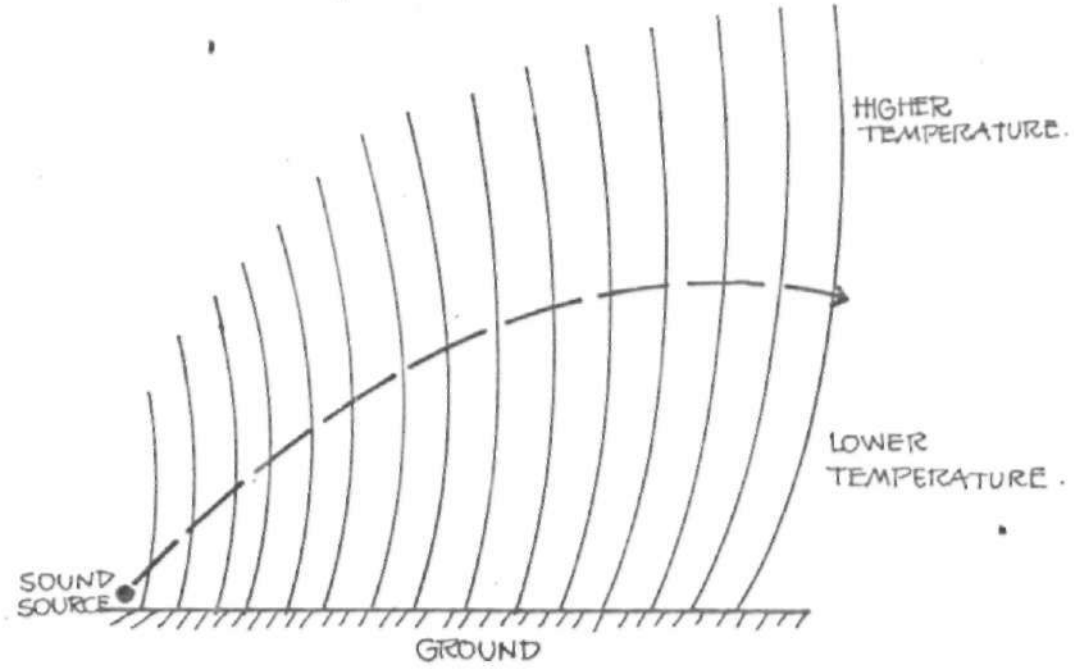


FIGURE 1.9 REFRACTION OF SOUND IN THE SAME MEDIUM.

1.2.11 Diffraction

This is the bending of sound waves around an object. This occurs when the size of the object is comparable to the wavelenght of the wave, This is why low frequency sounds are easily heard far off the axis of a loudspeaker than the high frequency sounds.

The frequencies that are diffracted can be calculated from the formula given below.

$$d = v/\lambda$$

where v = velocity of sound in air

λ= diamemeter of obstacle in metres.

For example an obstacle that is one meter wide is placed in front of a speaker, calculate the frequency range of sounds that would be diffracted.

$$d = v/\lambda$$

$$= \frac{340m/s}{1m} = 340/s = 340H_z$$

it shows that frequencies below $340H_z$ will be diffracted.

Diffraction of sound also happens when waves fall on small openings, if they are in the order of the wavelenght of the sound.

1.3 Recording of Sound

"The recording of sound starts with the acoustical signal in its proper acoustic environment" Josephs (1967). The environment could be an auditorium, studio or any room suitable for recording. In the case of a Music industry it is in a recording studio.

1.3.1 Recording on Wax

Leon Scott used an Apparatus he called the phonautograph to demonstrate the recording of sound in 1859. This was the first time the recording of sound was done. It consisted of a

cylinder mounted on bearings with a handle attached to one end of the spindle. He used a large parabolic horn to collect the sound and a pencil made a lateral trace of the vibrations on the cylinder. The pencil was carried by a lever.

In 1878 Edison produced the first talking machine. He did this by replacing the lever with a rigid point and covered the brass cylinder with tinfoil. The furrow cut was of varying depth, "hill and dale" recording. It was called the phonograph (Figure 1.10A). The quality of reproduction was improved by Berliner in 1887 by the introduction of "lateral or 'side to side' recording" Winstanley (1952). The disc was of a metal coated with wax, the stylus removes part of it when moving and exposes the metal. "Acid was then used to 'bite' the trace into the metal" Winstanley (1952). The reproduced sound came out of the small horn.

In 1898 Berliner improved his apparatus with a new model with a clockwork drive and the horn ended with a flare. (Figure 1.10 B and C show the early and improved models respectively).

In 1924 an important advance was made by the introduction of electrical recording which required a new type of gramophone to handle the more intense vibrations more efficiently. The sound is picked up by the microphone then amplified, This creates a current in the electromagnet which attracts the metal armature and consequently the stylus. The distance through which the armature is attracted depends on the signal received. Fig. 1.11A illustrates the electrical recording apparatus. The wax disc is then electroplated in an electrolytic bath and a thin strong

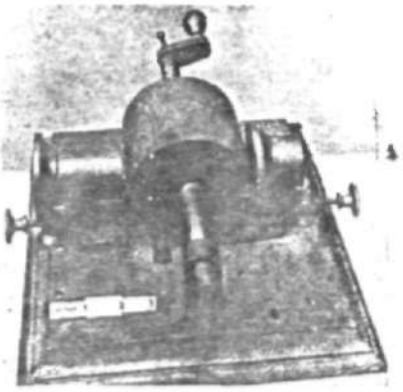


FIGURE 1·10A EDISON'S ORIGINAL PHONOGRAPH.

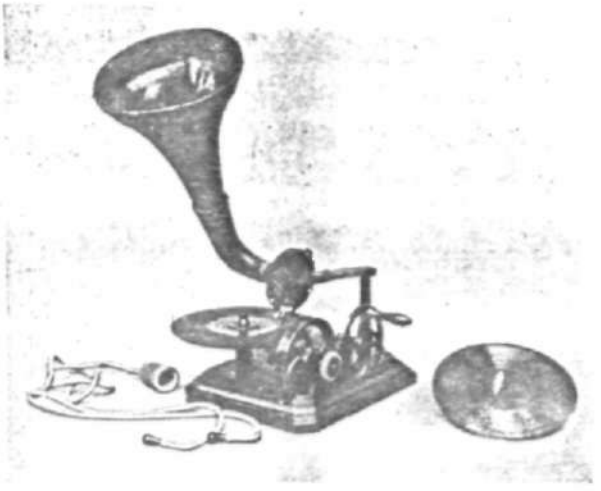
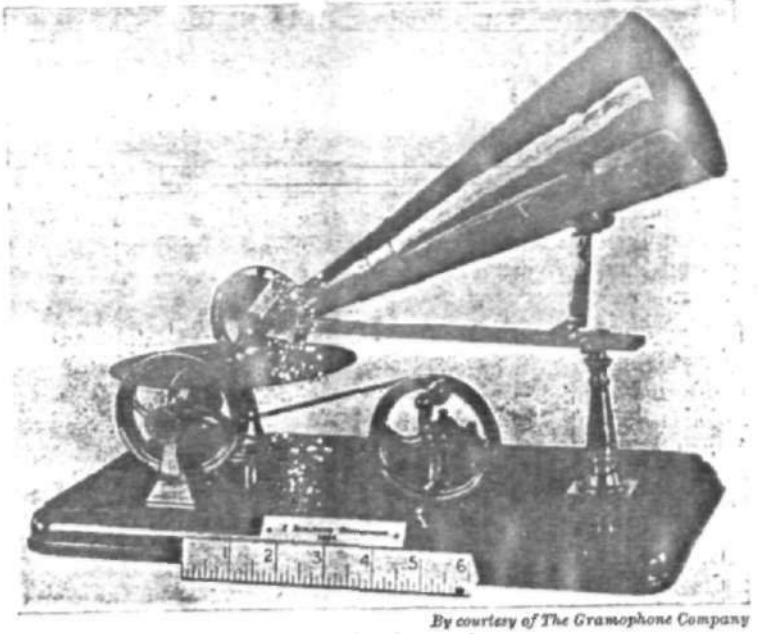


FIGURE 1·10B BERLINERS EARLY GRAMMOPHONE.



By courtesy of The Gramophone Company

FIGURE 1·10C BERLINERS IMPROVED MODEL [1894].

"negative" is produced. This "negative" is known as the "master". It is then immersed again to form a "positive" called the "mother". The "mother" is put back into the bath to form the "stamper" which is the "working matrix". Records are then pressed from the working matrix. "The material used for the records is a mixture of shellac, resin, copal and a number of other ingredients; it becomes plastic when hot but is hard at normal temperature" Yarwood (1953). The material is then graded to uniform thickness to form the sheets. When the sheet becomes cold and hardened (biscuits), they are broken off and taken to the press room. In the press room two matrices are fixed in position to make a double-sided record. The requisite label is put at the centre of each matrix, and from a heated slat one of the biscuits is rolled into a ball and placed at the centre of the lower matrix. By clossing the plates bearing the matrices, a pressure of about 100 tons is applied and steam is circulated behind the matrices followed by water cooling. The press is then opened and the disc, is removed and the surplus materials is broken from the edges, then polishing follows. It should be noted that now the process has changed due to mechanisation of some of the processes and improvements in the recording of sound.

1.3.2 Recording on Magnetic Tape

Valdemar Poulsen of Copenhagen invented the use of magnetic tape for recording in 1899. The machine consists of a constant speed motor driving a ribbon of tape made up of an iron oxide on a plastic base and a recording head.

The microphone picks up the sound and convert it into electric signal, which is amplified by an amplifier which

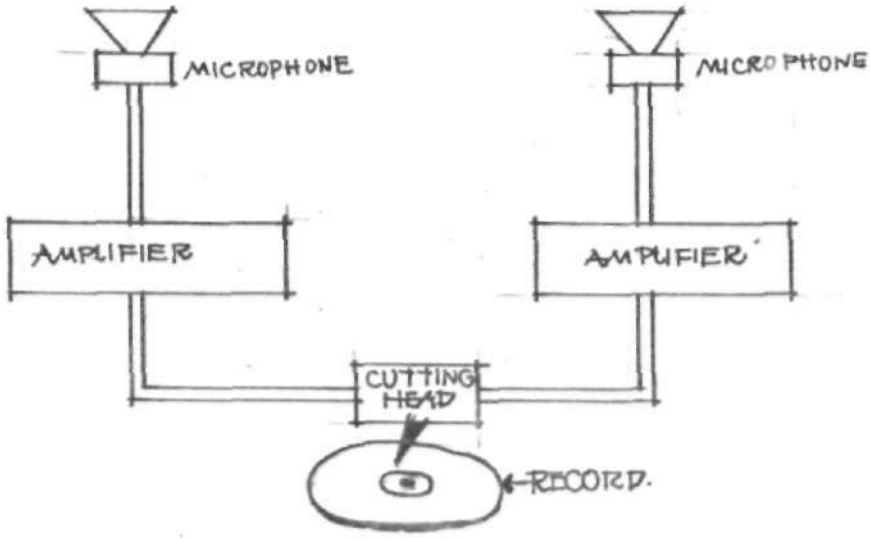
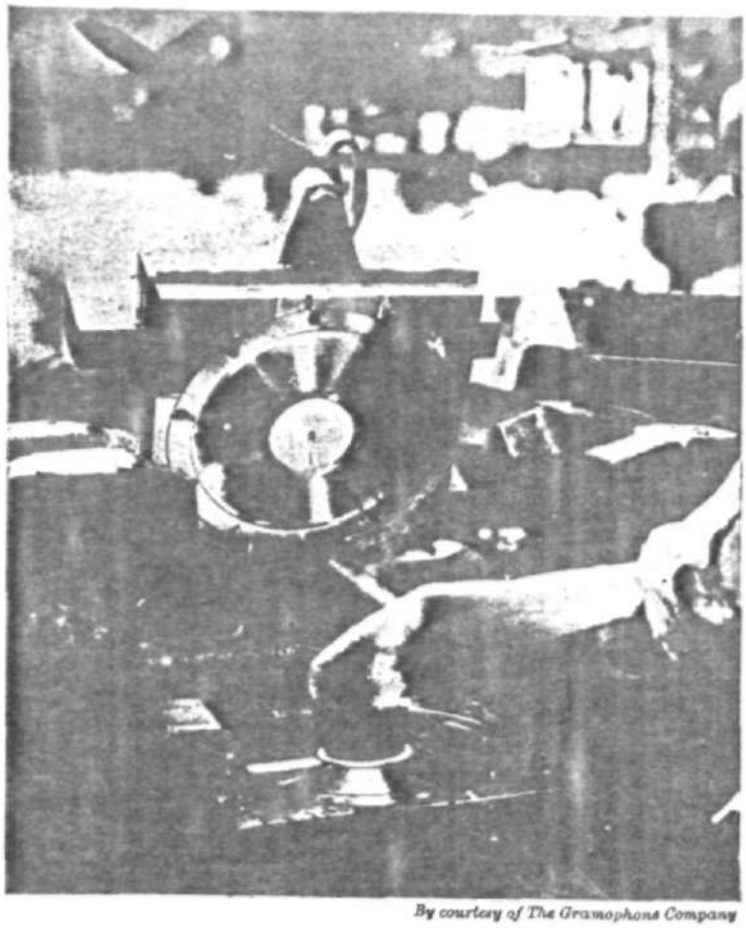


FIGURE 1·11A ELECTRICAL RECORDING APPARATUS.



By courtesy of The Gramophone Company

FIGURE 1·11B A HYDRAULIC PRESS FOR MAKING GRAMOPHONE RECORDS.

feeds the recording head with the current which magnetises the recording head. The recording head causes a change in the magnetization of the tape as it passes near the head. The magnetization of the tape is permanent until erased. Recording speeds vary from 1½ to 15 inches of tape per second.

The advantage of this kind of recording is that, an instant playback is possible, tape can be erased and used again (this can also be a disdanvantage in case of accidental erasing), long time of play and so on.

1.3.3 Recording on film

The method employed here is to convert sounds by use of microphones into electric currents then record them using an oscillograph. The record was made on a moving filmy the area exposed was determined by the deflection of the oscilograph, This was the system employed by W.D.B. Duddell one of the early inventors of photographic film recording. To reproduce the sound, a photo electric cell is needed. The film is directed on to a mirror and the reflection is focussed on to a narrow slit in a screen fixed vertically in front of the film (Figure 1.12) "The fluctuating phonic currents through the loop cause the mirror to turn in a vibratory manner, and this causes the beam of light to extend to varying distances across the slit and so across the film". The intensity of the sound is given by the magnitude of the changes in the ratio clear/opaque section across the sound track, the pitch is indicated by the number of 'peaks' per unit length of the film. This is the variable area recording.

Another system is the variable density recording, where a narrow streak of light exposes the full width of the sound track, and the intensity is varied by the phonic currents.

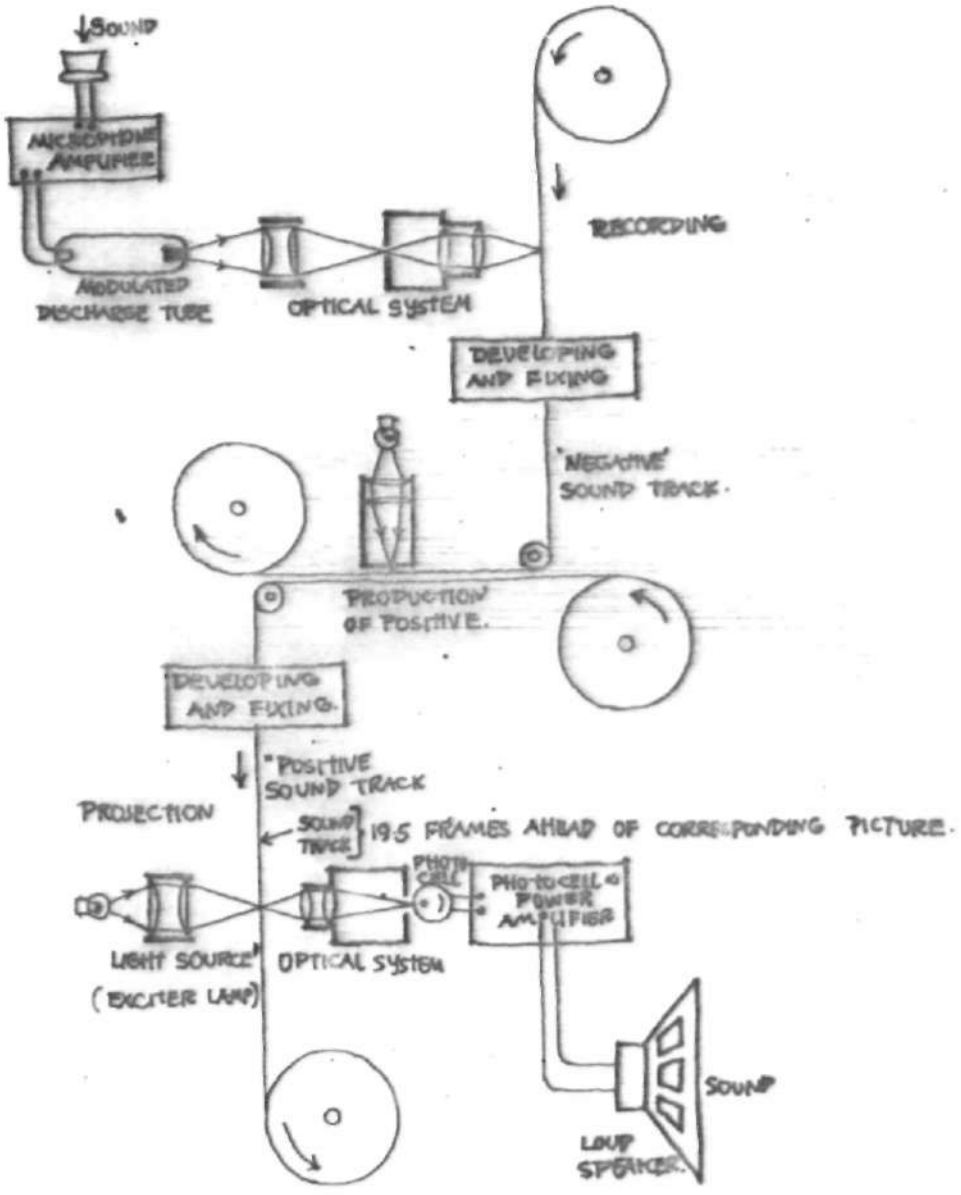


FIGURE 1·12 OPTICAL RECORDING SYSTEM.

CHAPTER TWO

ACOUSTICS AND INTERIORS

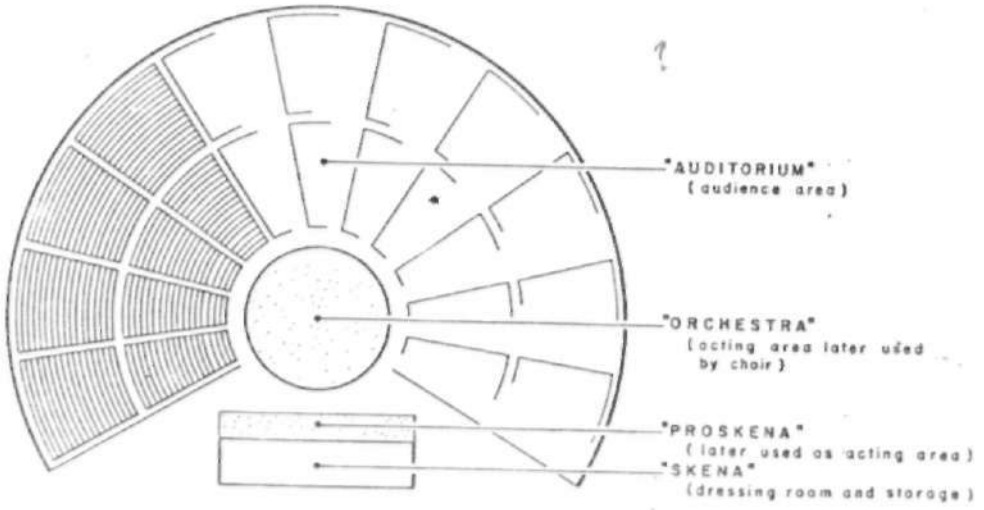
Acoustics is a branch of science which deals with the Generation, transmission and reception of sounds, under the generation of sounds, sources and reproducers of sounds are found. A source of sound is anything that can cause pressure fluctuations in the air while electronics like tape recorders reproduce sounds. Environmental Noise control and building Acoustics fall under the auspices of sound transmission. Reception of sound deals with Audiology and microphones, which are sensitive instruments used for picking up sounds.

2.1 Historical Development

As early as about 55 century before Christ the need for good acoustics for satisfactory hearing has been recognised and Vitruvius clearly stated this fact. He said 'at some places the sound will strike against solid bodies and check in its return the rise of the succeeding sound so that the word endings are migled into indistinct noises' in his book De architecture" Yarwood (1953).

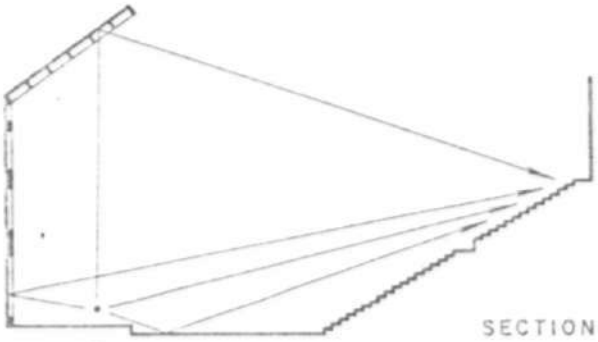
The ancient Greeks and Romans theatres had no roofs and their greatest defect is the lack of what Vitruvius called the "strengthening of the voice by reflections from well-placed surfaces". He suggested setting bronze vases in the theatres so as to boost the Actor's voice by the resonance of the air in the vessels.

The ancient Greek open theatre was divided into four parts, the Auditorium which is used by the audience for seating, the Orchestra is used as the acting area which later became the area used by the choir, the Proskena became the acting area later and the skena used as the dressing room

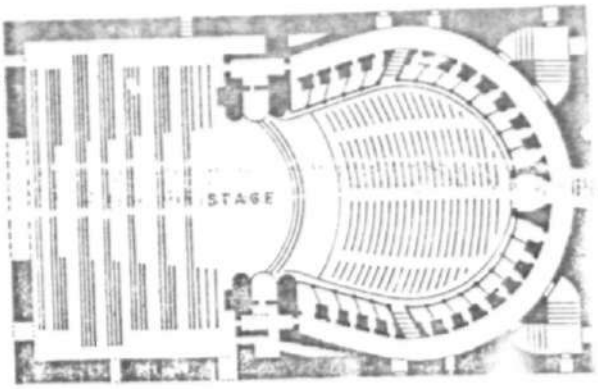


PLAN

[A] SCHEMATIC ILLUSTRATION OF AN ANCIENT GREEK THEATRE.



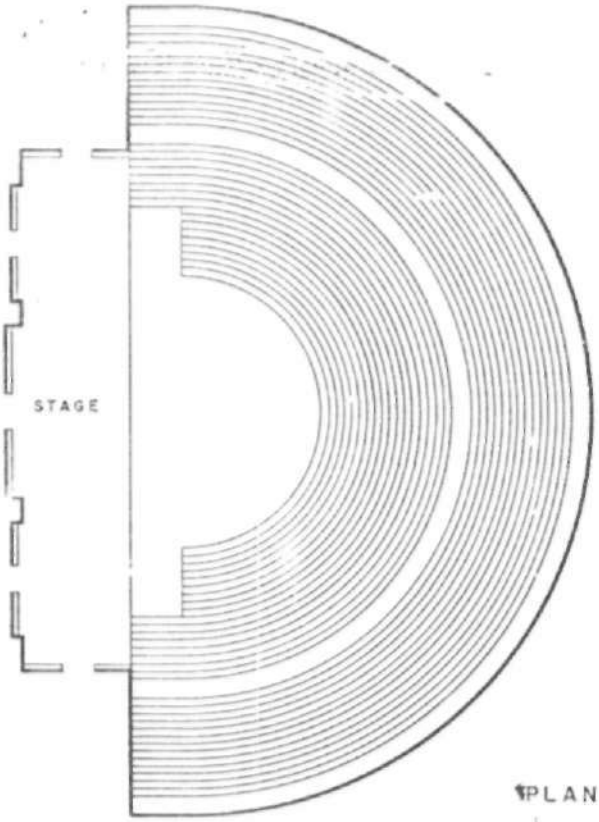
SECTION



PLAN

10 0 20 40 60 80 FEET
5 0 10 20 METERS

[C] TYPICAL HORSESHOE SHAPED EUROPEAN OPERA HOUSE.



PLAN

10 0 20 40 60 80 100 FEET
5 0 10 20 30 METERS

[B] ANCIENT OPEN AIR THEATRE AT ORANGE.

FIGURE 2·1 DEVELOPMENTS IN THEATRE DESIGNS.

and storage area.

The Church hall during the Middle Ages became the only type of Auditorium built. These halls were characterised by excessive reverberation, poor intelligibility and an overwhelming fullness of tone. This was so because the halls were not more open but covered. The council hall normally built within the city hall was later introduced after the 11th century mainly in Italy.

The horse-shoe-shaped opera house developed about the 17th century from the theatres that were built after the 15th century. This types of theatre had large stage area and stage with rings of boxes, or tiers placed on top of each other upto the ceiling. This helped in creating a suitable Acoustical environment needed for the brisk tempo of Italian Opera by shortening the reverberation time due to the large absorption of sounds by the boxes. About this time Athanasius Kircher wrote in his book Phonurgia about room acoustical phenomena. This was termed as the first "scientific" work on the subject. He reviewed the simple acoustical practice of earliest centuries which is a contribution towards the historical development of Architectural Acoustics. Another book Die Akustik (Acoustics) by a German Ernst F. Friedrick Chladni tried to explain the phenomenon of reverberation around the beginning of the nineteenth century.

Prior to the nineteenth century, Music was written for particular rooms, either for public or private rooms. Church music, Opera and choral music was written for public rooms (halls) while Chamber and symphonic music were for private rooms.

The designs of opera houses in the Nineteenth century were done without the knowledge of scientific acoustics but that of empirical acoustics. This can be seen "... in the words of Charles Garmier, the Architect of the Paris Opera House 'I must explain that I have adopted no principle, that my plan has been based on no theory; and that I leave success or failure to chance alone' Leslie (1972).

Prior to the 20th century only one auditorium was planned with due consideration to acoustical requirements. It had no rings of boxes or tiers and was built to suit the wagner's style of Music (figure 2.2).

Helmholt , Bell, Weber and Fechner contributed immensely to acoustics in the second half of the nineteenth century.

There has been a significant advancement in the subject of Architectural acoustics which is now an established branch in the area of engineering science. It was the introduction of the voice to the Cinema in the 1930s that brought up the phenomenon of high quality recording, amplification, and reproduction of sound. The development of the Radio and television broadcasting presented itself with new acoustical problems.

Progress was more pronounced in the area of room acoustics than in noise control in the first half of the twentieth century. Acoustical materials are mass produced there by providing building designers with the necessary means of controlling sound in Architectural spaces.

A study in room acoustics is never complete without mentioning the work of Wallace C. Sabine, he was called to remedy the intolerable acoustical defect found in the auditorium of the Fogg Art Museum. He was a Physics

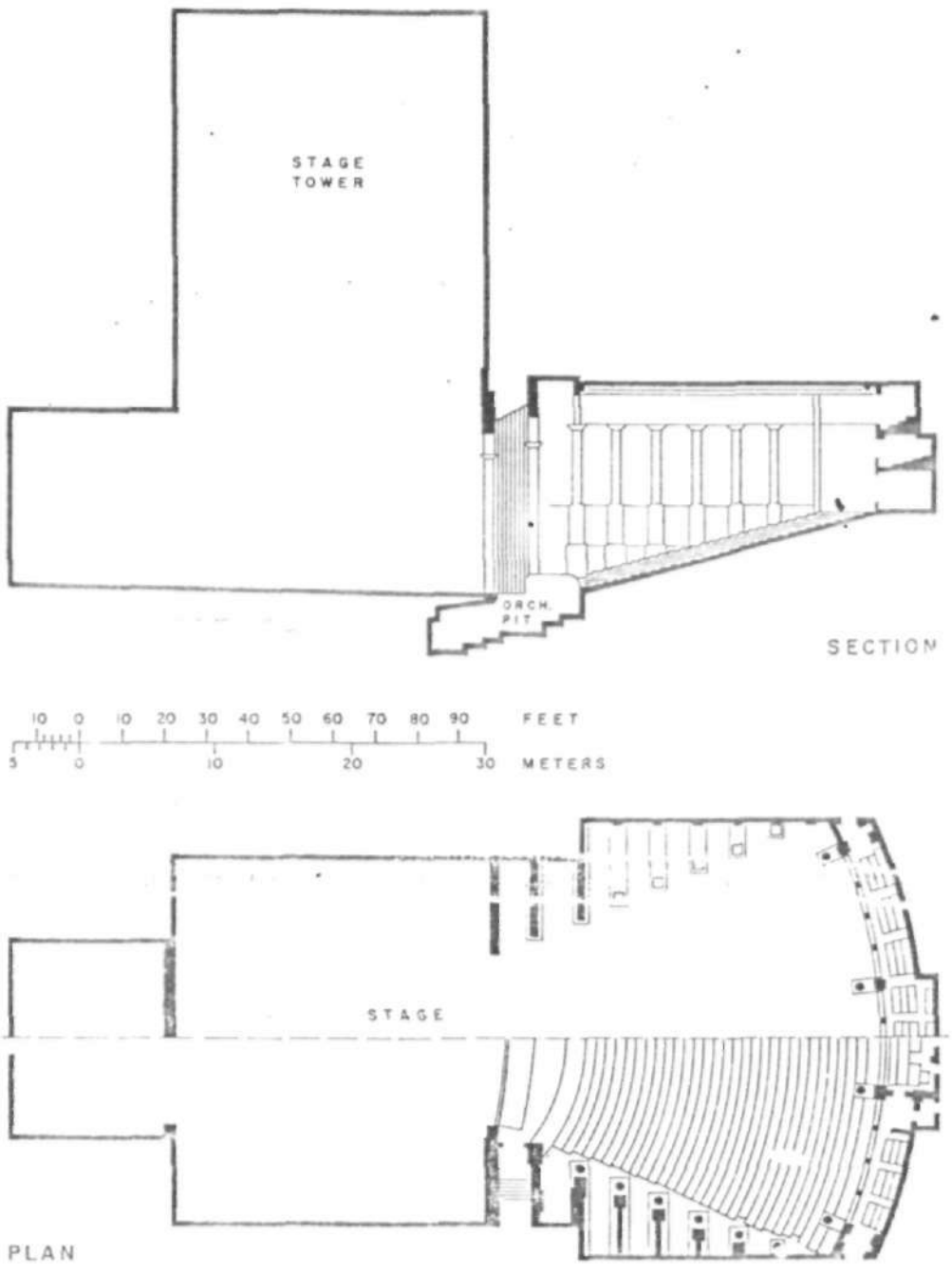


FIGURE 2.2. FIRST ACOUSTICALLY DESIGNED AUDITORIUM,

Instructor at Havard University and started his pioneering work on acoustics at about 1895. He started his work by laying down conditionalities that must be fulfilled in order to achieve good hearing in the auditorium. They were loudness: distortion and confusion.

(i) Loudness: The sound heard by the Audience must be loud enough. For a point source of sound on a level plain the sound spreads out in a hemispherical wave and diminishes in intensity as it travels further from the source. The intensity of the sound diminishes more if there is an audience due to sound being absorbed by their bodies. If the source of scund is raised above the audience, or the seats are raked, or a wall is placed behind the speaker, or the audience are brought nearer to the source by providing a gallery then we have a modern auditorium with an improved hearing condition due to the equalization of the sound intensity between the front and rear due to small volume and sound reflections which reinforces the direct sound from the speakers.

(ii) Distortion: The quality of the sound produced must not change. Changes in the quality of the sound in the auditorium can be by either resonance or destructive interference. When resonance occurs there is an increase in the intensity of sound, it happens when a component of the sound is increased by a reinforcement, This will invariably change the quality of the original sound. Interference occurs due to reflections of sounds from the surfaces. It can either be destructive interference where the incident sound

is out of phase with the reflected one by 180°, This will reduce the intensity of sound. Constructive inteference occurs when the reflected sound is in phase with the direct one, This will bring an increase in the intensity of the sound.

(iii) Confusion: There should be no overlap on the successive sounds in the speech or Music. In other words, excessive reverberations, echo, and added extraneous sounds should be eliminated. Reverberation refers to excessive reflections from the surfaces while an echo is a single reflection which is distinct from the original sound. The extraneous sounds may be due to the operations of the machinery in the building, for example the airconditioners, heating machinery and it can be due to distracting sounds (noise) from the outside.

Fogg Museum: The major problem found in its auditorium was that of excessive reverberation. He solved the problem by first measuring the reverberation time, he used a Gemshorn organ pipe of $512H_z$ and an initial intensity of 60dB as a constant sound source, the ear to record when the sound becomes inaudible and a timer. "He invented a term 'reverberation time' as the time, it takes for the sound that has been maintained steady by a constant source to decay to 1/1,000,000 of its original intensity after the source has been stopped". Jess J. Josephs The Physics of Musical sound. He found out that the reverberation time was independent of the positions of the source and the observer in the room, it was found to be 5.62 secs. Cushions were then brought into the Art museum to cover the seats and it was found that this lowered the reverberation time, this is an indication that part of the sound was absorbed by the cushions.

Figure 2.3 illustrates the results of Sabines experiments in the Fogg Museum. The result of the graph is a hyperbola represented by the equation $K = (x + a)_y$, where x is the area of cushion, y is the reverberation time and a the absorptance. The time taken for sound to fall to threshold was taken to mean reverberation time, this means that for a larger initial sound the constant K would be larger and as such the need to make K independent of the loudness aroused. A decay of 60dB was taken as the constant.

Sabine found out that the reverberation time of the Art Museum dropped to 1.14 sec after covering all surfaces including the aisle with the cushion. After the experiments with cushions other materials were used and their absorption measured and compared with that of the cushions which would produce the same effect. Conclusions which were reached after the experiments were: (i) The position of the absorbers does not affect its total absorptance (ii) The open window was accepted as the standard unit of absorptance, due to the fact that an open window allows all the sound to pass through, that is to say it has a unit absorptance. He then experimented again to find the nature of the constants K and a. He noted that K varied in a linear manner with the volume of the room. Each cushion was found to have an absorptance of 0.73 open window units; this is to say that a cushion square metre for square meter will absorb 0.73 as much sound as an open window. The name open window unit was later changed to sabines. To find the total absorbing power in a room it is only necessary to multiply the area of the surface of each material by its absorption coefficient and add the results.

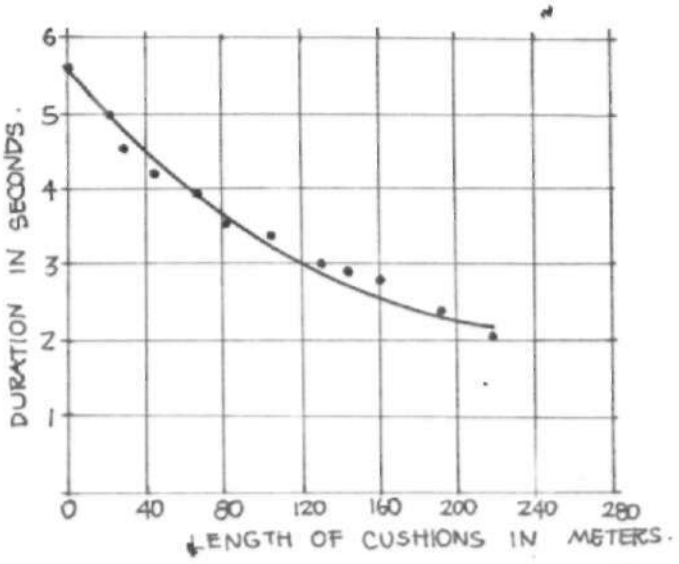


FIGURE 2·3 REVERBERATION TIME VERSUS LENGTH OF CUSHIONS.



FIGURE 2·4 SOURCE, PATH AND RECEIVER.

$$A = a_1 s_1 + a_2 S_2 + \ldots a_n S_n$$

Where a = absorption coefficient

" s = surface area.

Finally he carried out experiments in different rooms and found out for a given amount of absorbing power the reverberation time was proportional to its volume.

$$K/V = 0.164 \text{ if mesurements are in metres.}$$

Therefore $At/V = 0.164$

$$= \frac{0.164V}{A}$$

To test his work he planned a new hall and his theoretical calculations gave the correct reverberation time.

The other problem was that of an optimum reverberation time. To answer this, sabine used music judges from the faculty of the New England conservatory of Music. There was unanimity among them about the optimum reverberation time, Then a survey of musical opinions was made in order to find out the best halls for certain purposes, their reverberation times were then measured and compared with that of the judges.

Other factors like freedom from echo, diffusion of sound, freedom from noise and tonal distortion affected the Acousticians of a generation ago.

2.2 Why Acoustics for buildings

The study of Acoustics is done for buildings for the purpose of achieving optimum conditions needed for sound communications, This is done by providing favourable conditions for the production, transmission and the perception of sound, protection of occupiers of a space from noise and vibrations which could be distracting , annoying or dangerous to their health and for purpose of making

laws on the siting of certain institutions or activities in an area.

2.3 Source, Path, and Receiver

Every acoustical situation consists of three elements, the source of sound which is either desirable or undesirable, The path of trasmission of sound which includes the surfaces that either absorbs, transmit or reflect the sound, and the receiver which is either the human ear or another sensitive instrument that can detect the sound. In a Recording studio the human ear is replaced by a sensitive instrument (microphone) which can detect minute defects which the ear is not sensitive to.

The three elements representing all acoustical situations are shown in figure 2.4

If the sound source is a desirable one, then conditions that are favourable to its production transmission and reception must be provided. This can be done by emphasizing the source of sound by raising it adequately so as to be perceived, the transmission path must be made more effective by reinforcing reflections, and the listener must be relieved of all distracting sounds from the interior and exterior sources. Measures that are applicable to the realm of noise control must be taken in order to suppress the intensity of the source of sound if it is an undesirable one. These measures include the reduction of the effectiveness of the transmission path, the source of the noise must be placed far from the receiver and or the effective level of intensity of the noise should be reduced to a tolerable degree by use of a masking sound.

2.3.1 Hearing

It is the ultimate termination of most acoustic system, it is the natural method for the perception of sound by a listener. To be able to design acoustical spaces which are to terminate with the listener, it is necessary to understand some aspects of hearing. They are

(i) The interpretative aspect: This is the characteristic of hearing by which we recognise the sounds.

(ii) The loudness aspect: The mind orders the incoming sound on a scale from soft to loud or from quite to noisy.

(iii) The quality aspect: The mind classifies the sound perceived as being mellow or discordant, rich or drab, harsh or pleasing. The quality of the sound is used to differentiate sounds of equal frequencies but produced from different instruments.

(iv) The pitch aspect: A scale running from low to high is used by the mind as a means of evaluating the pitch.

(v) The tempo: This is an aspect of hearing by which the speaker's mood is noted, either the words were excitedly or deliberately spoken.

1.4 Reverberation:

It is the persistence of sound in a room after the source of sound has stopped. The reverberant sound gradually decay and its duration in a room depends on the intensity of the source and the amount of absorption in the room. In a highly absorbent room the reverberant sound decays very fast. Reverberation is important in room acoustics due to the fact that it helps the listener to understand what is being said

and gives quality to the perceived sound, and excessive reverberation intereferes with subsequent sounds and as such it reduces speech intelligibility. Figure 2.5 shows the detrimental effect of excessive reverberation on speech intelligibility. In a highly reverberant room the syllable U of the word University when uttered will persist so that when the syllable ni is uttered it still maintains 90% of its original intensity, when the third syllable ver is uttered the syllable ni maintains 90% of its original value while the first syllable has 80% of its original intensity, their persistence blurs the next syllable ver thereby reducing the speech intelligibility. Under this condition both the speaker and the listeners suffer.

2.4.1 Intelligibility and Articulation:

Intelligibility is defined as the percentage of arbitrary units correctly understood compared to the total presented. Intelligibility increases with an increase in the average sound pressure level and decreases as the duration of the unit decreases. Articulation is a quantitative test measure of the intelligibility although the test is done in an empirical manner and the result is given in the form of an articulation index.

2.4.2 Reverberation Time:

This is the time it takes the sound pressure level in a room to decay by 60dB after the source of sound is stopped. It is a standard measure in acoustical designs for the control of reverberation. The Sabine formula mentioned earlier, is still in use todayfor a simplified calculation of reverberation time (RT).

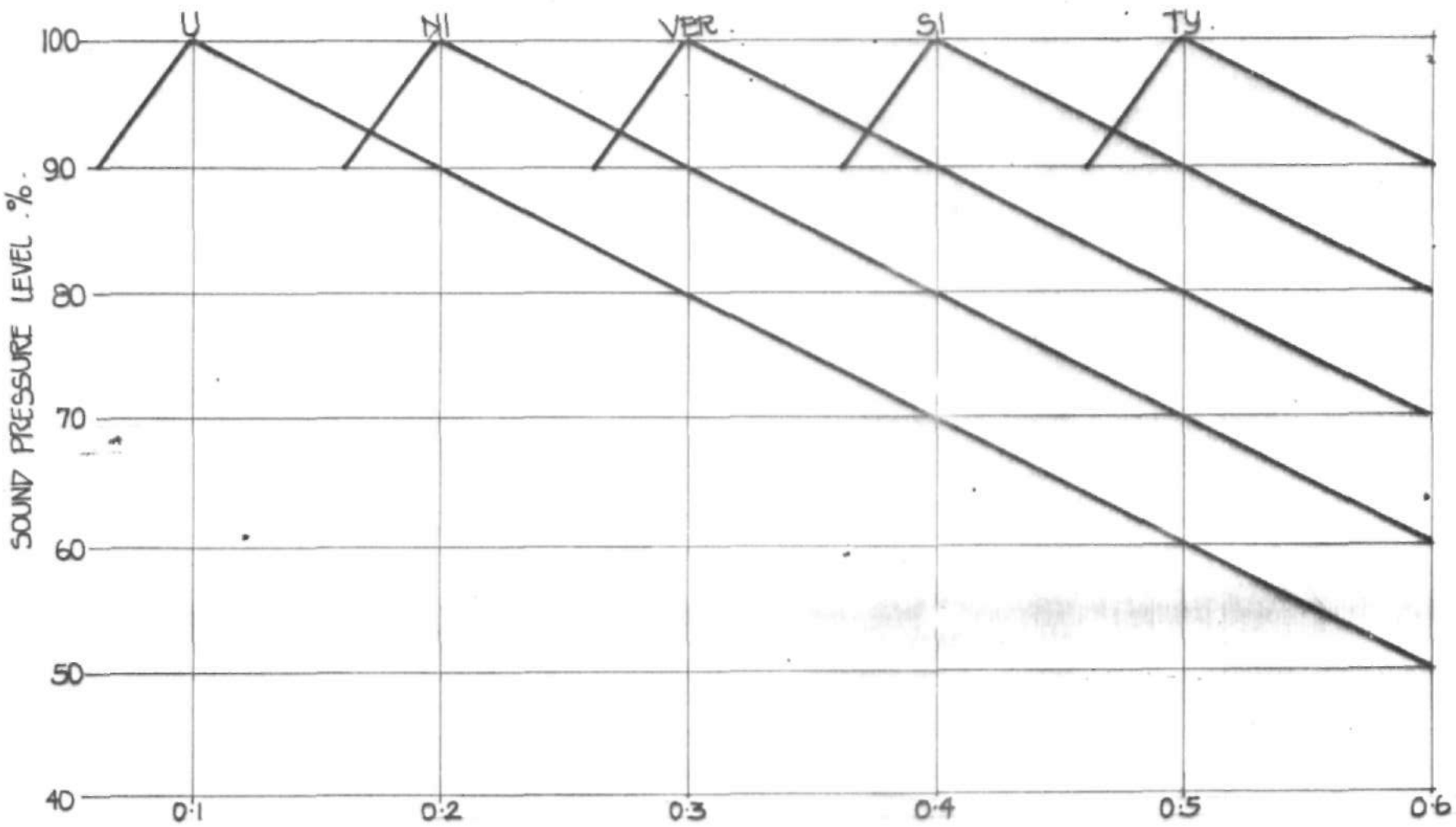


FIGURE 2:5 DETRIMENTAL EFFECT OF EXCESSIVE RT ON SPEECH INTELLIGIBILITY,

$$RT = \frac{0.05V}{A + xV}$$

Where RT = reverberation time, sec

V = room volume in cuft

A = total room absorption in sq-ft Sabins

x = air absorption coefficient.

For calculation of Reverberation time using the metric system the formular below is used.

$$RT = \frac{0.16V}{A + xV}$$

Where RT = Reverberation time, sec

A = total room Absorption in sq-m Sabins.

X = air absorption coefficient.

The air absorption coefficient depends on the frequency of the sound and on the temperature and humidity of the air in the room. Table 2.1 gives the values of air absorption at frequencies of 1000H_z and above.

The total room absorption A is found by multiplying its area S by its absorption coefficient α as shown below.

$$A = S1\,\alpha 1 + S2\,\alpha 2 + S3\,\alpha 3 \ldots + Sn\,\alpha n.$$

Where S1... Sn are individual surface areas

and Where $\alpha 1 \ldots \alpha n$ their respective absorption coefficients.

All reverberation formulas apply only to rooms where there is a perfect sound diffusion, surfaces in room are uniformly absorbent and free from disturbing ~~fum~~ fluctuations. The reverberation time of a room is also affected by the frequency of the sound and the volume of the room. Figure 2.7 shows the

DESCRIPTION.	FREQUENCY Hz		
	1000	2000	4000
AIR PER 1000 ft³ VOLUME, RELATIVE HUMIDITY 50%	0·9	2·9	7·4
AIR PER 100 m³ VOLUME, RELATIVE HUMIDITY 50%	0·3	0·9	2·4

TABLE 2·1 AIR ABSORPTION COEFFICIENTS.

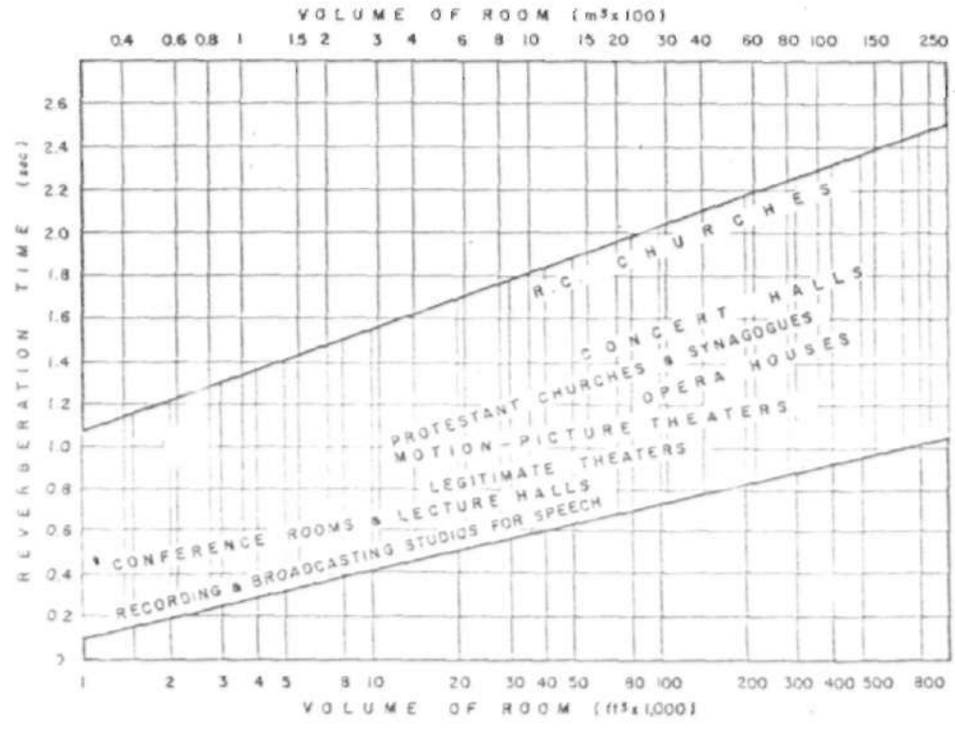


FIGURE 2·7. APPROXIMATE RANGE OF OPTIMUM RT AT MID FREQUENCY RANGE.

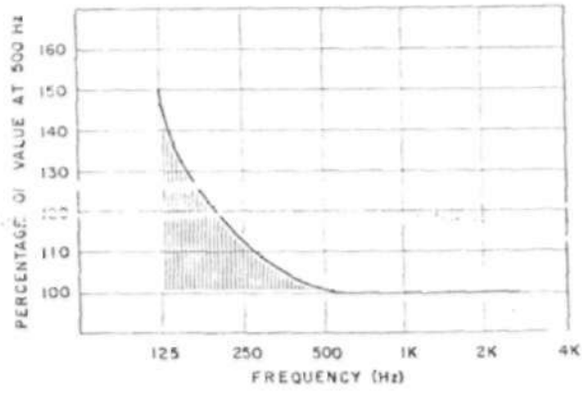


FIGURE 2·8 RECOMMENDED VARIATION OF RT WITH FREQUENCY.

relationship between optimum reverberation time and the volume of a room. The optimum reverberation time depends on the type of music or speech and the frequency. Generally speaking optimum reverberation times for music is higher than that for speech, for recording studios the trend is towards designing a "dead studio", that is to say a studio with reverberation time close to zero seconds. It should be noted that reverberation times are normally taken for a given frequency range and this given frequency range is the mid frequency of the audio region that is for the octave 500 to 1000H_z. From experience it was found that excessive variation of reverberation time at frequencies other than the mid frequency region creates unsatisfactory hearing conditions in a room.

Different Reverberation time versus frequency curves have been suggested by Acousticians, but a flat curve above 500Hz is the one generally recommended by them. Figure 2.8 shows the recommended frequency curve for Music, the reverberation time rises to about 1.5 times the value given at 500Hz at an octave less than this value (at 125Hz). For speech the value should remain flat down to the 125 Hz point. A deviation of 5 to 10 percent from the selected reverberation time value is acceptable in acoustical designs of rooms with a high degree of sound diffussion. Figure 2.9 illustrates the acceptable variation in the reverberation time for different frequencies and volumes of room.

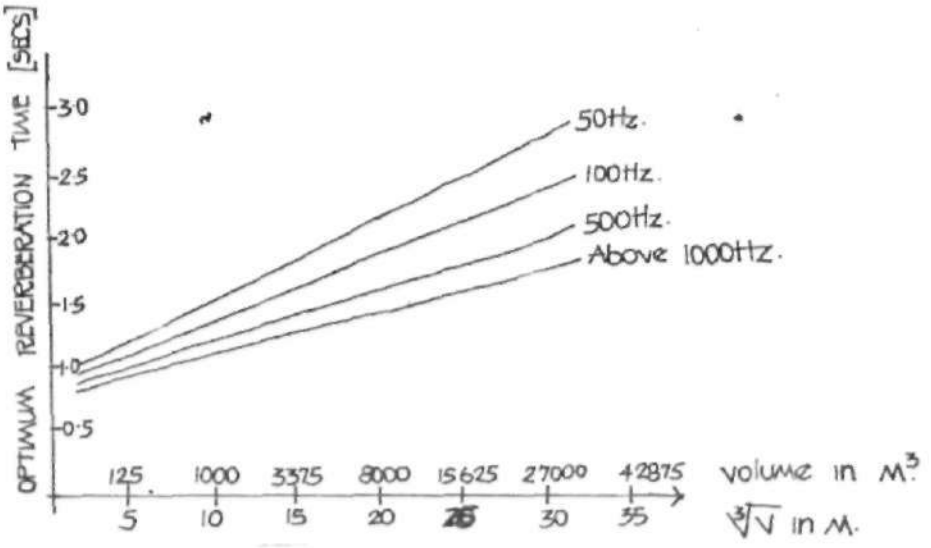


FIGURE 2·9 VARIATION OF RT WITH THE VOLUME OF ROOM.

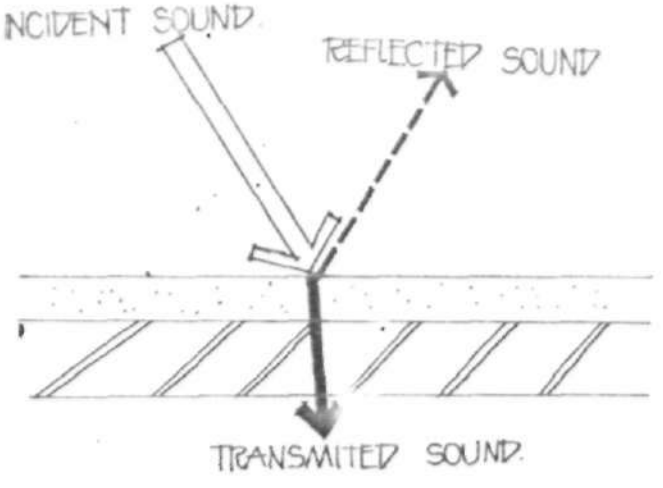


FIGURE 2·10 BEHAVIOUR OF SOUND ON A SURFACE

There are other formulae used for calculating the reverberation time of a room, but for Architectural practice the sabine formulae is employed. The other formulae are improvements on the sabine formula, complex and above the scope of this thesis.

2.5. Interiors

When one is speaking about the interiors of rooms used for the recording of Music, he is talking about the surfaces that mark out this interior. The surfaces in a studio includes the floor, ceiling and walls with their various finishes. Each material used for the construction has its own acoustical properties which includes, sound absorption, transmission and reflection values. Figure 1.10 shows the behaviour of sound on a surface.

2.5.1 Sound Absorption

The absorption of sound takes place when sound energy incident on a surface is turned into heat. An opening in a room have a 100% absorption in that all of the incident energy is turned into heat while a massive surface has a very low absorption with most of the incident energy reflected.

Sound absorption is important to Architects in that it helps them to reduce noise levels, shorten or prolong reverberation and to eliminate undesirable sound reflections. that could occur in a given space. The unit of sound absorption is the sabin or open window unit. It is found by multiplying the area of an absorber by its Absorption coefficient.

2.5.2 Absorption Coefficient (α)

It is the fraction of the sound energy incident on a surface that is absorbed. The absorption coefficient of a material depends on its density. The absorption coefficient is affected by the method of fixing and finishes applied on it as shown in figure 2.11 and 2.12 respectively. Figure 2.11 shows that the average absorption coefficient of an acoustical tile is more when suspended than when it is applied using an adhesive. This is so because of the absorption by the air between the ceiling and the roof. Figure 2.12 shows the effect of paint on porous prefabricated acoustical units.

The chosen frequency range for absorption coefficients of materials is between 125Hz and 4000Hz, this falls within the chosen frequency range for acoustical solutions in Architectural practice. The absorption coefficients of some building materials, acoustical materials and room contents is given in table 2.2 This is useful in making simple reverberation time calculations.

2.6 Sound Absorbers:

Each material absorbs sound to a certain degree, the absorbed sound is "partially converted into heat but is mostly transmitted to the other side of the layer, unless such transmission is restrained by a backing of an impervious heavy barrier. In other words, a good sound absorber is an efficient sound transmitter, and consequently an inefficient sound insulator" Leslie (1972). Sound absorbing materials and constructions used in acoustical designs are classified into three (a) porous materials (b) panel or membrane absorbers and (c) cavity (helmholtz) resonators.

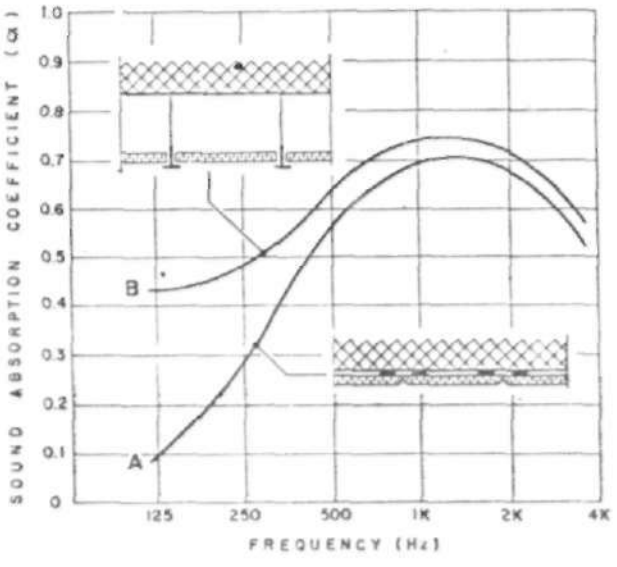


FIGURE 2·11 AVERAGE ABSORPTION COEFFICIENT OF A TYPICAL ACOUSTICAL TILE APPLIED WITH [A] ADHESIVE OR IN SUSPENSION [B].

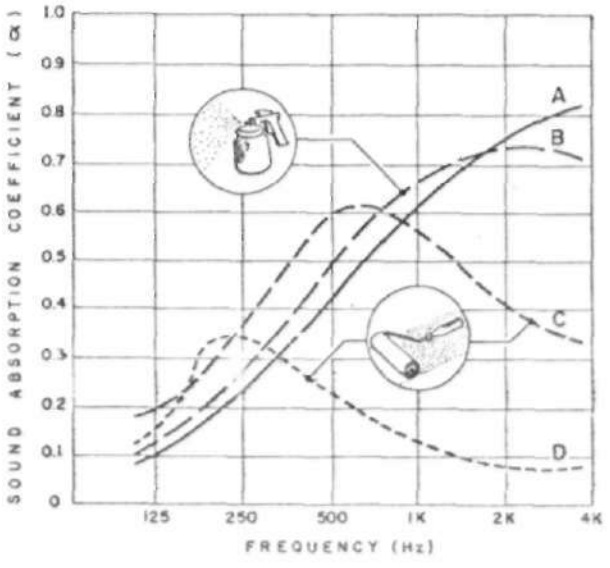


FIGURE 2·12 EFFECT OF PAINT ON POROUS PREFABRICATED ACOUSTICAL UNITS
[A] UNTREATED SURFACE.
[B] ONE COAT OF PAINT APPLIED WITH A SPRAY GUN.
[C] ONE COAT APPLIED WITH BRUSH
[D] TWO COATS OF PAINT APPLIED WITH BRUSH.

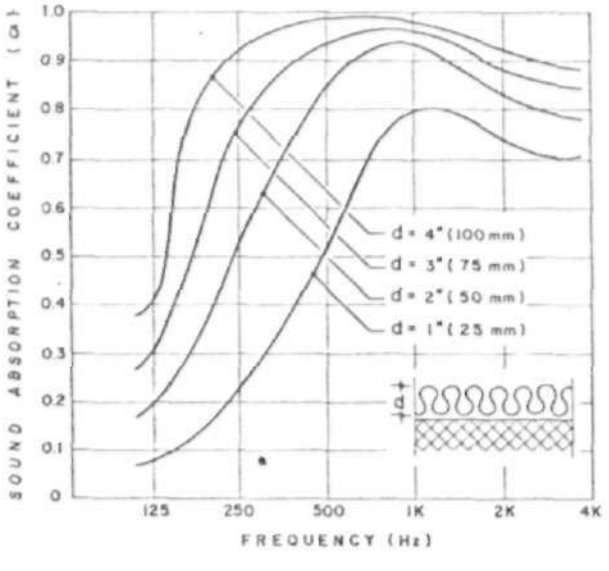


FIGURE 2·13 ABSORPTION OF POROUS MATERIALS WITH DIFFERENT THICKNESSES.

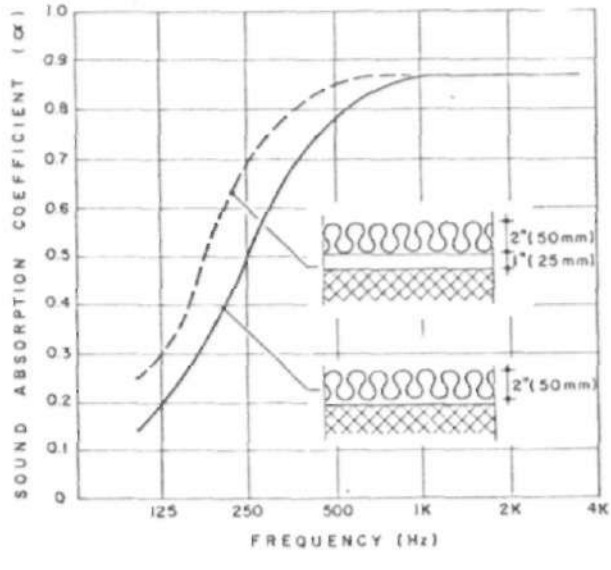


FIGURE 2·14 SOUND ABSORPTION OF A 50mm MINERAL-WOOL BLANKET INSTALLED ON RIGID BACKING AND ON 25mm FRAMING.

Description	Frequency, Hz						Source*
	125	250	500	1000	2000	4000	
Acoustical plaster, average	0.07	0.17	0.50	0.60	0.68	0.66	8
Acoustic steel deck, 6-in. (150-mm) ribs	0.58	0.64	0.71	0.63	0.47	0.40	7
Acoustone space tile, 32 in. (81 cm) OC, per unit	0.22	0.81	1.88	2.28	2.16	1.83	7
Air, per 1,000 cu ft volume, relative humidity 50%				0.9	2.9	7.4	6
Per 100 cu m volume, relative humidity 50%				0.3	0.9	2.4	6
Audience, in upholstered seats, per unit floor area	0.39	0.57	0.80	0.94	0.92	0.87	2
Unoccupied, well-upholstered seating, per unit floor area	0.19	0.37	0.56	0.67	0.61	0.59	2
Unoccupied, leather-covered upholstered seating, per unit floor area	0.15	0.25	0.36	0.40	0.37	0.35	5
Wooden pews, occupied, per unit floor area	0.57	0.44	0.67	0.70	0.80	0.72	8
Musician, with seat and instrument, per person	4.0	8.5	11.5	14.0	13.0	12.0	3
Brick, exposed, unglazed, unpainted	0.03	0.03	0.03	0.04	0.05	0.07	1
Carpet, heavy, on concrete	0.02	0.06	0.14	0.37	0.60	0.65	1
Heavy, on 40-oz (1.35 kg per sq m) hair felt or foam rubber	0.08	0.24	0.57	0.69	0.71	0.73	1
Concrete block, unpainted	0.36	0.44	0.31	0.29	0.39	0.25	1
Painted	0.10	0.05	0.06	0.07	0.09	0.08	1
Concrete, poured, unpainted	0.01	0.01	0.02	0.02	0.02	0.03	2
Fabrics, medium velour, 14 oz (0.48 kg per sq m), draped to half area	0.07	0.31	0.49	0.75	0.70	0.60	1
Floors, concrete or terrazzo	0.01	0.01	0.015	0.02	0.02	0.02	1
Linoleum, vinyl, rubber, or cork tile on concrete	0.02	0.03	0.03	0.03	0.03	0.02	1
On subfloor	0.02	0.04	0.05	0.05	0.10	0.05	5
Wooden	0.15	0.11	0.10	0.07	0.06	0.07	1
Wooden platform, with air space beneath	0.40	0.30	0.20	0.17	0.15	0.10	2
Ceramic tile, 32 in. (81 cm) OC, per unit	0.13	0.74	2.35	2.53	2.03	1.73	4
Glass, heavy plate	0.18	0.06	0.04	0.03	0.02	0.02	1
Ordinary window	0.35	0.25	0.18	0.12	0.07	0.04	1
Gypsum board ½ in. (13 mm), on 2- by 4-in. (50- by 100-mm) stud, 16 in. (41 cm) OC	0.29	0.10	0.05	0.04	0.07	0.09	1
Plaster, gypsum or lime, smooth finish, on brick	0.013	0.015	0.02	0.03	0.04	0.05	1
On concrete block	0.12	0.09	0.07	0.05	0.05	0.04	2
On lath	0.14	0.10	0.06	0.04	0.04	0.03	1
On lath, over air space, or on studs	0.30	0.15	0.10	0.05	0.04	0.05	3
Plywood, ¼ in. (6 mm) over 3-in. (75-mm) air space, 1-in. (25-mm) glass-fiber backing	0.60	0.30	0.10	0.09	0.09	0.09	5
Soundblox unit, type B, 8-in. (20-cm) thick, painted	0.74	0.57	0.45	0.35	0.36	0.34	4
Wood panel, ⅜ to ½ in. (10 to 13 mm), over 2- to 4-in. (50- to 100-mm) air space	0.30	0.25	0.20	0.17	0.15	0.10	2

*1, Acoustical and Insulating Materials Association; 2, L. L. Beranek; 3, P. H. Parkin and H. R. Humphreys; 4, P. G. Geiger and R. N. Hamme; 5, National Research Council of Canada; 6, C. M. Harris; 7, manufacturer's claim; 8, estimated.

TABLE 2.2 SOUND ABSORPTION COEFFICIENTS OF SOME BUILDING MATERIALS AND ROOM CONTENTS.

2.6.1 Porous Materials

They absorb sound due to frictional dissipation of the air molecules within their pores. They have a network of cellular interlocking pores. The remaining fraction of the sound energy that was not absorbed is reflected from the surface of the material.

$$\alpha + r = 1$$

where α = absorption coefficient

r = reflection coefficient

Figure 2.13 and 2.14 compares coefficient absorption of fibreglass blankets with that of mineral wool blankets, both are porous materials.

Porous material (surface absorbers) have poor frequency performance at lower frequencies and a fairly uniform absorption at high frequencies. Examples of porous materials in use are fibre boards, soft plasters, minerals wools, eel grass quilting, curtains and generally soft furnishings.

There is a restriction in the use of porous materials because they are generally not hard wearing and difficult to clean. Some of them need a containing cover. Their surfacesc can be improved in two ways.

(a) By adding a front membrane. This is in the form of a tough material for example a thin plastic sheet. This plastic sheet will not affect the low frequency response upto a particular frequency (f) above which it starts to affect it. This frequency can be calculated from

$$f = \frac{20}{m}$$

Where m = density of the front membrane in lb/sqft.

(b) By addition of a perforated panel. The absorption remains the same upto an upper frequency (f).

$$f = \frac{40P}{d}$$

Where P = % of open area

d = diameter of holes in inches.

or $$f = \frac{16P}{d^1}$$

where d^1 = diameter of a hole in centimeter.

The percentage of openings affects the absorption coefficient of the materials as clearly shown on figure 2.17. It can be seen that the higher the percentage of openings the more the absorption.

There are three categories of commercial porous materials. (i) Prefabricated Acoustical units (ii) Acoustical plasters and sprayed-on materials, and (iii) Acoustical (isolation) blankets.

(i) Prefabricated Acoustical Units. There is a wide range within which to choose from, they can be perforated, unperforated, fissured, or textured cellulose and mineral-fibre tiles, panels, planks, and perforated metal pans with absorbent pads.as the absorber. Figure 2.18 illustrates different edge conditions of some tiles, which can be mounted in several ways, for example nailed or screwed to a wood framing, suspended or cemented to a solid backing according to manufacturers' details.

Their use in acoustical treatment of surfaces offers the advantages of being reliable with a factory guaranteed absorption), economical installation and maintenance, some can be redecorated without a detrimental effect on the absorption, services in the building can be functionally and

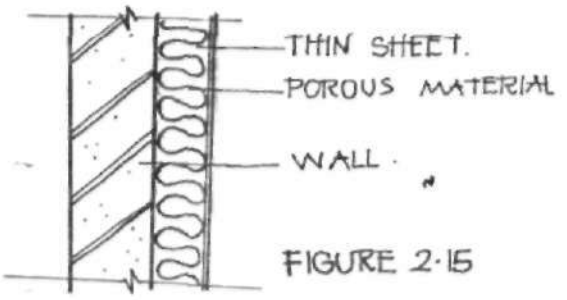


FIGURE 2·15

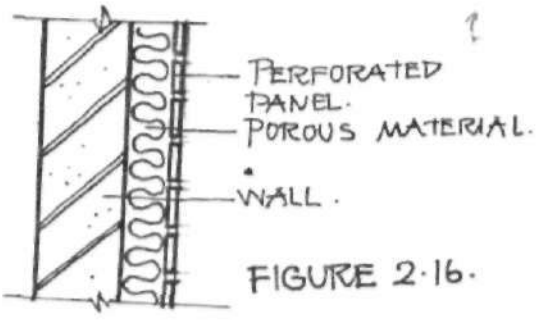


FIGURE 2·16.

METHODS OF IMPROVING THE SURFACES OF POROUS MATERIALS.

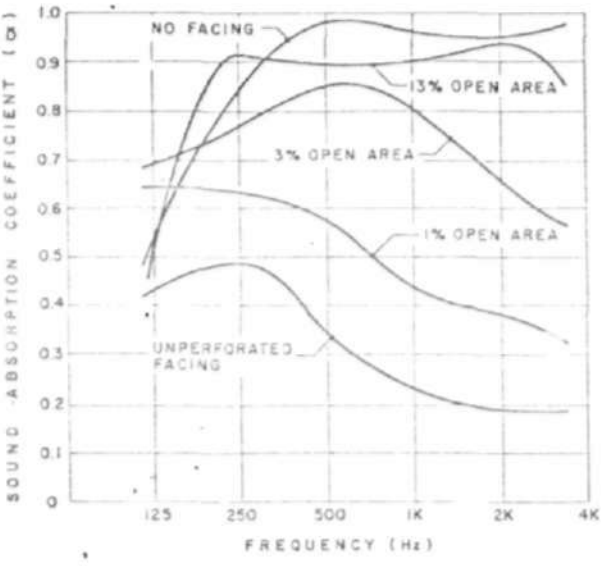
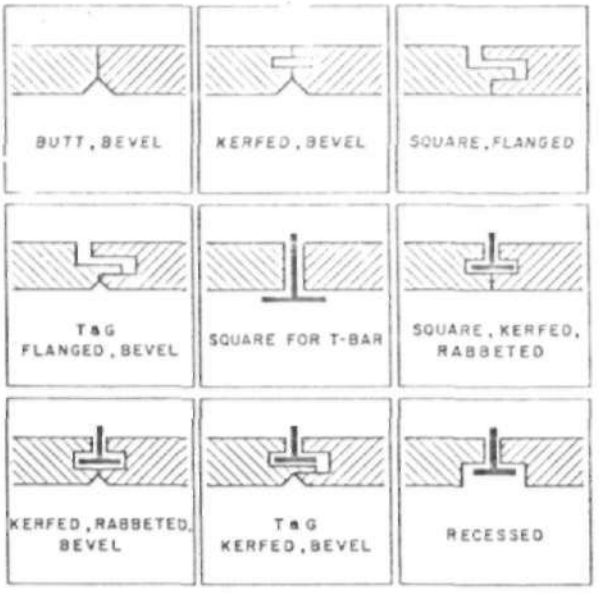


FIGURE 2,17 EFFECT OF PERFORATED FACING ON THE ABSORPTION COEFFICIENT OF POROUS MATERIALS.



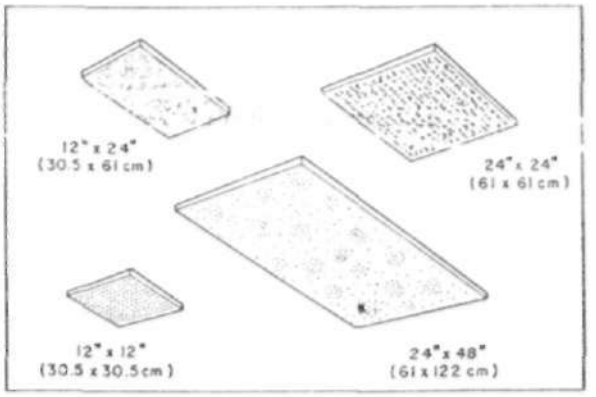


FIGURE 2·18 A. SIZES OF TYPICAL COMMERCIAL ACOUSTICAL TILES.

FIGURE 2·18 EDGE CONDITIONS OF TYPICAL COMMERCIAL ACOUSTICAL TILES.

visually integrated into them, and they help in the noise reduction and offer flexibility in partitioning. However their application also presents a few problems of being subscessible to mechanical damage if installed at lower levels of walls, difficult to conceal joints between adjacent units and the interior may look monotonous in a large room.

(ii) Acoustical Plasters and Sprayed-on Materials

They are mostly used for noise reduction purposes and sometimes in rooms where the application of other acoustical treatment is impractical because of irregular shape or curved surfaces. A spray gun or trowel is used to apply them in a semiplastic consistency. Examples are sprayed limpet Asbestos, Zomolite, Dekoosto and so on.

They are more efficient at higher frequencies and this depends on the thickness and composition of the plaster mixture, amount of binder used, condition of the undercoat at the time of application and the manner in which the finish is applied. In using this, manufacturers' specification must be followed to the letter in order to obtain the desired result.

(iii) Acoustical (Isolation) Blankets.

They are installed on wood or metal framing in varying thickness between 25and 125mm for different accoustical purposes, a considerable low frequency absorption could be achieved when the thickness is upto 75mm and above. It should be noted that their absorption increases with thickness. They are manufactured from rock wool, glass fibres, wood fibres, hair felt and so on. They are normally covered with suitable

perforated board, wood slats, fly screening to provide a more aesthetic view. Figure 2.19 shows different wood slats suitable for protecting isolation blanket, while figure 2.20 shows an existing example of the use of wood slats.

Iv) Carpets and Fabrics. Apart from their traditional role as floor covering, carpets are being used as versatile acoustical materials in that they absorb airbone sounds and noises within a space. They are used in the elimination of impact and surface noises, could be used for floor and wall covering for a psycological noise control in that they create a tranquil atmosphere.

Fabrics and draperies used for the control of light, glare and solar heat contribute to sound absorption, The heavier the fabric the higher the absorption (figure 2.21). Greater air space between the drapery and wall will increase the low frequency absorption.

2.6.2 Panel (Membrane) Absorbers

They are impervious materials installed on a solid backing with an air space between them. They absorb sound energy principally by vibrating when struck by sound waves. For a noticeable vibration to take place the panel has to be thin, although very thin membrane will rattle when a higher frequency absorption is needed. They are used mainly for low frequency absorption, could be used aesthetically and stiffners could be used to strengthen the absorption when applied in the front due to the increase in the surface area by them. The maximum absorption is found at the resonance frequency (fo).

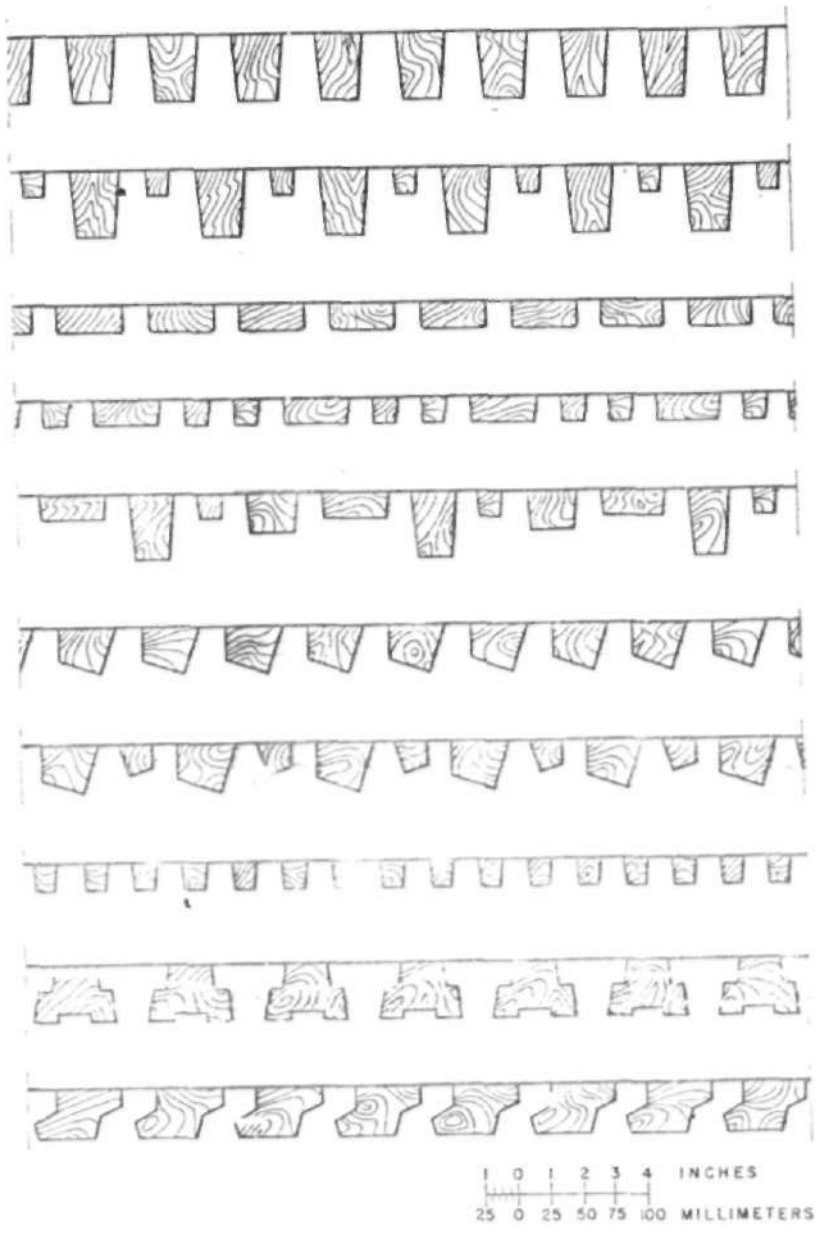


FIGURE 2·19 SUITABLE WOOD SLATS FOR PROTECTING ISOLATION BLANKET.

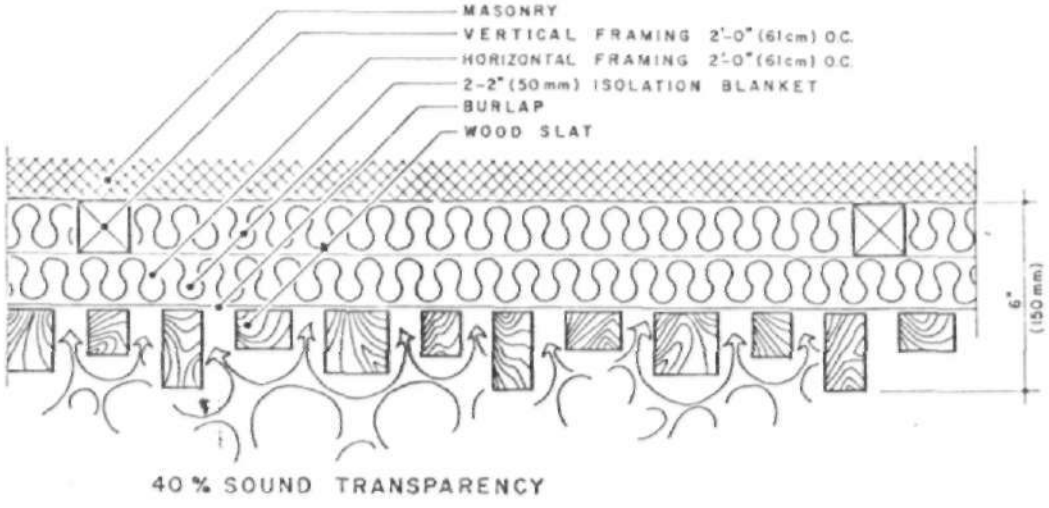


FIGURE 2·20. WOOD SLATTED ACOUSTICAL TREATMENT USED AS A SUIT RESONATOR ABSORBER IN A 250 SEAT LECTURE HALL, UNIVERSITE LAVAL, QUEBEC.

$$fo = \frac{170}{(dm)^{\frac{1}{2}}} \quad \text{or} \quad fo = \frac{60}{m'd'}$$ where m' = surface density in Kg/M^2. d' = depth of air space in Meters.

where d = depth of airs space behind the board in feet (ft).

where m = surface density in lb/ft^2.

Figure 2.22 illustrates the effect of the an isolation blaket placed behind the panel.

Wood and hardboard panels, gypsum boards, suspended plaster ceilings, furred-out plasters, rigid plastic boards, windows glazings, doors, wood floors, and platforms, and metal plates (radiators) are examples of panel absorbers which contribute to low frequency absorption.

Porous materials act like panel absorbers when spaced away from their solid backing as shown in figures 2.13 and 2.14.

2.6.3 Cavity (Helmholtz) resonators

It consists of an air cavity linked to a neck or a cylindrical attachment. Such a cavity resonates at a frequency determined by the volume of the cavity, diameter and length of the neck. It is extremely selective in absorption, that is to its maximum absorption is confined to a narrow frequency band. Cavity resonators can be used as (i) individual units (ii) perforated panel resonators, and (iii) slit resonators.

(i) Individual Units. They were used in ~~medieval~~ medieval Scandinavian Churches made of empty clay vessels, their effective absorption spread between 100 and 400Hz. A contemporary use of individual units is in the form of a standard concrete blocks with slotted cavities, called soundblox units. They are economical to use in that additional sound-absorptive surface treatment is not needed(figure 2.23)

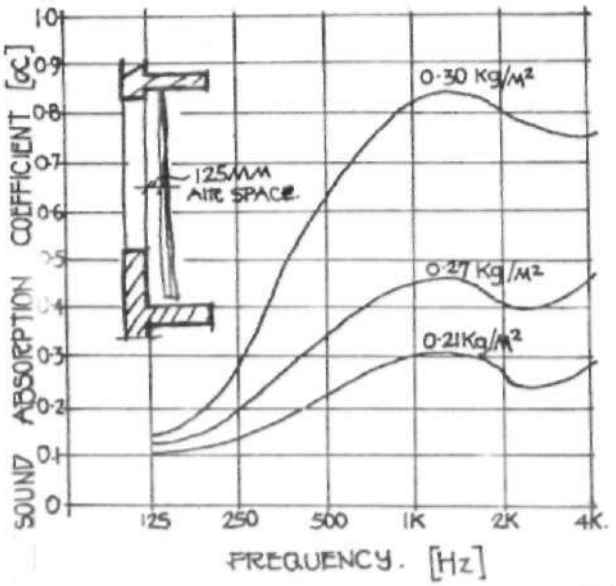


FIGURE 2·21 SOUND ABSORPTION OF FIBREGLASS FABRIC.

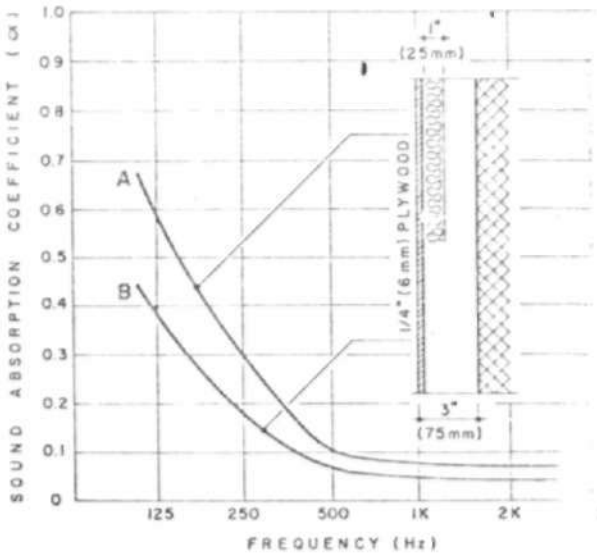


FIGURE 2·22 EFFECT OF AN ISOLATION BLANKET PLACED BEHIND A PANEL ABSORBER.

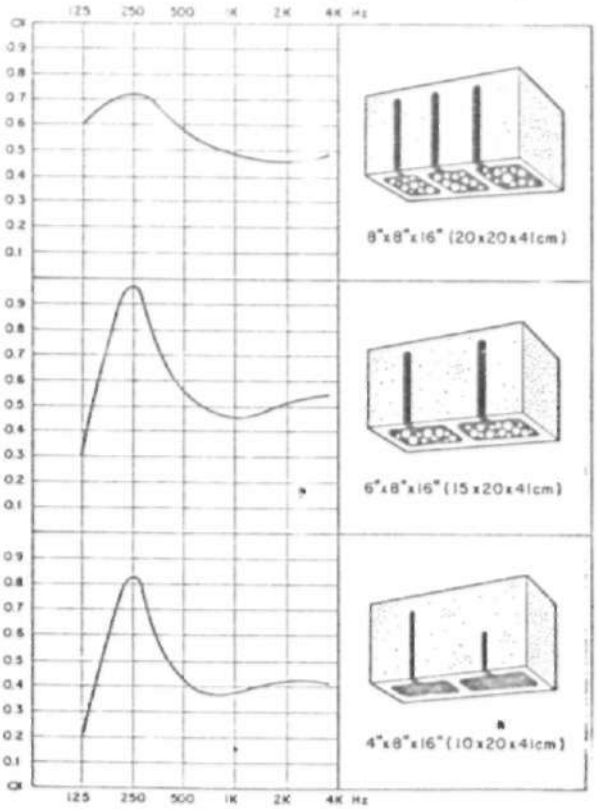


FIGURE 2·23 TYPICAL SOUNDBLOX UNITS USED AS INDIVIDUAL CAVITY RESONATORS.

Two types of the blocks are cast, type A and B. The type A units have approximately 6mm slots and a noncombustible filler elements in their cavities. Both types have their cavities closed at the top combining with the slots to act like a helmholtz resonator. Their exposed surfaces can be painted and they are very durable, this permits their use in industrial plants, depressed highways, swimming pools and so on.

(ii) Perforated Panel resonators

When perforated panels are fixed away from a solid backing they act like resonators. They contain a large number of necks (pores) with the air space behind them divided into bays by the elements of the framing to form the cavity. It is evident that they have a resonable uniform absorption with a maximum value in the medium region and an apparent drop above 1000Hz (figure 2.17).

Commercial panels or boards are available in perforated form such as cement asbestos sheets, hardboards (Masonite), plain, corrugated, and expanded steel or Aluminium sheets, rigid plastic sheets, wood and plywood panels, reinforced fibre glass panels are all available in the market. Figure 2.26 are examples of different perforated panel resonators used by designers.

(iii) Slit Resonators

To achieve required absorption needed in a room relatively inexpensive isolation blankets along the surfaces could be applied, but due to their porosity they need protection against abraision. This is done using elements with relatively small cross section and resonable spacing to permit sound waves to penetrate and hit the absorbers. Figures 2.27 and 2.28 show

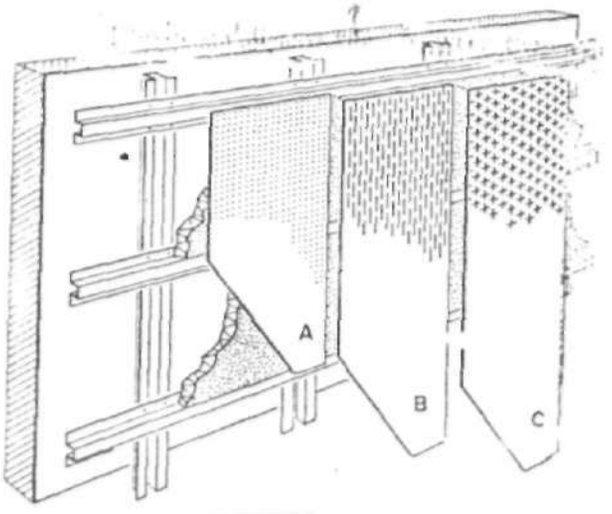


FIGURE 2·24 TYPICAL INSTALLATIONS OF PERFORATED PANEL RESONATORS. [A] PERFORATED BOARD [B] SLOTTED HARDBOARD [C] PERFORATED METAL OR PLASTIC.

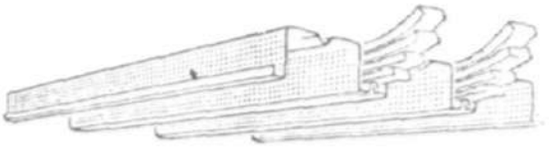
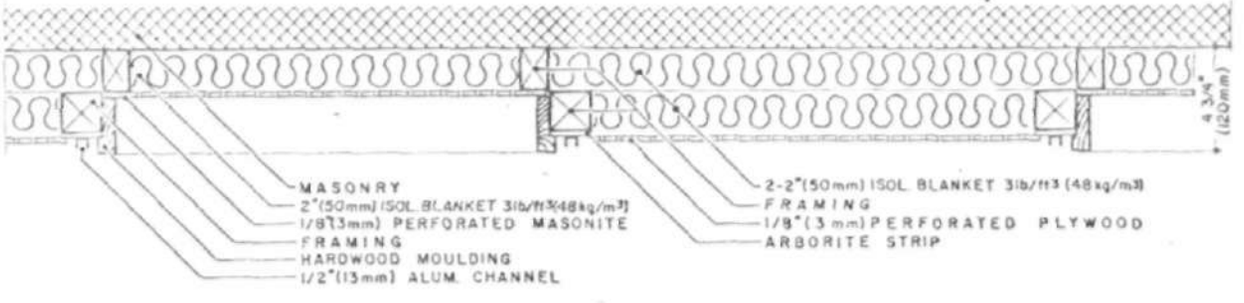
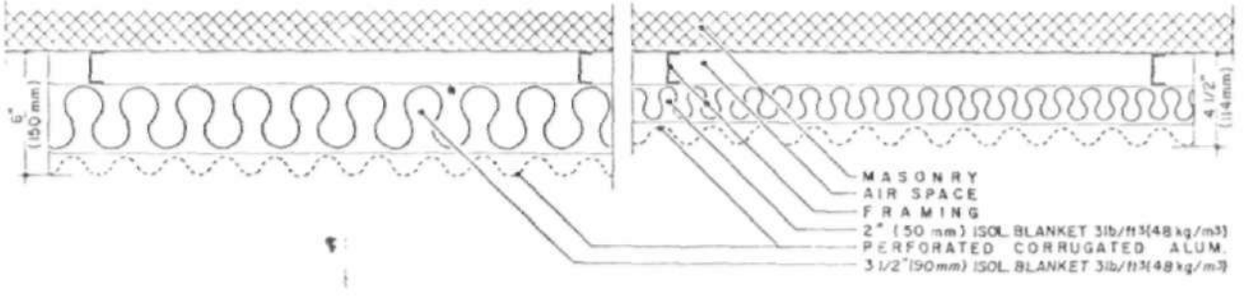


FIGURE 2·25 ACOUSTICAL STEEL DECKS USED AS PERFORATED PANEL RESONATOR

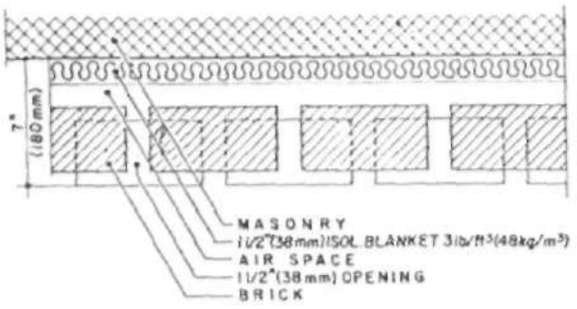


LITTLE THEATER , ACADEMIE DE QUEBEC , AMYOT VAGI , ARCHITECTS

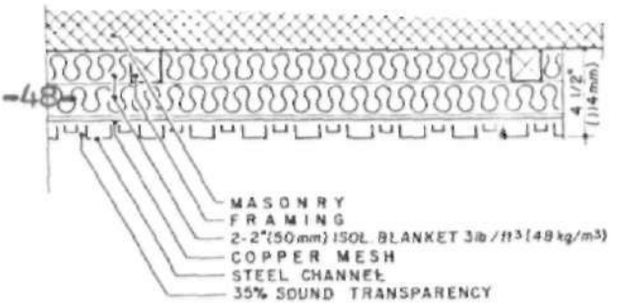


VERSAILLES THEATERS , MONTREAL , ELIASOPH BENKOWITZ , ARCHITECTS

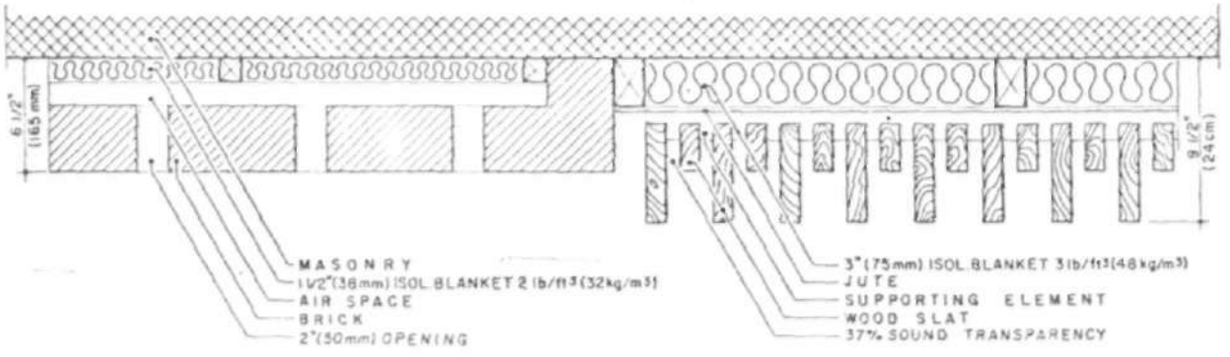
FIGURE 2·26 EXAMPLES OF PERFORATED PANEL RESONATORS USED IN BUILDINGS.



LECTURE HALL , UNIVERSITE LAVAL , QUEBEC
GAUTHIER GUITE , ARCHITECTS



AUDITORIUM , INSTITUT PSYCHIATRIQUE , MONTREAL
BLOUIN BEAUVAIS LUSIGNAN , ARCHITECTS



SYN. OGUE , BETH-ZION CONGREGATION , MONTREAL , ROSEN CARUSO VECSEI SHAPIRO WOLFE , ARCHITECTS

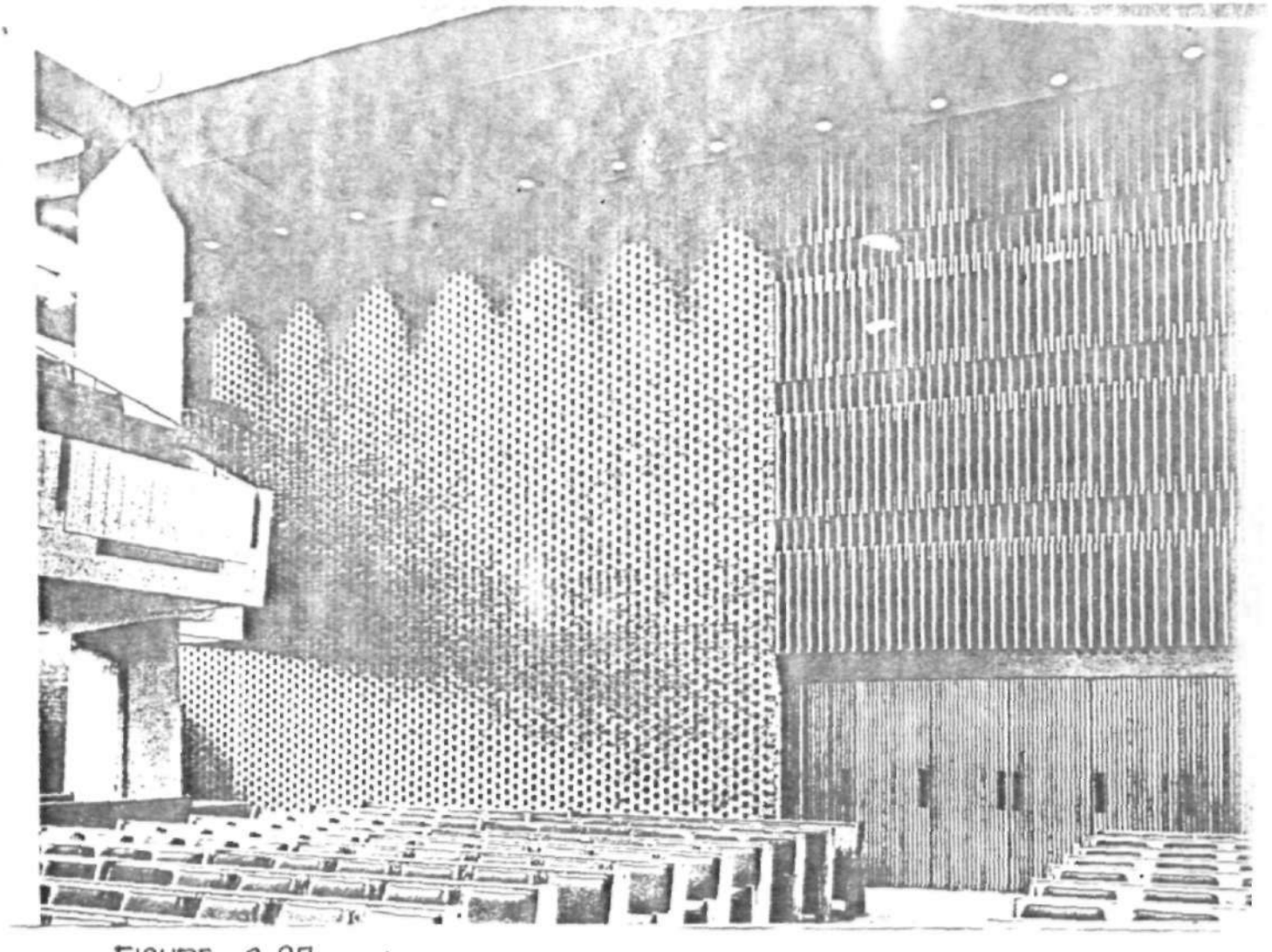


FIGURE 2·27 SUT RESONATOR.

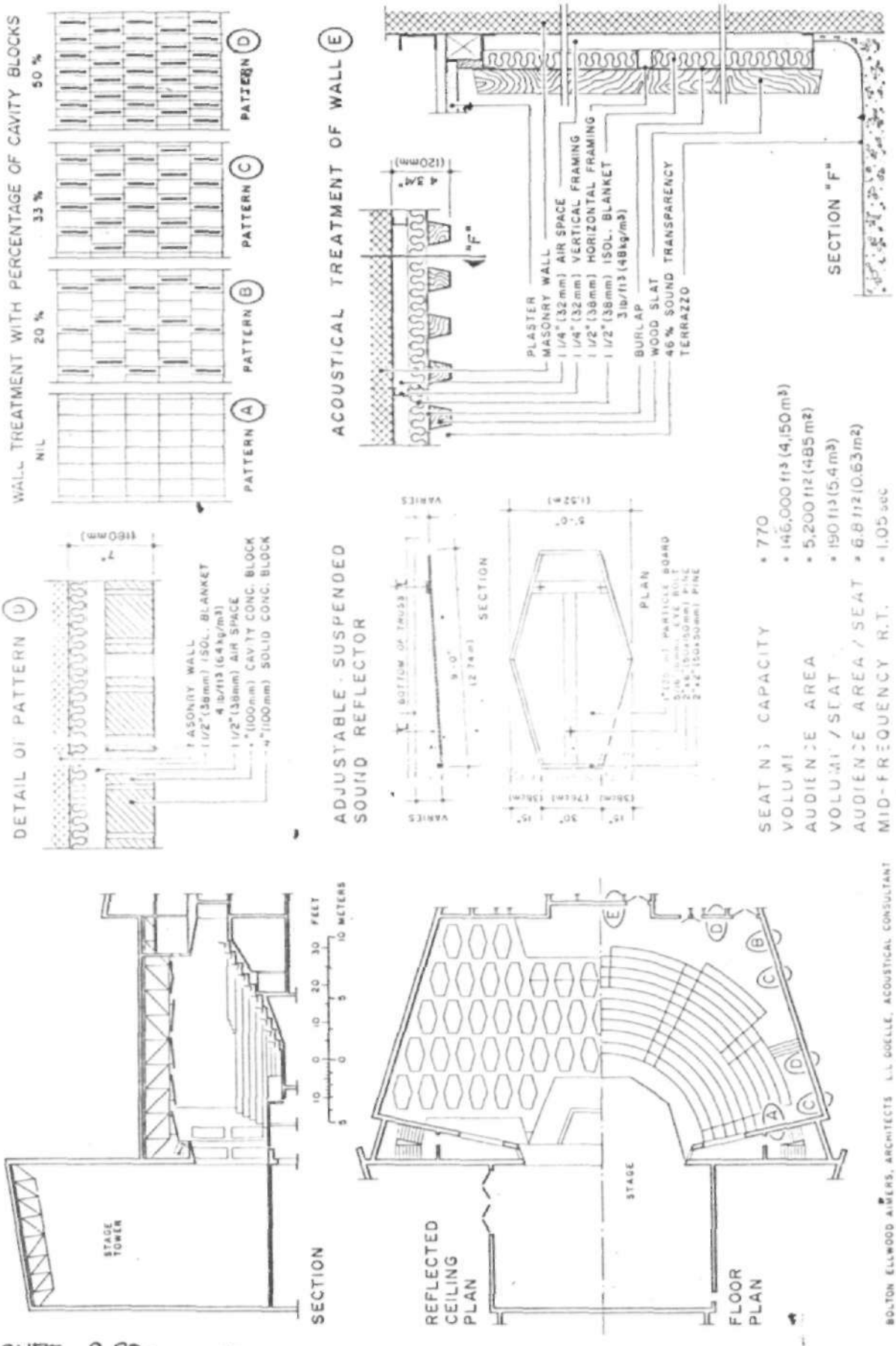


FIGURE 2·28A SUIT RESONATORS.

some slit resonators in use in acoustical treatments of surfaces.

The slit resonator works like the panel resonator and should have a sound transparency not less than 35 percent of the total area of the acoustical treatment. Its popularity lies on the fact that it offers a wide choice for individual design, although they are more expensive than the commercial sometimes monotonous standard acoustical materials.

(iv) Space Absorbers

They are individual sound absorbing units suspended from the ceiling (figure 2.29) when the surface of the room do not provide suitable or adequate area for conventional acoustical treatment.

They have an advantage of being easily installed or removed without interfering with existing equipments. They are made of perforated metal or hardboard sheets using different shapes and filled with or lined with sound absorbing materials such as rock, wool, glass wool and so on.

They are particularly good for treatment of noisy spaces for example a production hall due to the fact that the noise produced will hit it from all sides and as such the absorption will be high. Their efficiency depends on their spacings and they should be co-ordinated with the lighting layout.

(v) Variable Absorbers

They are designed for rooms where there is a marked difference in the reverberation time requirement for different activities. Figure 2.30 illustrates different possibilities to their designs.

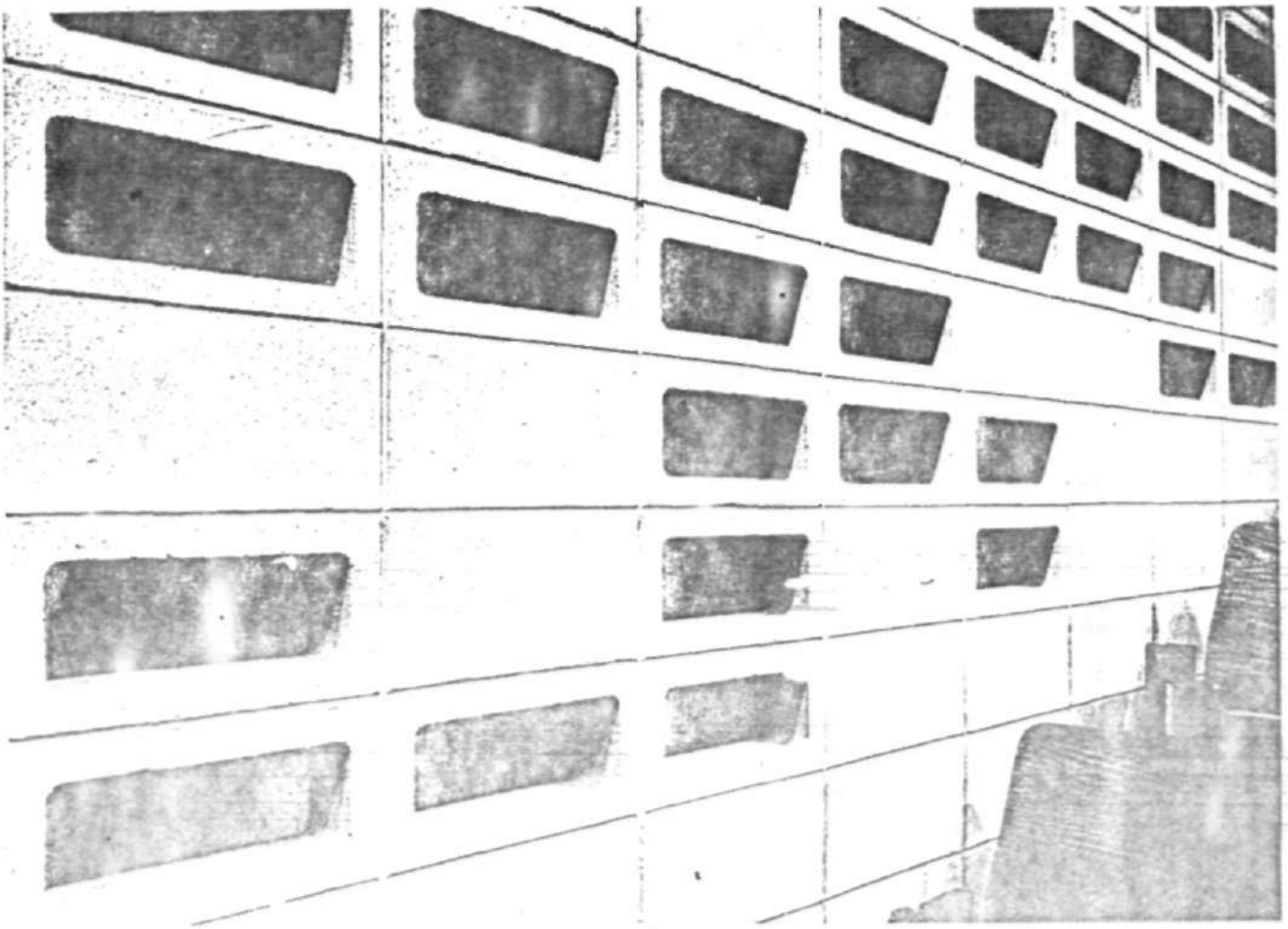


FIGURE 2·28 B CONCRETE CAVITY BLOCKS USED AS SLIT RESONATORS IN THE 700 SEAT HIGH SCHOOL AUDITORIUM, QUEBEC.

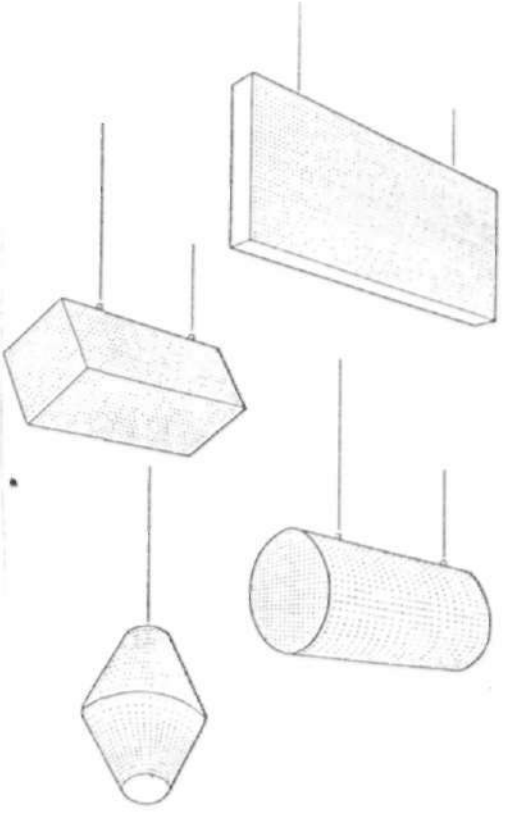


FIGURE 2·29 SPACE ABSORBERS.

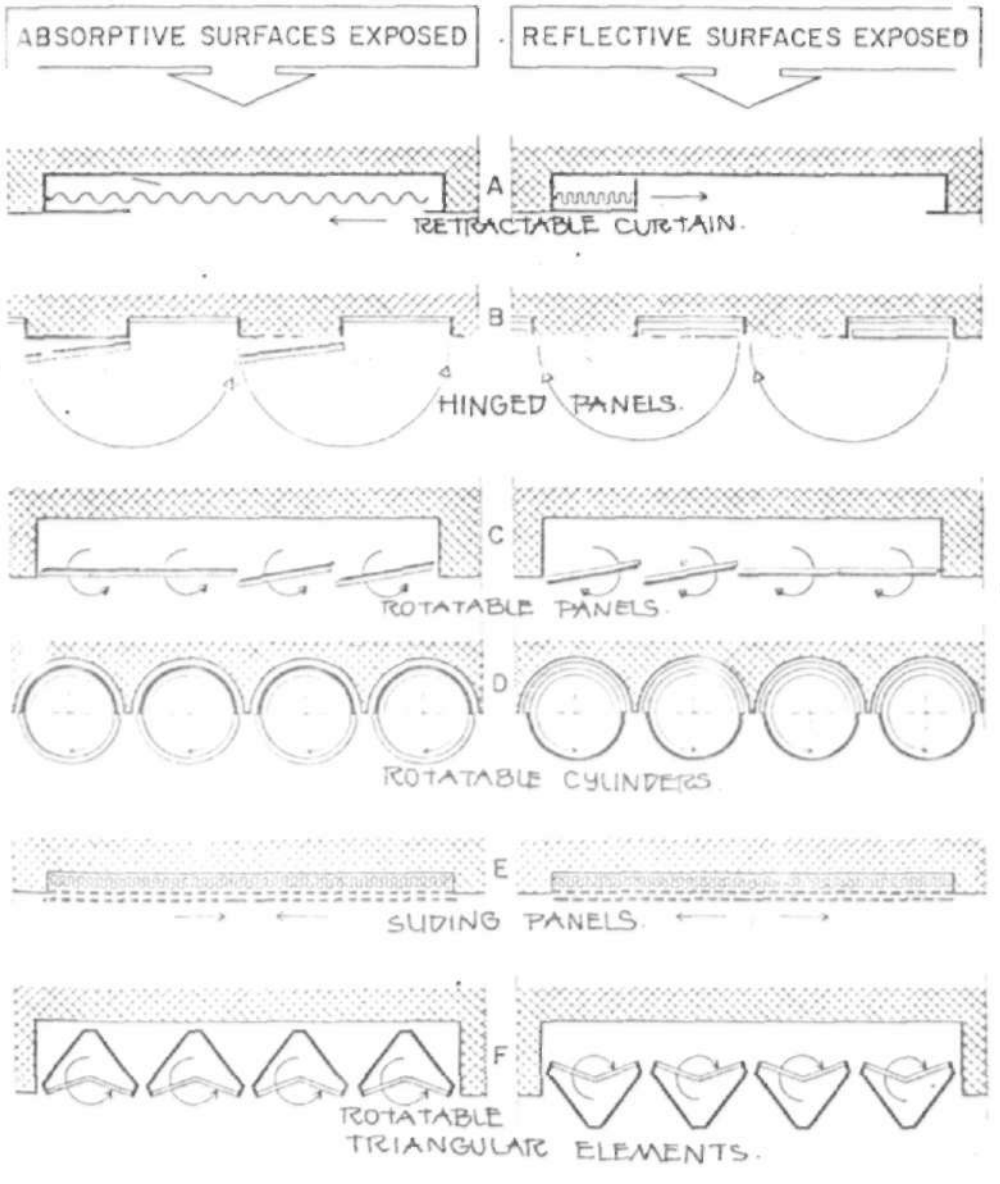


FIGURE 2·30 VARIABLE ABSORBERS.

Variable Absorbers should be designed for rooms with trained personnel permanently around, like in the recording studios. Their construction is justified only if it will be capable of producing a 20 percent (minimum) change in the total absorption over a considerable region of the audio frequency.

2.6.4 Criteria for Choosing Sound Absorbers

Considerations other than acoustical ones need be taken before selecting acoustical materials and constructions to be used since they form the finishes of the interior.

For a uniform reverberation time to be achieved, finishes that will produce uniform absorption characteristics throughout the audio-frequency range must be chosen; if it were perforated panel or slit resonator they have excessive medium and high frequency absorption) then this must be counter balanced by installing low-frequency panel absorbers.

The criteria for choosing sound absorbing finishes and constructions are as follows:

(1) The sound absorption coefficients at representative frequencies.

(2) Appearance, which includes the size, edges, joints, colour and texture.

(3) Degree of fire resistance needed.

(4) Cost of installation

(5) Ease of installation and removal.

(6) Durability which includes the degree of resistance to impact, abraision and so on needed

(7) Light reflectance

(8) Maintenance and effect of redecoration on the absorption

(9) Job conditions, that is to say the temperature and humudity during installation and readiness of backings.

(10) Sound insulation requirement

(11) Thermal insulation value

(12) Intergration of room elements like windows, doors and services

(13) Accessibility to the ceilings or furred spaces.

(14) Thickness and weight of materials

(15) Moisture and condensation resistance

(16) Attraction for vermin, dry rot and fungus.

(17) The space available for the treatment.

2.7 Sound Reflectors

As earlier mentioned the other fraction of sound that is not absorbed by a surface is either reflected or transmitted through the surface, although the reflected sound is with an energy less than that of the incident sound. Sound reflectors are used for the reinforcement of the direct sound in a space and for insulation of the other space next to the source of sound. A good sound reflector is an efficient sound insulator, since most of the sound energy is reflected.

The degree of reflection of the sound depends on the density of the material. For an incident pressure pi

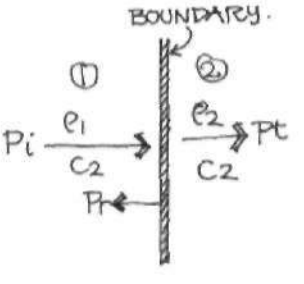
$$pi = Ai \cos(\omega t - Kix).$$

for the reflected pressure wave

$$pr = B1 \cos(\omega t + Kix)$$

and the transmitted pressure wave

$$Pt = A2 \cos(\omega t - K2x)$$



Pressure is continuous accross the boundary

Therefore pi + pr = pt

$$A1 \cos(\omega t - k_1 x) + B_i \cos(\omega t + k_1 x) = A2 \cos(\omega t - k_2 x)$$

- Equation (1)

Similarly particle velocity is contineous across the boundary

ui + ur = Ut

$$\frac{A1}{\rho_{1c1}} \cos(\omega t - k1x) - \frac{B1}{\rho_{1ci}} \cos(\omega t + kx) = \frac{A2}{\rho_{2c2}} \cos(\omega t - K2x)$$

Equation (2)

Let the boundary be at x = 0

Then equation (1) and (2) become

$$A1 \cos \omega t + B1 \cos \omega t = A2 \cos \omega t.$$

$$\frac{A1}{\rho_{1c1}} \cos \omega t - \frac{B1}{\rho_{1c1}} \cos \omega t = \frac{A2}{\rho_{2c2}} \cos \omega t.$$

$$A1 + B1 = A2 \quad - (3)$$

and

$$\frac{A1}{\rho_{1c1}} - \frac{B1}{\rho_{1c1}} = \frac{A2}{\rho_{2c2}} \quad - (4)$$

Substitute for A2 from (3) and (4)

$$\frac{A1}{\rho_{1c1}} - \frac{B1}{\rho_{1c1}} = \frac{A1 + B1}{\rho_{2}\, c2}$$

$$\frac{A1 - B1}{\rho_{1c1}} = \frac{A1 + B1}{\rho_{2c2}}$$

$$\frac{A1 - B1}{A1 + B1} = \frac{\rho_{1c1}}{\rho_{2c2}}$$

$$\frac{1 - \frac{B1}{A1}}{1 + \frac{B1}{A1}} = \frac{\rho_{1c1}}{\rho_{2c2}}$$

$$\left(1 - \frac{B1}{A1}\right) = \frac{\rho_1 C_1}{\rho_2 C_2} + \frac{\rho_1 C_1}{\rho_2 C_2} \times \frac{B1}{A1}$$

$$1 = \frac{\rho_1 C_1}{\rho_2 C_2} = \frac{B1}{A1}\left(1 + \frac{\rho_1 C_1}{\rho_2 C_2}\right)$$

$$\frac{B1}{A1} = \frac{1 - \frac{\rho_1 C_1}{\rho_2 C_2}}{1 + \frac{\rho_1 C_1}{\rho_2 C_2}}$$

$$= \frac{\rho_2 C_2 - \rho_1 C_1}{\rho_2 C_2 + \rho_1 C_1}$$

but $\frac{B1}{A}$ is the ratio of reflected pressure over incident pressure and in is known as the amplitude reflection coefficient. The energy is proportional to the square of the pressure.

Therefore Energy reflection co-efficient (αr) is

$$= \left[\frac{\rho_2 C_2 - \rho_1 C_1}{\rho_2 C_2 + \rho_1 C_1}\right]^2$$

If $\rho_1 C_1 \simeq \rho_2 C_2$

$\alpha r = 0$

but if $\rho_1 C_1 \gg \rho_2 C_2$

$\alpha r = 1$

Hard dense surfaces like concrete, steel and so on are good reflectors of sound. Figures 2.31 and 2.32 show the use of panels as sound reflectors.

2.8 Transmission of Sound

The other factor associated with interiors of acoustical spaces is the transmission of sound. Like sound reflectors the amount of sound to be transmitted through a surface depends on its density; although in an opposite manner, the higher the density the less the transmission of sound through the wall.

The formulae for calculating the energy transmission coefficient of a material can be similarly found as done for that of reflection.

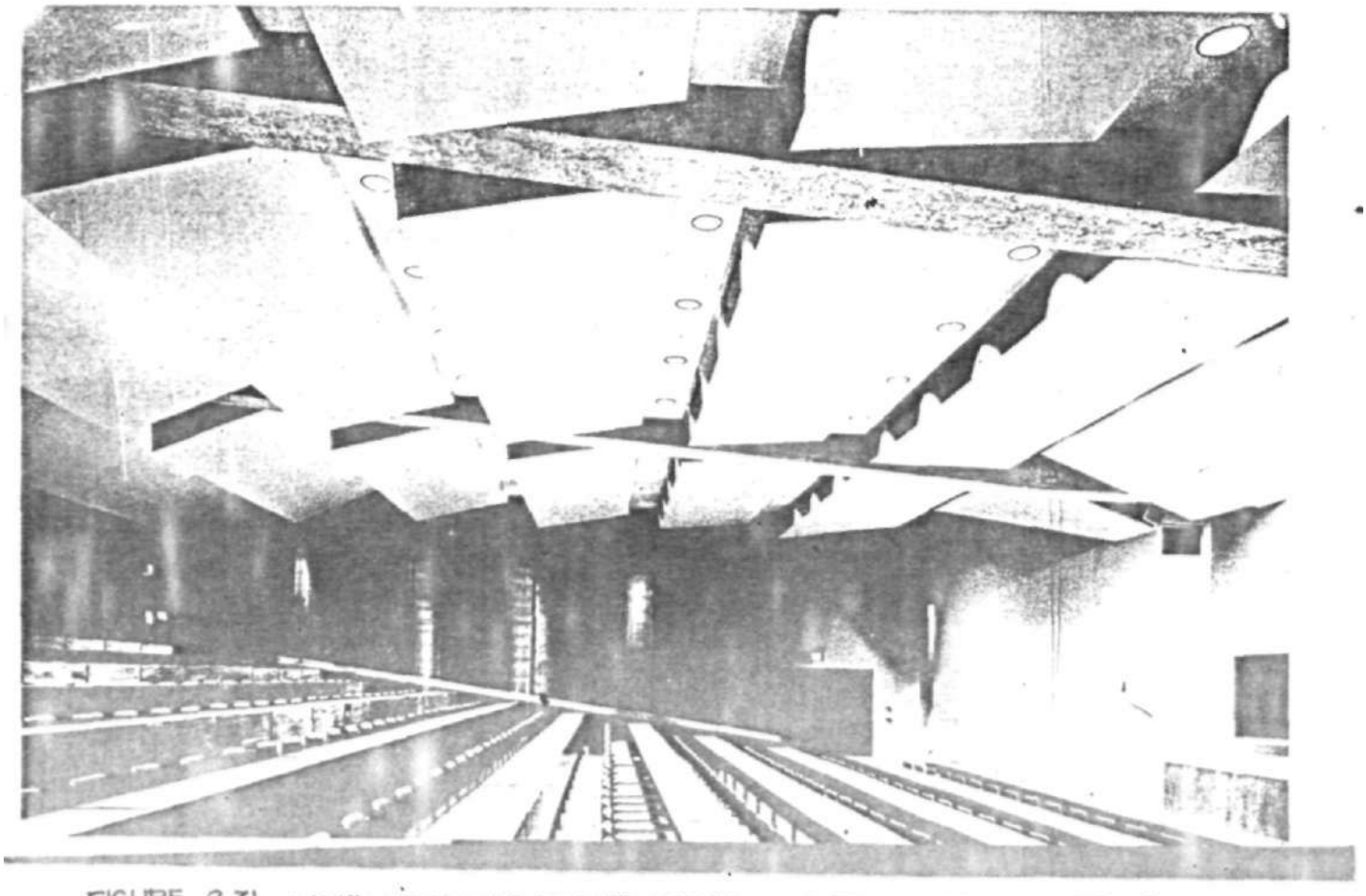


FIGURE 2·31 SOUND REFLECTING CEILING PANELS, IN A 350 SEAT LECTURE HALL UNIVERSITE DE MONTREAL.

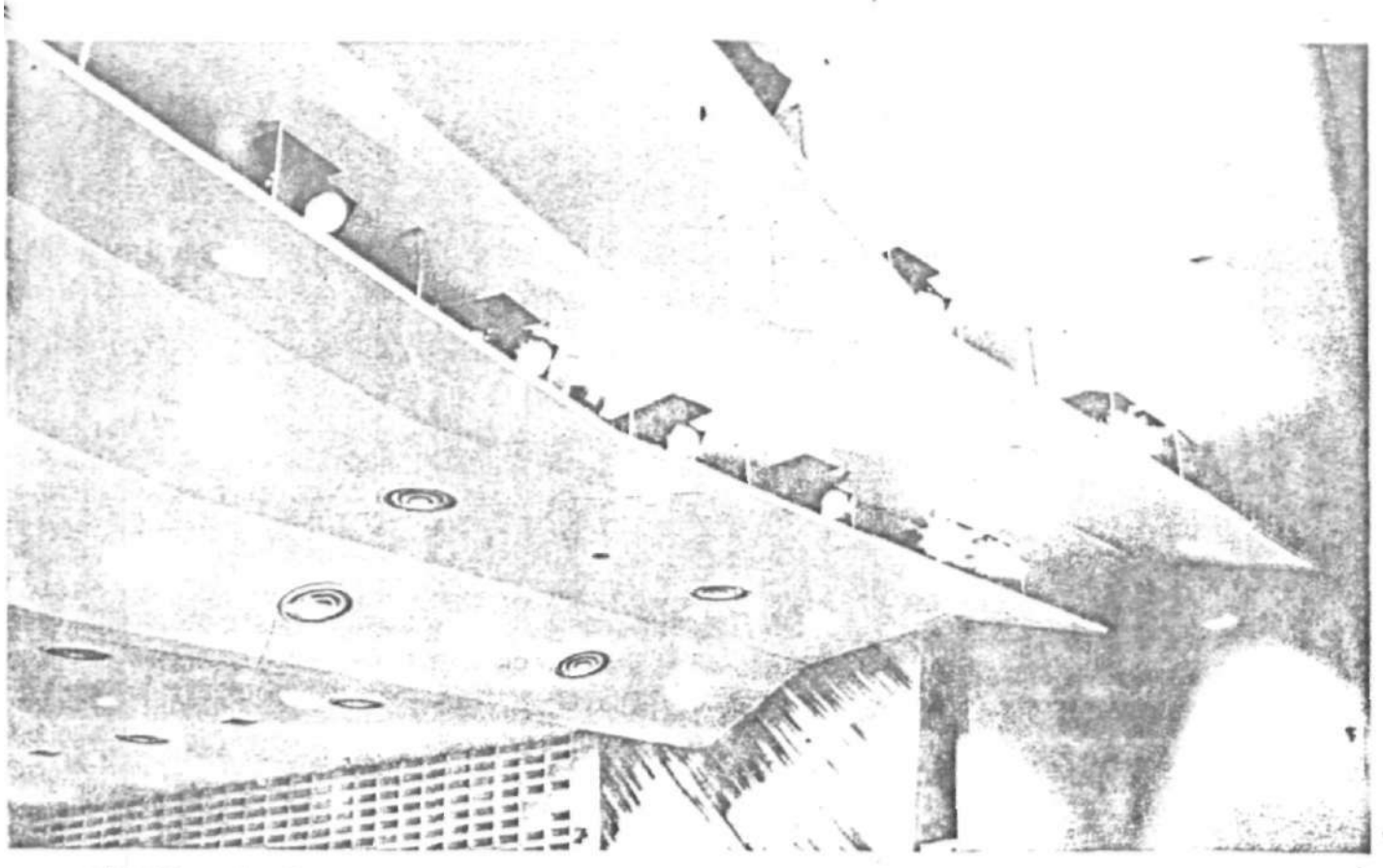


FIGURE 2·32 SOUND REFLECTING CEILING OF A 700 SEAT HIGH SCHOOL AUDITORIUM IN QUEBEC.

Quoting equation (3) above

$$B1 = A2 - A1$$

and substituting into (4)

$$\frac{A1}{\rho_1 C_1} - \frac{A2-A1}{\rho_1 C_1} = \frac{A2}{\rho_1 C_2}$$

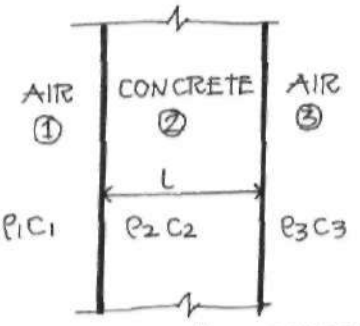


Figure 2·33 transmission of sound through a wall.

$$\frac{2A1 - A2}{\rho_1 C_1} = \frac{A2}{\rho_2 C_2}$$

$$\frac{2\,A1 - A2}{A2} = \frac{\rho_1 C_1}{\rho_2 C_2}$$

$$\frac{2 - \frac{A2}{A1}}{\frac{A2}{A1}} = \frac{\rho_1 C_1}{\rho_2 C_2}$$

$$\frac{A2}{A1}\left(1 + \frac{\rho_1 C_1}{\rho_2 C_2}\right) = 2$$

$$\frac{A2}{A1} = \frac{2\,\rho_2 C_2}{\rho_2 C_2 + \rho_1 C_1}$$ but $\frac{A2}{A1}$ is the amplitude transmission coefficient.

Energy transmission coefficient (dt) is obtained from

$$I = \tfrac{1}{2}\,\frac{P2}{2\rho c}$$

Where I = Incident intensity

$\frac{1}{2}\,\frac{A_2^2}{\rho_2 C_2}$ = transmitted intensity

Therefore $dt = \frac{A2^2}{\rho_2 C_2} \times \frac{\rho_1 C_1}{A_1 2}$

$$= \frac{\rho_1 C_1}{\rho_2 C_2}\left\{\frac{A2}{A1}\right\}^2$$

$$= \frac{\rho_{1C1}}{\rho_{2C2}} \qquad \frac{2\rho_{2C2}}{\rho_{2C2} + \rho_{1C1}}$$

$$= \frac{4\ \rho_{1C1}\ \rho_{2C2}}{(\rho_{2C2} + \rho_{1C1})^2}$$

If $\rho_{1C1} \gg \rho_{2C2}$

$$\alpha t = \frac{4\rho_{1C1}\ \rho_{2C2}}{(\rho_{1C1})^2}$$

$$= 0$$

but if $\rho_{1C1} = \rho_{2C2}$

$$\alpha t = \frac{4\ (\rho_{1C1})^2}{(2\ (\rho_{1C1})}\ 2$$

$$= 1.$$

Transmission of sound through a wall decreases with the frequency of the sound. A wall consist of two boundaries that is Air concrete - Air (figure 2.33)

let l = wall thickness in m

k_2 = wave number in wall

which is = $\frac{2\Pi}{\lambda\omega}$

λ = wavelength in wall.

Quoting the result without proof.

$$\alpha t = \frac{4\ \rho_{3C3}\ \rho_{1C1}}{(\rho_{3C3} + \rho_{1C1})2\ \cos^2 lk2 + (\frac{\rho_{2C2} + \rho_{1C1}\ \rho_{3C3}}{\rho_{2C2}})2 \times \sin^2 lk2}$$

if $\rho_{1C1} = \rho_{3C3}$, then

$$\frac{4\ \rho_1^2 C_1^2}{(2\rho_{1C1})^2\ \cos^2 lk2 + (\frac{\rho_{2C2} + \rho_1^2 C_1^2}{\rho_{2C2}})^2\ \sin^2 lk2.}$$

but in practice $\rho_{2C2} \gg \rho_{1C1}$.

Therefore $\alpha t = \dfrac{4}{4\cos^2\left(\frac{2\pi l}{\lambda_2}\right) + \frac{\rho_2 c_2}{\rho_1 c_1}\sin^2\frac{2\pi l}{\lambda_2}}$

but at low frequencies

$$\lambda_2 \gg l$$

Therefore

$$\alpha t = \frac{4\rho_1^2 c_1^2 \lambda_2^2}{4\pi^2 \rho_2^2 c_2^2 l^2}$$

The study of sound transmission in buildings can not be in isolation of noise control, so it will be done under the chapter on noise control.

2.9 Geometrical Factors in room acoustics

The size and shape of a studio affects the general acoustical condition of the studio. Various shapes are available from which to choose, but the length should not be upto 17m or else echo will be produced in the room. In cases where a particular dimension has to be upto 17m, then the back should be treated with sound absorbing materials or it should be made irregular so as to produce a diffuse sound. Some typical room plans are treated below.

2.9.1 Rectangular Shapes

Two sets of parallel walls are used. Multiple reflections take place between the walls and standing waves can occur. Sound tends to repeat the same path round the room (figure 2.34)

If the path of sound is equal to an integral number of wavelength, then resonance occurs. Right angled corners tend to return sound along the direction of incidence or back to the source. This does not help in diffusing the sound.

2.9.2 Concave Shapes

Concave shape tend to focus sound to a point and thus produce a non uniform distribution of sound energy. Figure 2.35 illustrates this point. If a concave shape is in built in design then the focus should be outside the room.

2.9.3. Convex Shapes

They tend to diffuse the sound, thereby produce a uniform sound distribution in the room.

2.10 Acoustical Design of Studios

Room acoustical requirements for recording studios must be met with greater precision, than is applicable in auditorium, because the ear is replaced by a more sensitive instruments that is the microphone which could indicate any acoustical defect in the studio. A microphone will indicate it clearly, when the reverberation characteristics of the room is not optimum, sound diffusion is low, when acoustical defects like echo, sound concentration and so on are present and the existence of the faintest noise or vibration.

A wider frequency range than normal is considered in the acoustical designs of studios (figure 2.37). The microphone picks up sound like a person with monaural hearing (hearing through one ear).

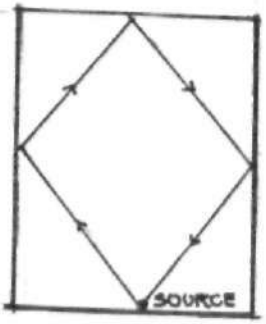


FIGURE 2·34 RECTANGULAR SHAPE.

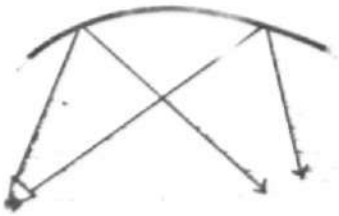


FIGURE 2·35 CONCAVE SHAPE.

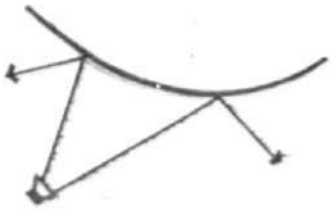


FIGURE 2·36 CONVEX SHAPE.

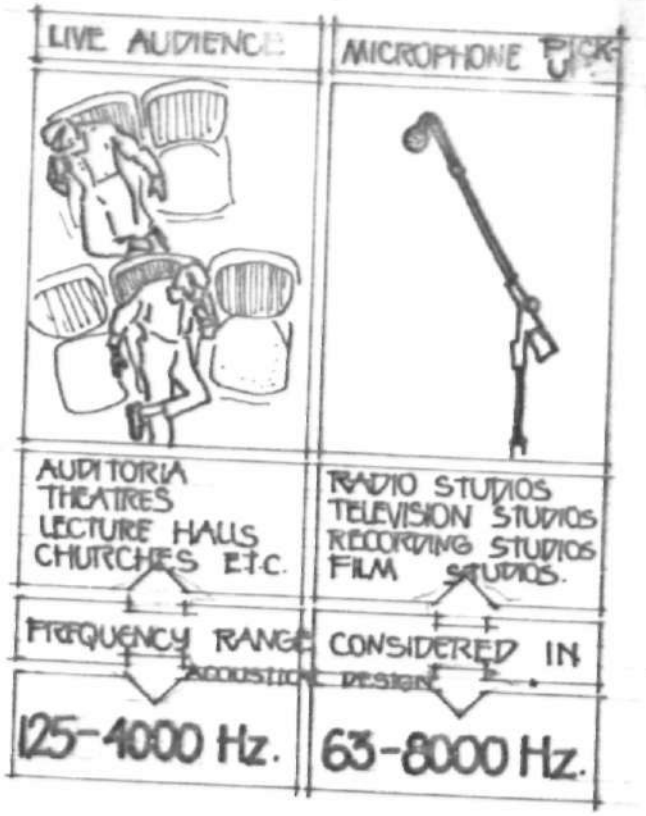


FIGURE 2·37 FREQUENCY RANGE CONSIDERED IN ACOUSTICAL DESIGNS..

2.10.1 Acoustical requirements

In the design of recording studios attention must be given to the following requirements because a studio form an acoustical link between a sound source and microphone. These requirements are: (1) An established optimum size and shape is needed. The size of s studio depends on the function it is to carry out, this is to say that it depends on the physical spatial requirements for the occupants, equipments and furniture, and by the acoustical requirements. The minimum dimension acceptable is 2.4m. Table 2.3 givesthe spatial requirements for people in the studio. If an audience is to be allowed in the studio then a separate floor area should be given to them .

Table 2.4 shows a generally advocated room proportions for rectangular studio, it should be noted that there are no Universally or unanimously accepted ones as being optimum. Room proportions become insignificant in studio acoustics when the studio is non rectangular, there is a generous application of acoustical finishes, high degree of sound diffusion has been provided, the volume is above 710m^3 and when the ideal reverberation characteristics has been achieved. (ii) A high degree of sound diffusion is needed. This is needed so as to eliminate points with noticeable sound pressure so that microphones could be safely placed at any convenient place.

ACTIVITY	AREA M^2
INSTRUMENTALIST IN A SMALL STUDIO	0·55 - 0·95
MUSICIAN IN A SMALL STUDIO	1·40 - 1·85
MUSICIAN IN A LARGE STUDIO	1·85 - 3·75
SINGERS	0·37 - 0·55

TABLE 2·3 SPACE REQUIREMENTS IN A STUDIO.

STUDIO TYPE	HEIGHT	WIDTH	LENGTH
SMALL	1	1·25	1·60
MEDIUM WITH RELATIVELY LOW CEILING	1	2·50	3·20
MEDIUM	1	1·50	2·50
MEDIUM WITH UNUSUAL LENGTH RELATIVE TO WIDTH.	1	1·25	3·20

TABLE 2·4 RECOMMENDED PROPORTIONS FOR RECTANGULAR STUDIOS.

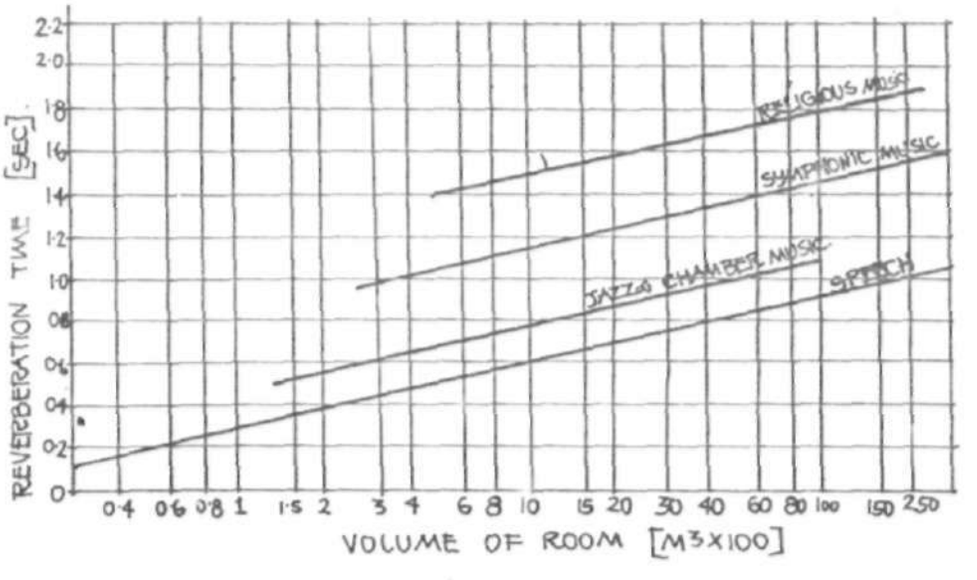


FIGURE 2·38 OPTIMUM RT FOR STUDIOS AT THE MID FREQUENCY RANGE.

(iii) Provision of ideal reverberation characteristics. Shorter reverberations times are needed for studios.than for auditoriums. Figure 2.38 illustrates the optimum reverberation times needed at mid frequency (500 - 1000Hz) range for studios. The reverberation time characteristics is of vital importance to the final quality of the music.

Recording studios are used for programmes with different reverberation times requirements and as such a flexible design is needed. The flexibility can be achieved by using portable acoustical screens, variable absorbers on wall or ceiling surfaces or mechanisms for controlling reverberation time electronically.

(iv) Acoustical Defects must be prevented. Sound concentrations, echos, must be eliminated. Parallel surfaces must be eliminated in medium and large studios or treated with acoustical materials which are highly absorbtive throughout the frequency range between 63 and 8000Hz.

(v) Noise and vibrations must be eliminated. Noise tend to distract attention, but a certain degree of noise is needed to make music more enjoyable. Noise and vibrations control are treated in chapter 2.

2.10.2 Control rooms

This links the recording studio to the outside world, in that it is here that all sound sources are controlled and mixed before our taking it out for processing. Visual contact is necessary between this room and the studios, this is done by either using a wide control window with an unobstructive view to the studio or by a closed circuit. Visual unit. If the studio floor is not more than 75 to 110m^2, then the control

room and studio are placed on the same floor, level, but it must be elevated if the studio is larger than this.

The spatial requirements for a control room depends on the equipments and how many people it is to accommodate. Equipments like the audio console, monitoring and talk back facilities, tape and disc reproducers, tape recorders, effects rack, intercom key panel and seats for the control personnel.

Reverberation characteristics similar to that of an average living room is needed in a control room. The recommended reverberation time is 0.4 sec at the mid frequency range.

CHAPTER THREE

NOISE AND VIBRATION

3.1 Noise

Broadly speaking noise is defined as a sound that interferes in anyway with an activity going on in a space, this is to say that any undesirable sound is termed as noise by the recipient. The degree of undesirability will depend on the loudness, frequency, continuity, time of occurence, information content and the origin of the sound.

The provision of an acceptable acoustical environment for various activities is the fundamental objectives of noise control in buildings.

3.1.1 Effects of Noise

Noise could be distracting, annoying on harmful to communication and health. It has been found out that excessive noise adversely affects the output of workers in a factory and increase the liability to error. A sudden violent noise such as an explosion causes a change in the rate and regularity of the heartbeats and is a great shock to the whole nervous system. A persistent series of noise have a cummulative effect, the first symptom is a violent headache. Temporary and in some cases permanent deafness resulted from prolonged exposure to noise level above 85dB, heart disease, hypertension and stomach ulver can also result from a prolonged exposure to loud noise.

3.2 Noise Sources

Sources of noise can be divided into two groups depending on whether they are produced within a room or from an external source. Noise originating within a building is termed an interior noise while the one with an external origin is an outdoor noise.

3.2.1 Interior Noise

Common among the interior noise sources are conversation, radio and television, door opening and closing, traffic along the staircase, children playing and so on. Another group of noise is that produced by machines and house hold equipments termed the building noise, from fans, motors, air conditioners and so on. In an industry noise is produced within the production hall, offices, cafetaria and so on. Figure 3.1 show some of the interior noise sources and their levels of intensity.

The sound level at any position in the room is made up of two parts, the one directly received and the reverberant sound. Further away from the noise source the reverberant sound prevails in the room. The distance at which this happens is termed the room radius (r).

$$r = \sqrt{\frac{A}{16\pi}}$$

Where A = total absorption of room in sabins

3.2.2 Outdoor Noise

They includes noise produced by vehicular, rail, water and air transportation. Noise from exposed mechanical equipments for exammle, cooling towers, air conditioners compressors and so on. Before siting buildings that needs quite, a preliminary noise survey should always be made.

Figure 3.2 gives the intensity and sources of some outdoor noises. The reduction of the outdoor noise is covered by the inverse square law. A drop of 6dB will be noticeable every time the distance between the recipient and sound source is doubled.

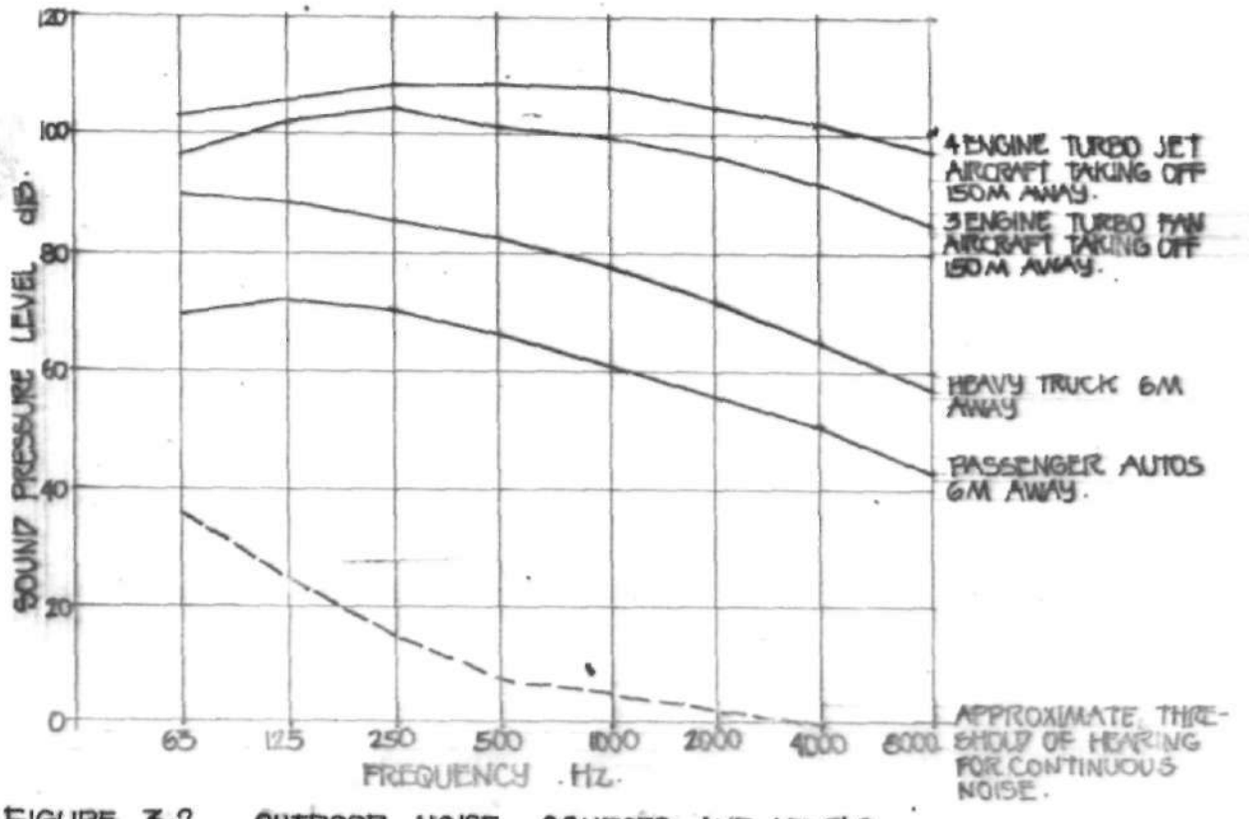


FIGURE 3·2 OUTDOOR NOISE SOURCES AND LEVELS.

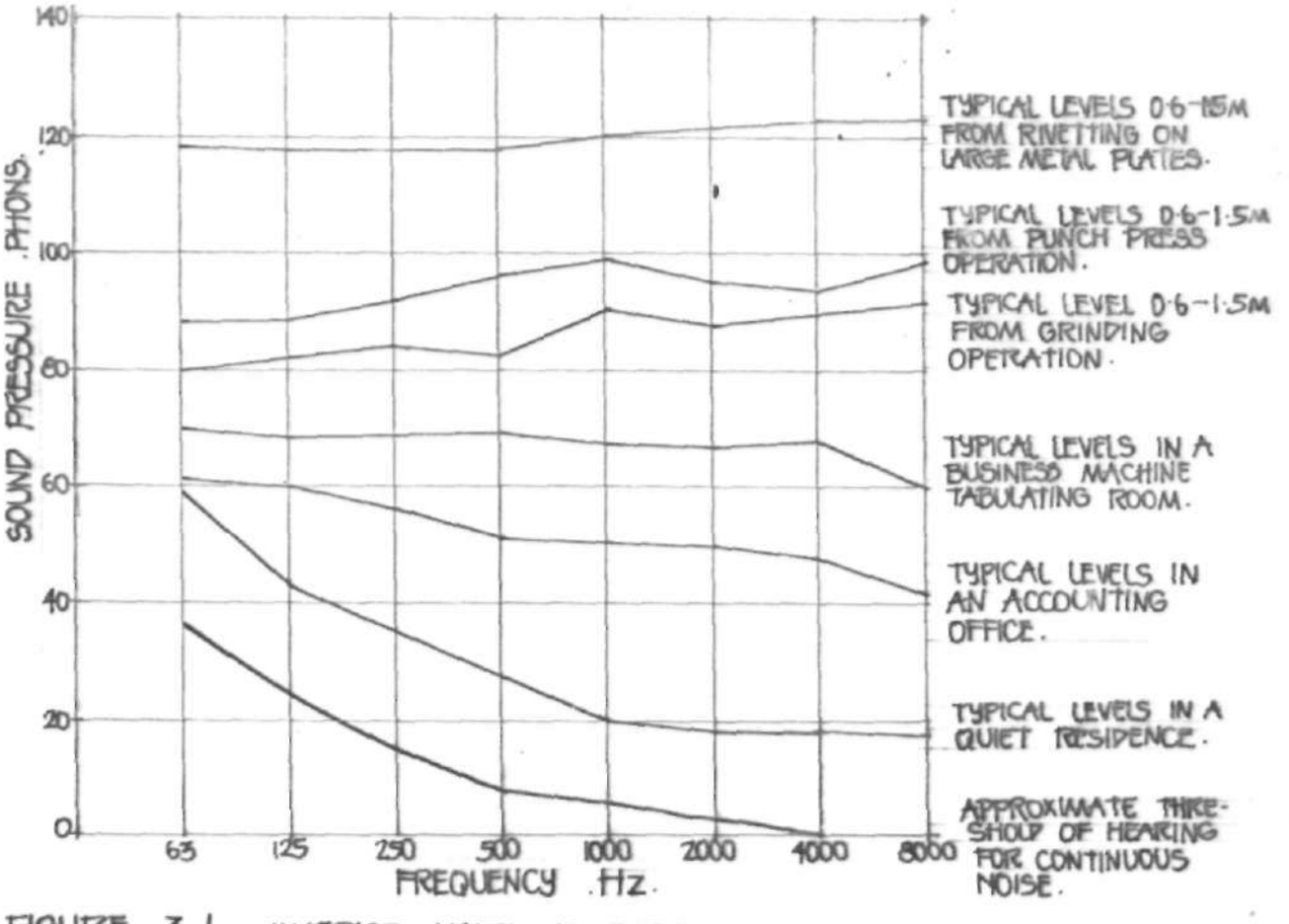


FIGURE 3·1 INTERIOR NOISE SOURCES AND LEVELS.

3.3 Transmission of Noise

There is a difference between the transmission of airborne and structure borne noise. The airborne noise is normally attenuated by the intervening enclosures and by air absorption, thereby making it confined to the areas of its origin. In the case of structure borne noise, the solid parts of the building structure are set into vibration, the effect of this is a multiplication of the sound - radiating surface and thus increasing the sound pressure. In some cases the "extension of the sound - radiating surface is useful, even desirable, as for such musical instruments as the cello, double bass, and piano. In most cases this phenomenon is very harmful". Leslie (1972).

It is important to note that different methods are employed in insulating against either structure borne or airborne noises, so it must be determined whether the noise to be controlled is airborne or structure borne.

3.3.1 Airborne Noise

Figure 3.3 illustrates the different routes by which airborne noise originating from one room can be transmitted into another. These routes are through openings (doors and windows), ventilating ducts and grilles, crawl spaces, shaft, gaps and cracks around the pipes, conduits and so on, and by forced vibration set up in the boundaries of the source room then reradiated into the receiving room.

3.3.2 Structure-borne Noise and vibration

They are best treated by preventing the transmission of the noise from the sources onto the structure. This can be

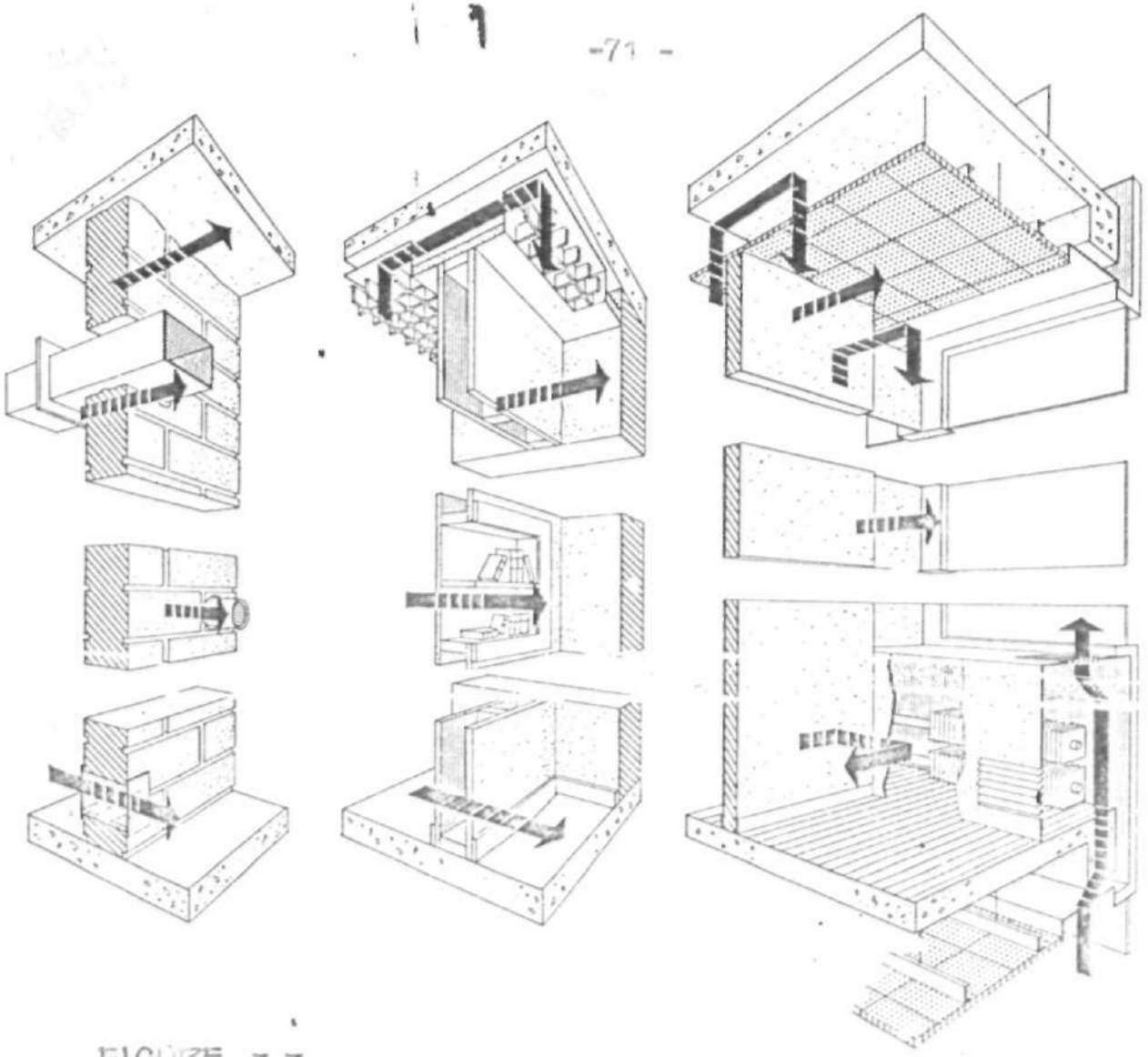


FIGURE 3.3 SOUND LEAKAGE PATHS COMMONLY FOUND IN BUILDINGS.

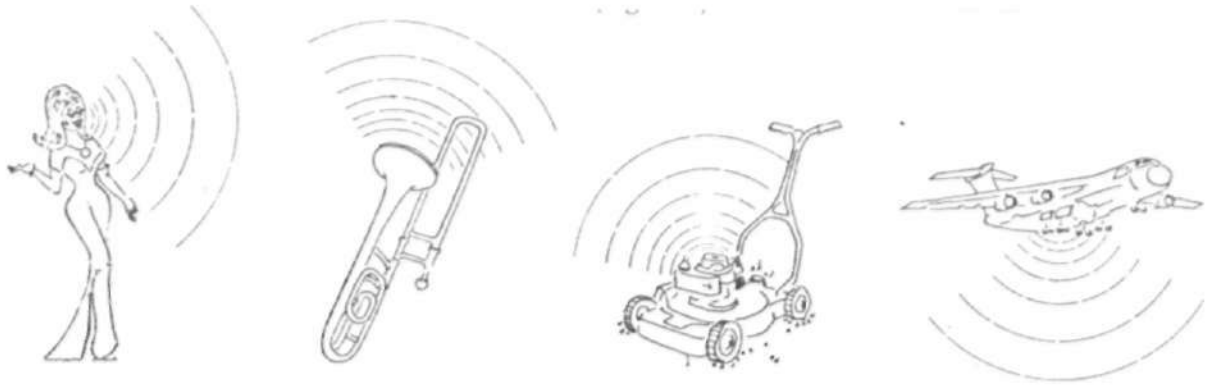


FIGURE 3.3A SOME SOURCES OF AIRBORNE NOISE.

done by using flexibe mountings, antivibration pads, floating floors, for machine produced noise and by reducing impact transmission into the floor by use of adequate resilient flooring for example carpeting, rubber tile, cork tile and so so on.

3.4. Insulation against Airborne sound

The problem of noise control in buildings increased due to the construction methods employed. Thin prefabricated building elements are used in construction so as to save time and money, due to their nature they are not good sound insulators and as such sound insulating constructions are needed for sensitive rooms.

3.4.1 Sound Transmission Loss (TL)

This is a maesure of the sound insulation property of a partition stated in decibels. The transmission loss of a partition is independent of the acoustical properties of the two spaces separated by it, it varies with the frequency of the sound but depends on the construction of the partition. Figure 3.4 defines the transmission loss of a partition graphically. See Appendix A and B for the sound insulation values of partitions.

3.4.2. Single leaf Partitions.

The frequency of the transmitted sound and the surface weights of the homogenous single leaf partition are the determinants of its transmission loss. For a doubling in the frequency of the incident sound or that of the weight the transmission loss is increased by about 5 to 6 dB upto a limit due to flanking transmission. The mass law assumes that there

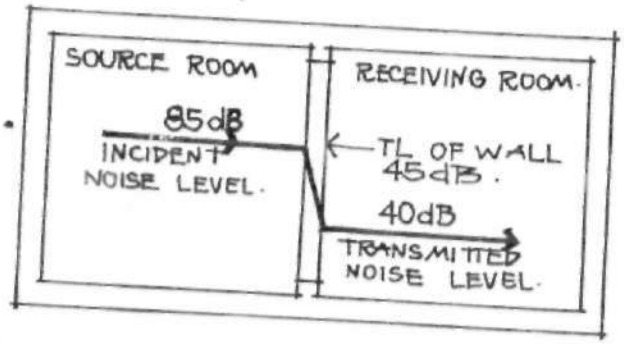


FIGURE 3.4 TRANSMISSION LOSS OF A WALL.

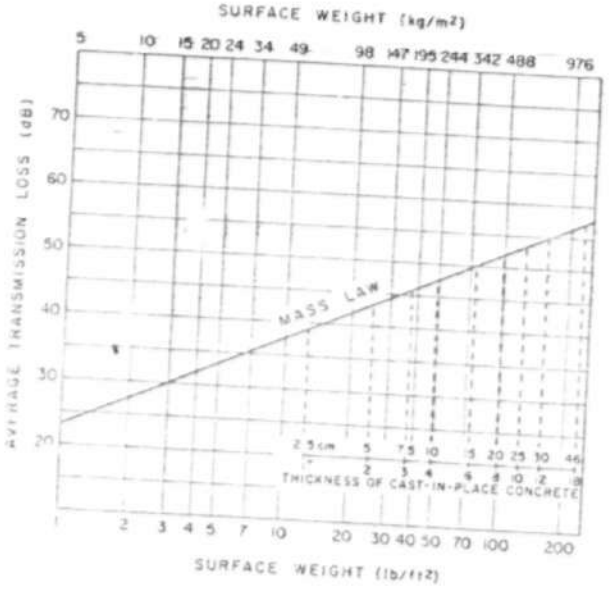


FIGURE 3.5 THE MASS LAW.

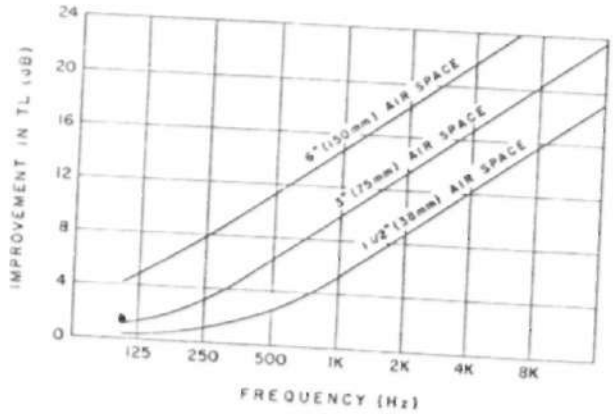


FIGURE 3.6 APPROXIMATE IMPROVEMENT IN TRANSMISSION LOSS [TL] OF A MULTIPLE PARTION OVER A SINGLE ONE WITH THE SAME SURFACE WEIGHT.

is a random incident of sound on the partition (figure 3.5).

It should be noted that the transmission loss is much less than predicted by the mass curve for some frequencies due to a special condition called the coincidence effect.

3.4.3 Multiple Partitions

It is more advisable to use a multiple partition in areas where a high degree of sound insulation is required, than trying to increase the weight of the single leaf partition due to functional, spatial, structural and economic reasons, and due to the fact that the multiple partition will provide a higher transmission than would a wall with the same weight. This is so if there is a consistency in the separation, a maximum distance has been established, a reasonable maximum total weight has been established, the leaves are of different materials or same with different thickness, Noise leaks have been avoided and a continuous layer or patches of sound absorbing material have been mounted in the air space.

Figure 3.6 compares effectiveness of a multiple partition to a single leaf on while figure 3.7 gives the average Tl of multiple partitions with different air spaces. Figure 3.8 compares the average Tl of a wall with an isolation blanket with the same wall without the blanket.

3.4.4 Composite Barriers

A composite barrier is a partition that is made up of more than one element. It can be a door or window or any opening incorporated into the wall. This opening affects the overall insulation of the partition, infact it determines the

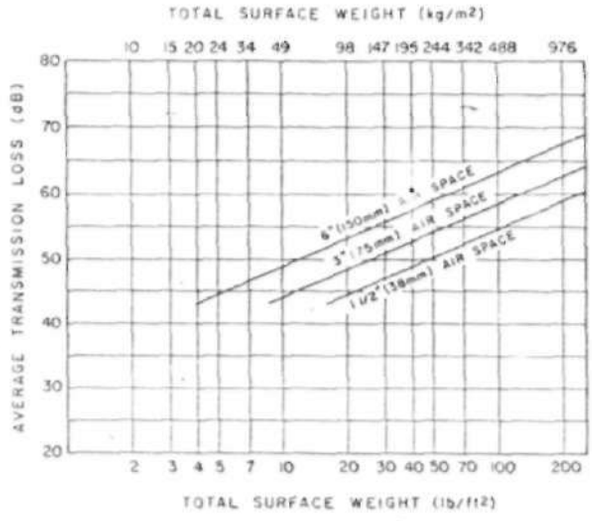


FIGURE 3·7 AVERAGE TL OF MULTIPLE PARTITIONS.

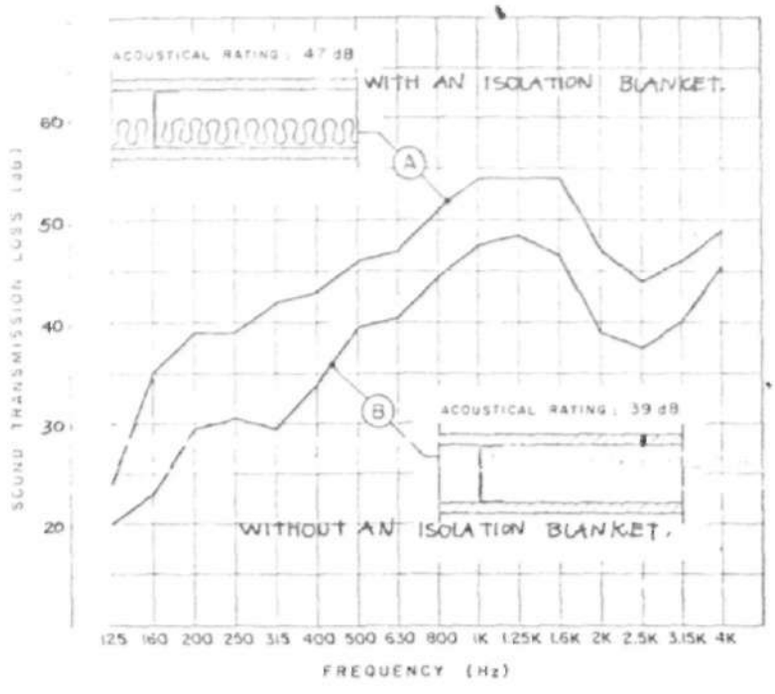


FIGURE 3·8 EFFECT OF ISOLATION BLANKET ON THE TL OF A PARTITION.

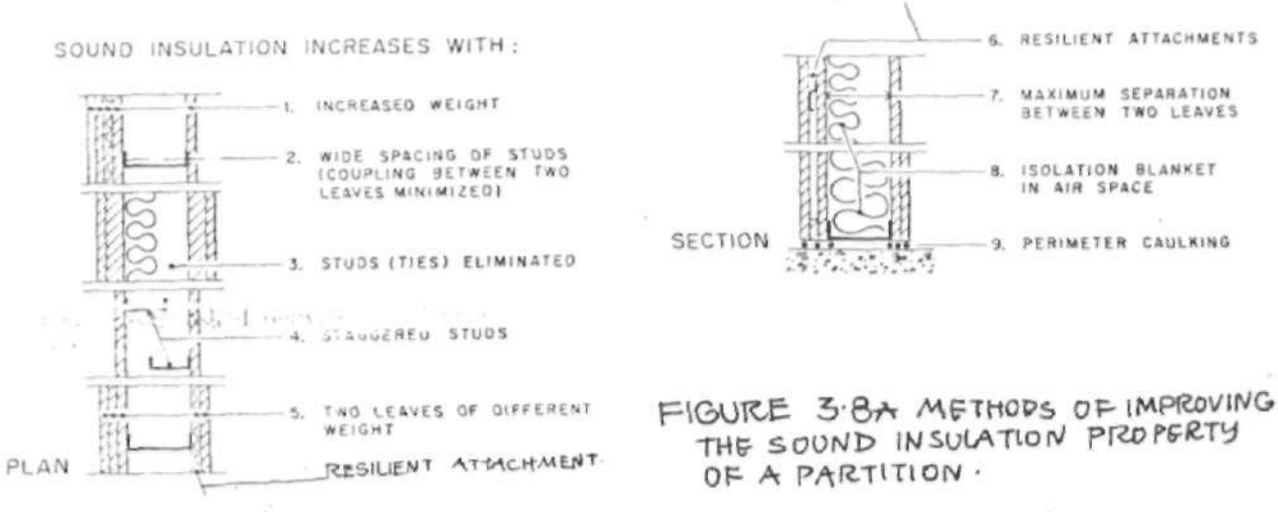


FIGURE 3·8A METHODS OF IMPROVING THE SOUND INSULATION PROPERTY OF A PARTITION.

the total insulation property of the partition. Figure 3.9 shows how to calculate the overall transmission loss of a composite barrier.

3.5 Sound Transmission Class (STC)

The noise reduction (NR) is used for quantifying the sound insulation properties between rooms because it takes into consideration the acoustical properties of these rooms. The Noise reduction (NR) expressed in dB is found from the formula.

$$NR = L1 - L2$$

$$\text{or } NR = T1 + 10\log \frac{A2}{S}$$

Where L1 = average sound pressure level in source room, dB

L2 = Average sound pressure level in receiving room, dB.

T1 = Transmission loss of partition, dB.

A2 = total absorption of receiving room, m^2 sabins

S = area of partition, m^2.

It should be noted that if all the surfaces in the receiving room are completely absorbent, then the Noise reduction will exceed the Transmission loss by about 5dB, thereby making NR = T1 + 5dB.

3.7 Insulation against Structure borne (impact) Noise

As mentioned earlier structure borne noise travel efficiently from one part of a rigid structure to another. A floating floor or a resiliently supported ceiling helps in the insulation against airborne noise (Figure 3.11). It should be noted that the addition of a soft floor finish does not

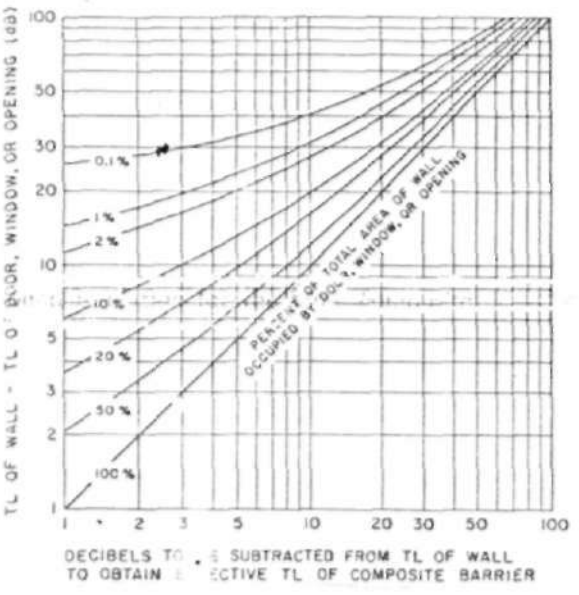


FIGURE 3·9 CHART FOR CALCULATING THE EFFECTIVE SOUND INSULATION VALUE OF COMPOSITE BARRIERS.

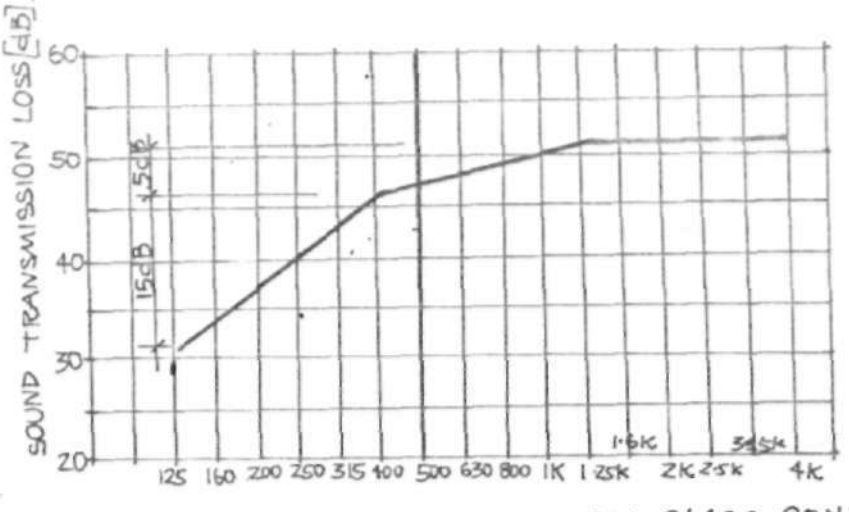


FIGURE 3·10 SOUND TRANSMISSION CLASS CONTOUR.

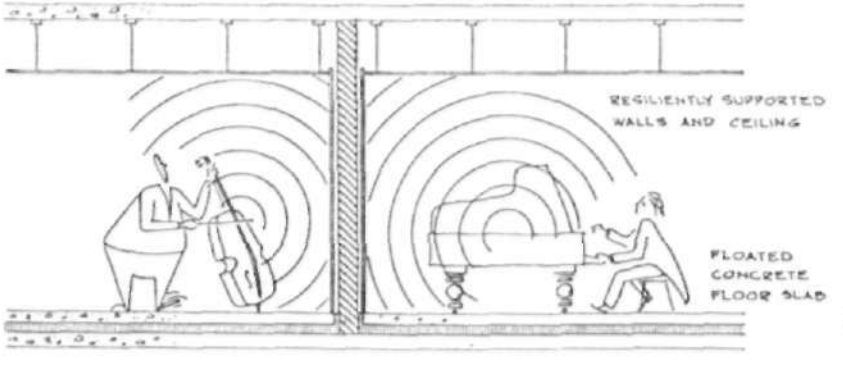


FIGURE 3·11. INSULATION AGAINST AIRBORNE NOISE.

provide extra insulation against airborne sound but reduces or eliminates impact noise, other methods employed are, a floating floor construction, resilient mounts, and resiliently suspended solid ceiling. Figure 3.12 helps in illustrating the above mentioned points.

3.8 Sound Insulating Building Constructions

Three factors are considered before the selection of a wall or floor construction is done. The acceptable or desirable masking noise in the receiving room should be established, the level of the existing noise should be known and the efficiency of the enclosure should be established.

The masking noise is a melee of various noises existing in the unoccupied room brought by the mechanical and electrical services of the building, vehicular traffic and so on. The masking noise should be continous, not too loud, unobstrucsive and should carry no information (intelligible speech or identifiable music) for it to be effective.

3.8.1 Walls

Its degree of efficiency against air borne noise will be very high if, its area have a uniformly distributed mass, its periphery is effectively sealed (figure 3.13), the construction is unobstructed both horizontally and vertically, and if its built from structural slab to slab or adequate acoustical measures have been taken to compensate for its missing portion above the suspended ceiling.

The sealant should be a non hardening, non skinning and a nonsetting caulking compound. Cracks on the wall should all be sealed by using plaster on the wall.

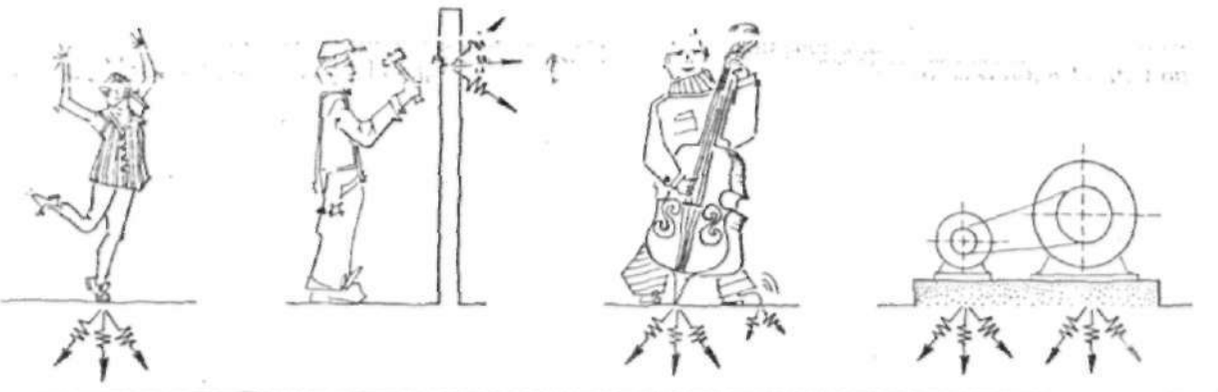


FIGURE 3·12A EXAMPLES OF SOURCES OF STRUCTURE BORNE NOISE.

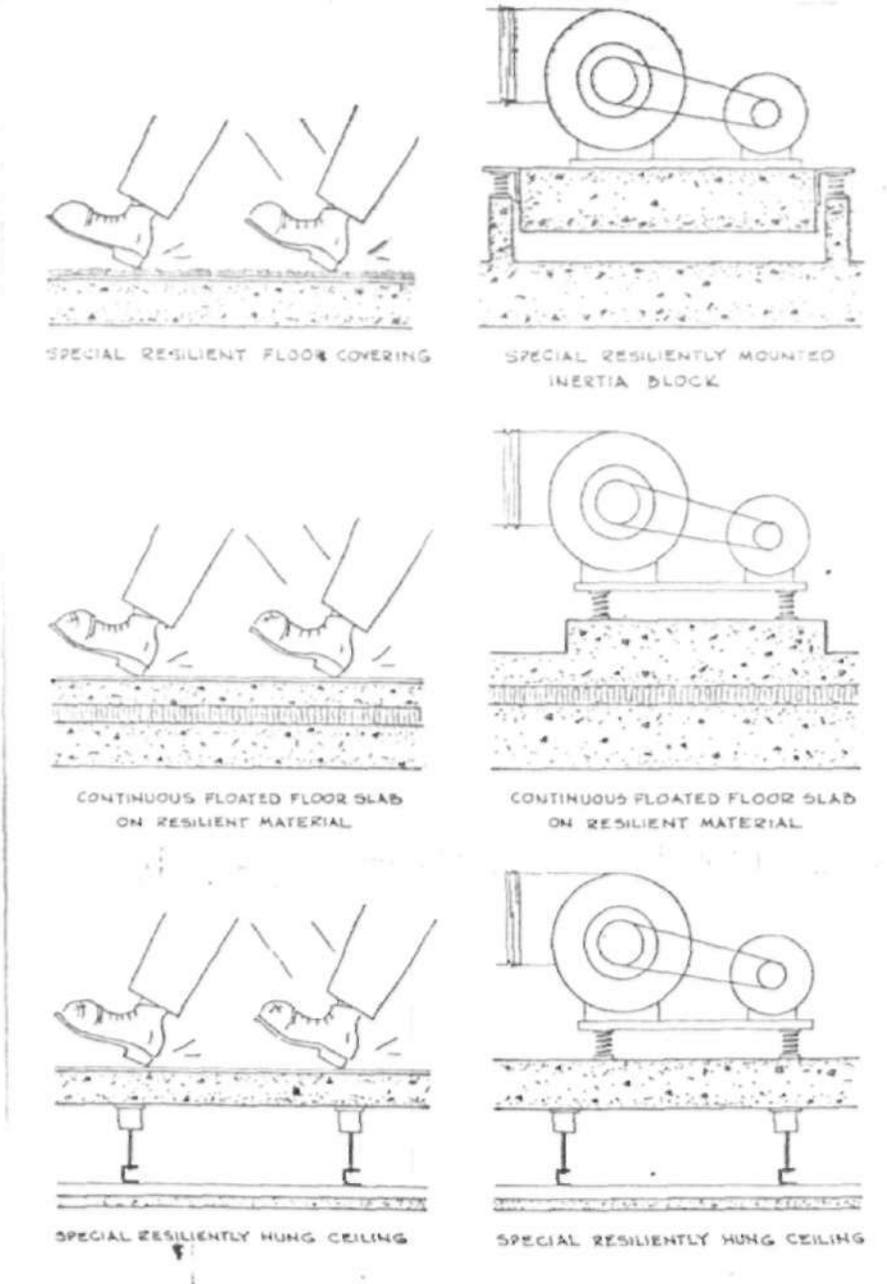


FIGURE 3·12B INSULATION AGAINST STRUCTURE BORNE NOISE.

3.8.2 Floors and Ceilings

An acoustically efficient floor should provide enough protection against both airbone and impact noises. Suspended ceilings contribute substantially to the sound insulation of a floor against both the airbone and impact noises, if the membrane weight not less than 25Kg/m^2, if it is not too rigid, if all the gaps between it and the structure are well sealed if the number of suspension points is to a minimum and the mounting is on resilient hangers and not on rigid ones. Figure 3.14 shows various hangers used in resiliently suspended ceilings.

3.8.3 Doors and Movable Partitions

The overall transmission loss of a partition is always reduced by whenever a door is installed on it. They constitute the acoustical weak elements of the walls because, their low frequency resonances occurs at a more critical range of the audio frequency spectrum, due to the fact that their surface wieght is smaller than that of the wall and the gaps around their edges are passages for sound transmission in cases where they are not well sealed. Figure 3.15 illustrates methods used for sealing sound insulating doors.

The seal along the perimeter of a sound insulating door could be destroyed if the door is of light weight material, so a heavy solid core construction is needed. The bottom edges of the door could have a replaceable strip of felt or foam rubber attached to it, but a more effective method is to have a dropbar draft excluders installed, they are called automatic threshold closers (figure 3.15).

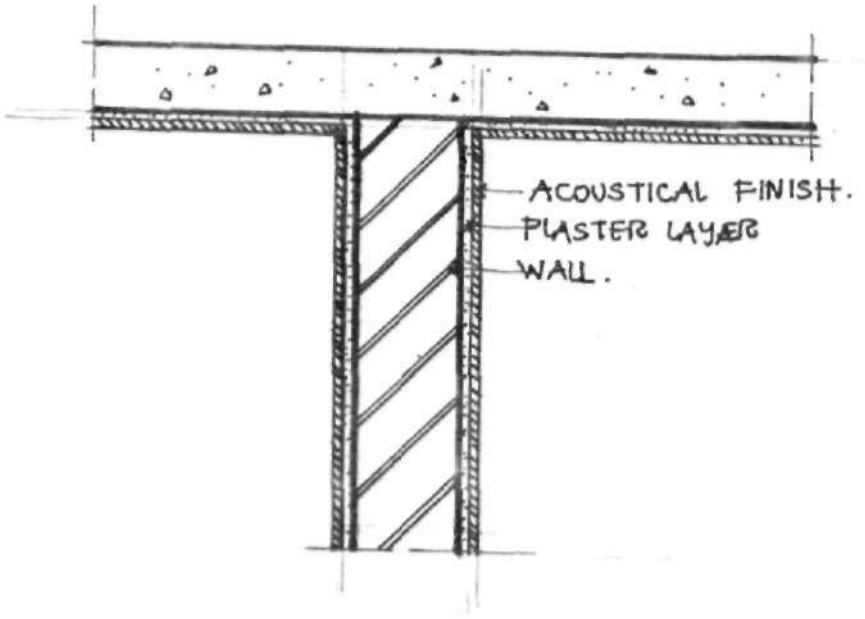


FIGURE 3·13 METHOD OF SEALING A BRICK WALL.

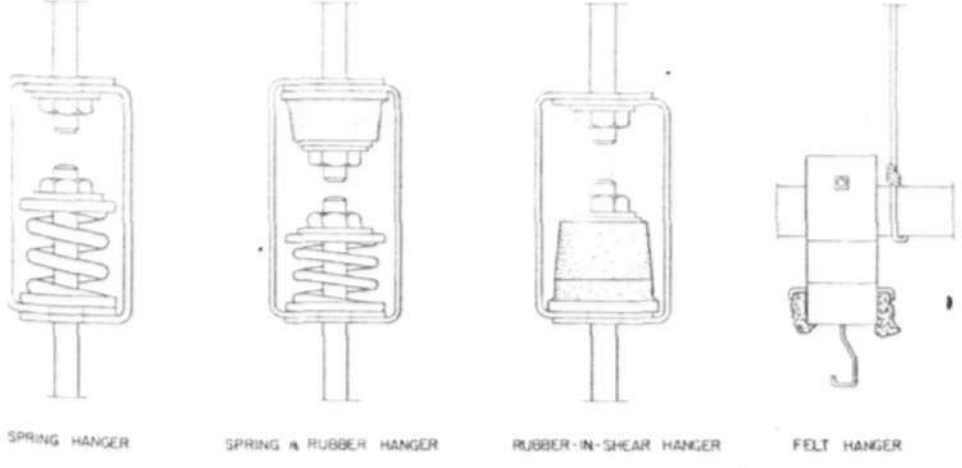


FIGURE 3·14 HANGERS USED IN SUSPENDING CEILINGS.

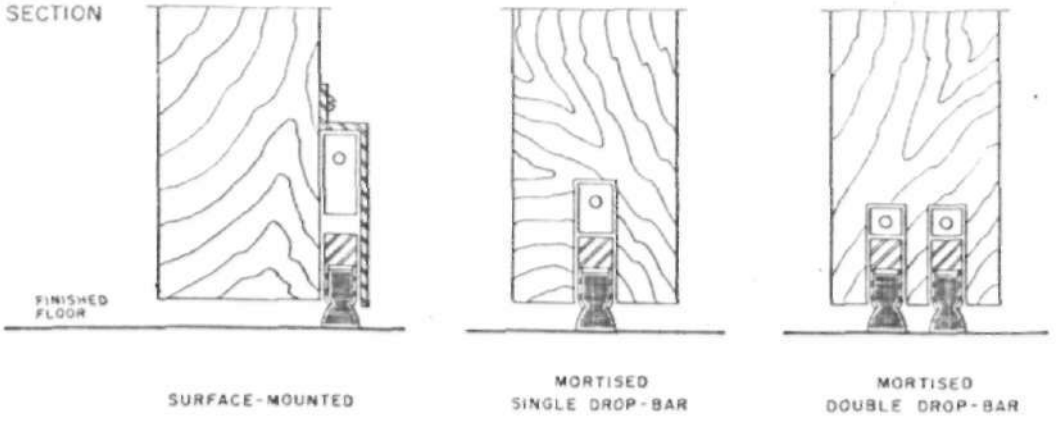


FIGURE 3·15 AUTOMATIC DROP BAR THRESHOLD CLOSERS.

In cases where a very high degree of sound insulation is required, the doors are built so that a separation between the two faces of the door is carried through (from edge to edge) in both directions. It is noteworthy to know that ordinary doors with leather padding on their surface does not help in reducing the impact of airborne noises between the source and receiving room.

Figure 3.16 illustrates a sound insulating double door with a steel frame. Figure 3.17 compares the transmission loss diagrams of various door constructions. The difference between the transmission loss of a wall and door should be kept between 5 and 10dB.

Sound locks could be used to create a high degree of sound insulation which only an expensive sound insulating door could provide, doors along a corridor should be staggered so as to achieve a higher degree of acoustical privacy (figure 3.18).

Movable partitions should provide both visual and acoustical privacy in rooms where their use is employed and they should not require space-consuming areas for storage. Their maintenance and servicing requirements should be a minimum and the panels used for constructing them should not warp or twist under unfavourable conditions of temperature and humidity. Their acoustical performance covers a wide range and could be as high as 55dB (STC value). Figure 3.19 illustrates the construction of a movable partition.

3.8.4 Windows

Like doors, they constitute another group of acoustical weak components. They provide a direct path for sound transmission if their perimeter is not well sealed. They have the advantage of allowing masking noises to enter the building.

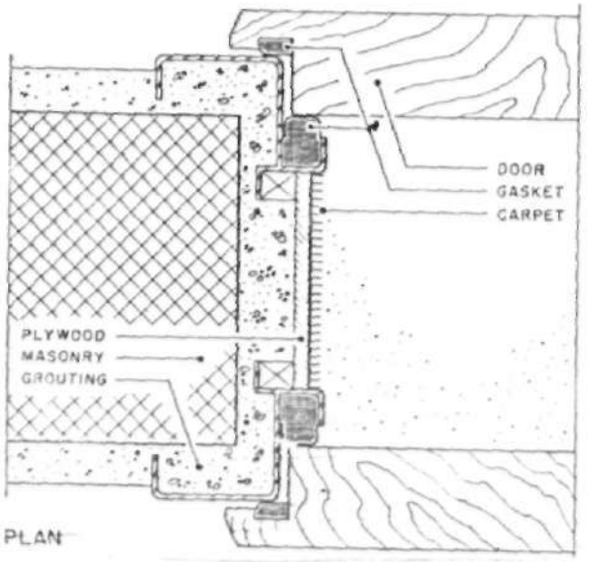


FIGURE 3·16 A SOUND INSULATING DOUBLE DOOR.

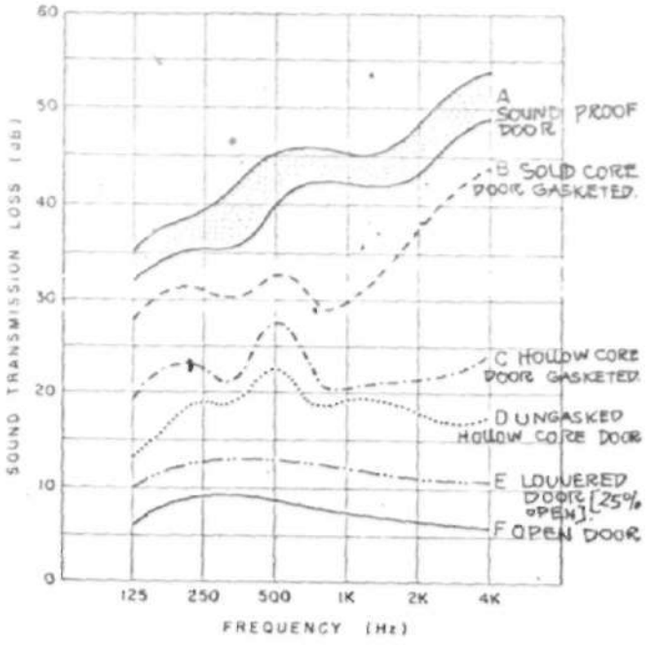


FIGURE 3·17 TRANSMISSION LOSS OF VARIOUS DOOR CONSTRUCTIONS.

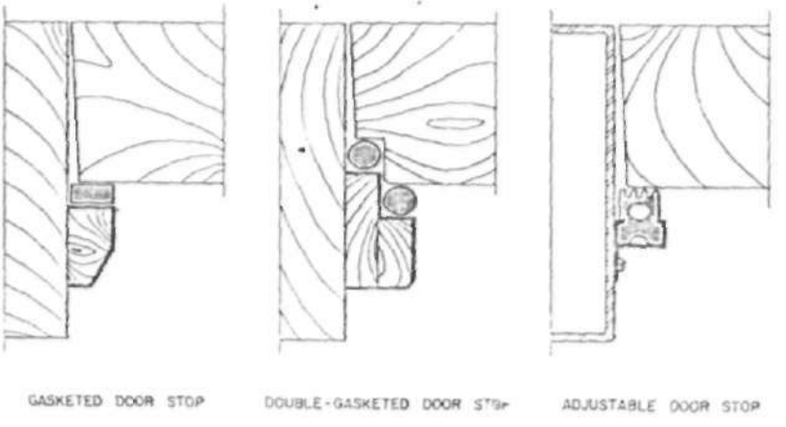


FIGURE 3·17A DOOR STOPS USED AT THE JAMBS AND HEADS OF SOUND INSULATING DOORS.

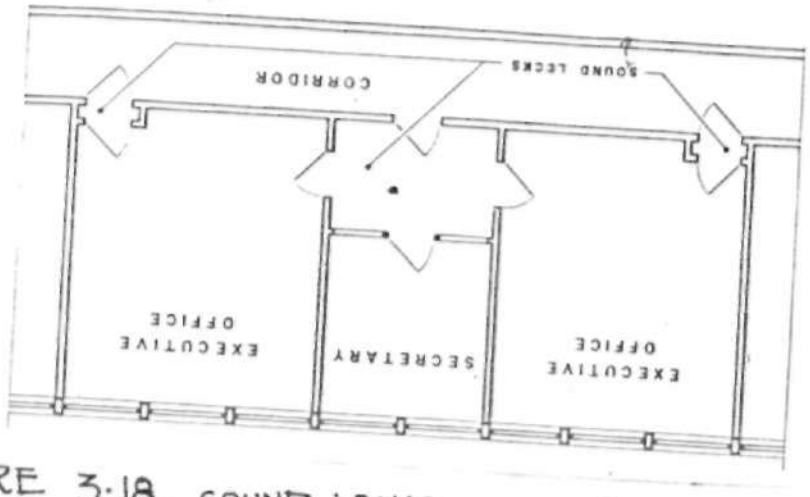


FIGURE 3.18 SOUND LOCKS.

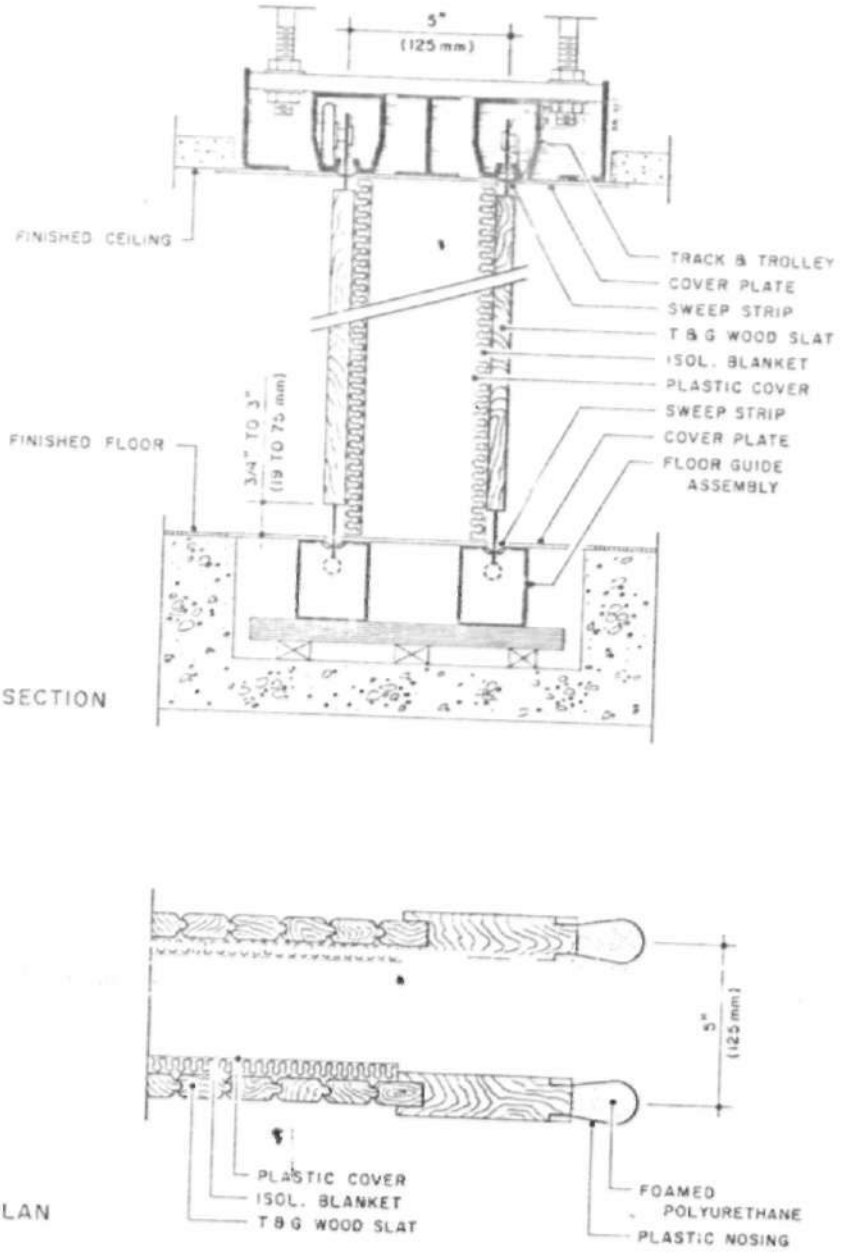


FIGURE 3.19 CONSTRUCTION OF A MOVEABLE PARTITION.

Figure 3.20 compares the transmission loss value of various window construction. It should be noted that the transmission loss value of a window depends on their thickness, number in use and the relative positions of the panes. Figure 3.21 gives the the ranges of sound insulation property of windows. The distance between the panes in the window have an effect on the average transmission loss, in that it increases it with an increase in the distance, but in cases where the distance can not be increased upto a certain limit, then a thicker pane should be used.

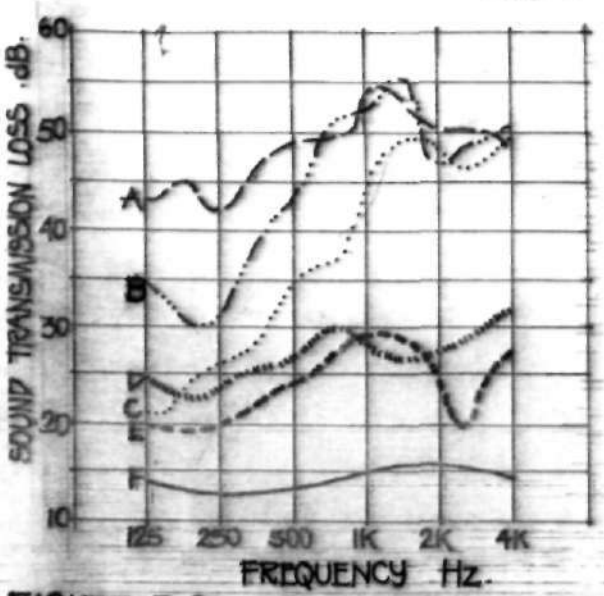
For better acoustical efficiency each pane should be of a different thickness or weight per unit area, this will help in eliminating resonance and acoustical coupling. The addition of sound absorbing treatment around the perimeter and the avoidance of parallelism between the panes will increase the transmission loss of the window. Figure 3.22 shows the construction of a control window.

3.8.5 Discontinuous Construction

This is a type a construction whereby the whole room is built within a shell. This is done for rooms requiring a very high degree of sound insulation against airborne, structure borne and vibrations. The normal practice is to have a floating floor and a resiliently mounted suspended ceiling figure 3.23. The room is accessable through a sound lock.

3.9 Control of Traffic Noise

This can be done through Architectural design and by enacting laws governing the use of vehicles which should include speed limit, number of stops along the route, reduction in the number of vehicles and so on. Architecturally this could be



A. DOUBLE WINDOW, 13MM PLATE GLASS AND 20 CM AIR SPACE.
B. DOUBLE WINDOW, 24 OZ 3MM GLAZINGS AND 20 CM AIR SPACE.
C. DOUBLE WINDOW, 24 OZ 3MM GLAZINGS AND 100MM AIR SPACE.
D. SINGLE WINDOW 13MM PLATE GLASS.
E. SINGLE WINDOW 24-OZ-[3MM] GLAZING.
F. OPEN WINDOW.

NOTE:
ALL DOUBLE WINDOWS [A, B, AND C] HAVE SOUND ABSORPTIVE REVEALS.

FIGURE 3-20 TRANSMISSION LOSS VALUE OF VARIOUS WINDOW CONSTRUCTIONS.

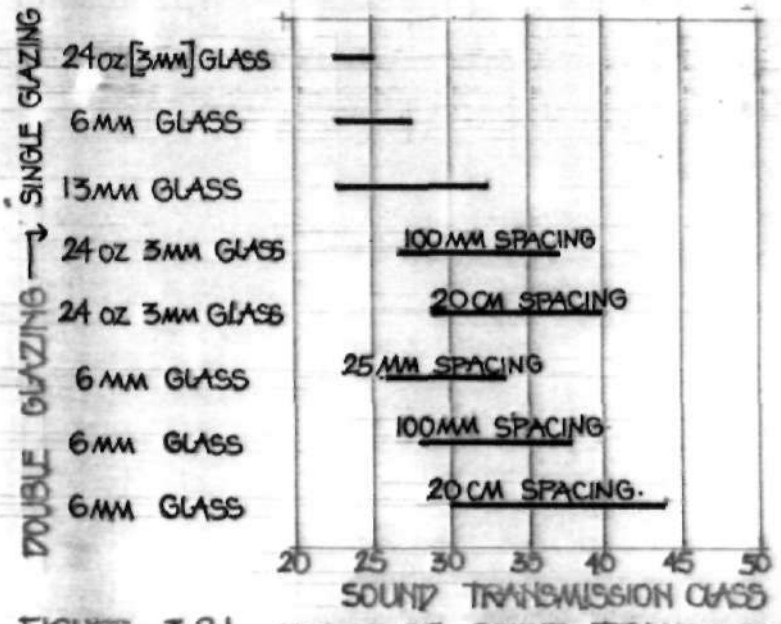


FIGURE 3-21 RANGE OF SOUND TRANSMISSION CLASS OF GLASS.

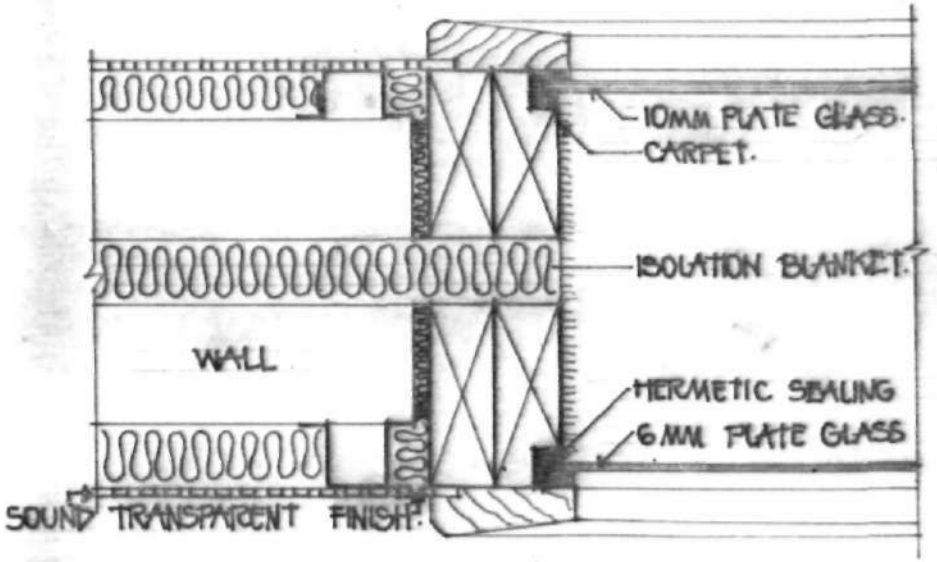


FIGURE 3-22 CONSTRUCTION OF A CONTROL WINDOW.

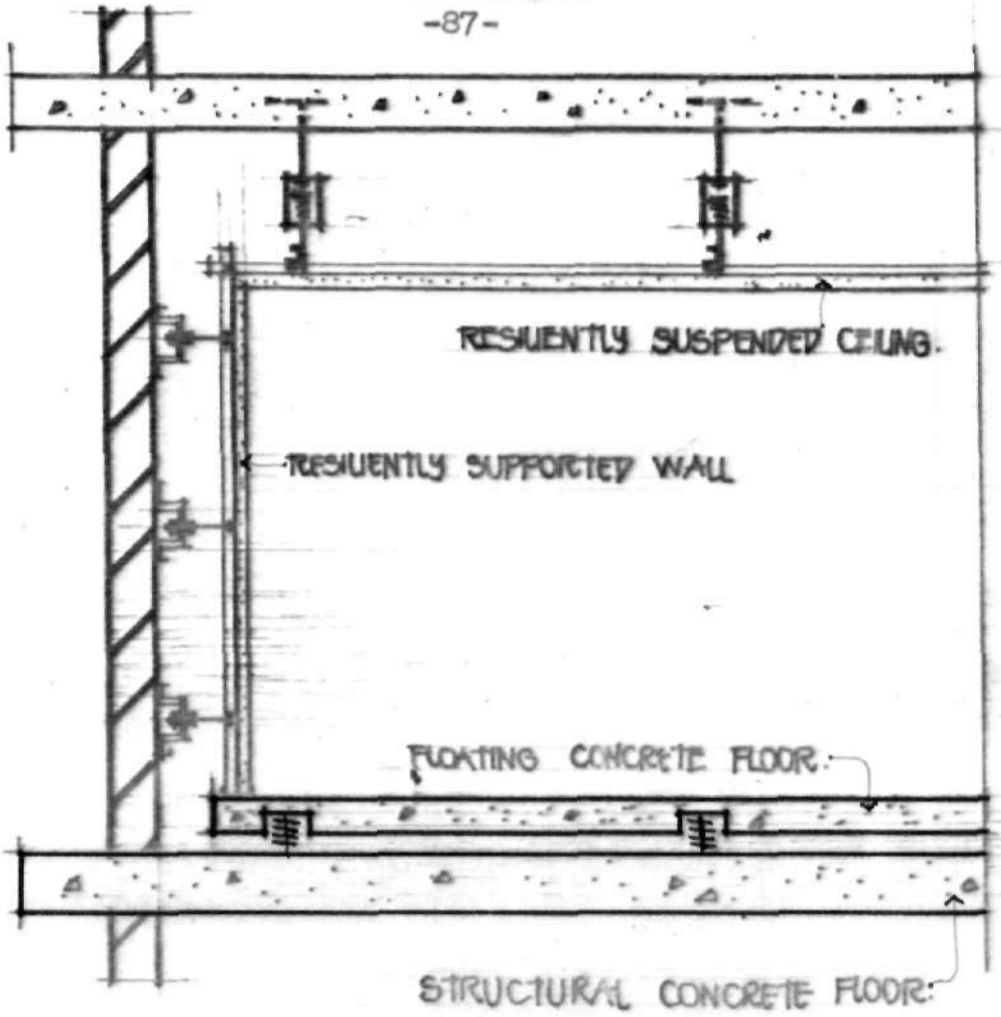
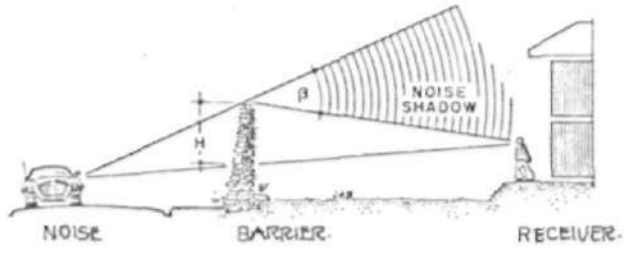


FIGURE 3·23 DISCONTINUOUS CONSTRUCTION.



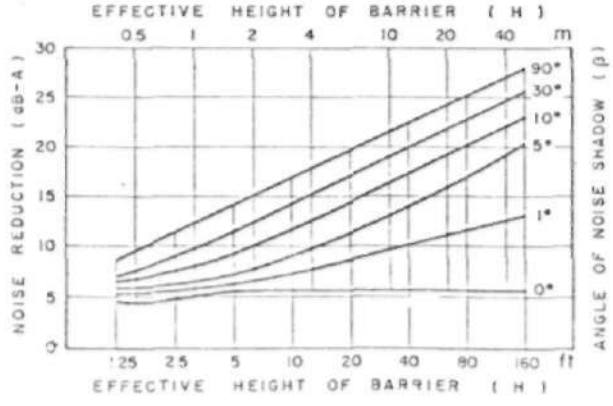


FIGURE 3·24 NOISE REDUCTION VALUES BY BARRIER.

done by proper zoning of activities on the site and by use of distance and barrier. There is a correlation between the effective height of a barrier and its noise reduction value (figure 3.24). Use of greenery like shrubs and grass help in reducing the traffic noise. The reduction is about double of that to be received if the surface between the road and the building were a hard one.

3.10 Control of Mechanical Noise and Vibrations

In the control of mechanical noise the complete elimination of it is not the objective, but its reductions to an acceptable level, due to its importance as a masking sound. Mechanical noise is generated by the ventilating, lighting, heating, plumbing systems and other machineries in use in the room.

The control of mechanical noise and vibration is the responsibility of a mechanical engineer, but its knowledge is important to an Architect due to the fact that he does the zoning of activity on the site, and should know the spatial requirements for duct works in order to design a building where these equipments and machinery could be incorporated aesthetically.

3.101 Sources of Mechanical Noise and Vibration

They can be grouped into four categories.

(i) Self noise. This is caused by the high velocity of airflow around sharp bends or turbulances created by the grilles, diffusers, dampers or pressure regulators in use in the buildings.

(ii) Exterior noise. This is transmitted through exposed parts of the duct into the building. This group of noises are

from the exterior sources like vehicular traffic, noise from electric generators and so on.

(iii) Mechanical equipment noise. They are caused by individual air conditioning systems or by fans, motors, compressors or pumps and so on from the centralised ventilating systems. They could also be caused from the machinery in use in the room or by the lighting fixtures. This group of noise can affect rooms that are not served by them.

(iv) The last category of noise is that of cross talk from one space to another. The noise travels through a supply or return duct work irrespective of the direction of airflow.

3.10.2 Noise from Plumbing System

Generally speaking the intensity of noises from these systems is not high, but it can be annoying and embarrassing. Noise from plumbing systems could come from any of the sources mentioned below, drainage of water, hammering caused by the sudden interruption of water flow, turbulent flow of water, pump noise caused by motor driven pumps, loose or defection from parts of fixtures, running and splashing of water when a bath tub is being filled or a shower is being used and by the entrapped air in the plumbing system.

To reduce this category of noise, the best procedure is to suppress it at the source by installing supply and drain pipes as far as possible from the quite areas. Transmission along the pipe can be reduced by inserting a flexible pipe between the sources and metal pipe.

In a music industry noise from plumbing system does not constitute a major problem in that the areas that need the water are placed far from the acoustically sensitive areas.

3.10.3 Noise from Ventilating and Air Conditioning Systems

The level of noise created by airhandling systems should be about 5 to 15dB below the desired level of background noise in order not to interfere with intelligibility in rooms used for listening to music. In other rooms like the offices, restaurants and so on the aims is to create a balance between the mechanical noise and other noises. The noise here should be reduced upto a level that it would not interfere with the desired activity. This level is given by the noise criteria.

For a successful control of ventilating and air conditioning noise, the principal noise producing parts should all be treated These are the (i) central mechanical equipment (ii) The supply and return ducts, and (iii) the supply and return grilles.

The central mechanical equipment should be placed far from the noise sensitive rooms and it should be a quietly operating one. For the recording studios a low velocity system should be used. Figure 2.25 illustrates the method of installation of a machinery on a floor. Additional measures that could be employed in control noise from ventilating system are:

(i) use of noise absorbing wall linings (figure 3.26).
(ii) use of bent ductwork system.
(iii) supporting ducts by resilient hangers (figure 3.25)
(iv) Acoustical separation of ducts from walls and floors at points of penetration.
(v) use of silencers (figures 3.27)
(vi) Absorption of noise within the room supplied by air
(vv) The use of seperate duct work for each room will help in the reduction of cross talk (figure 3.26).

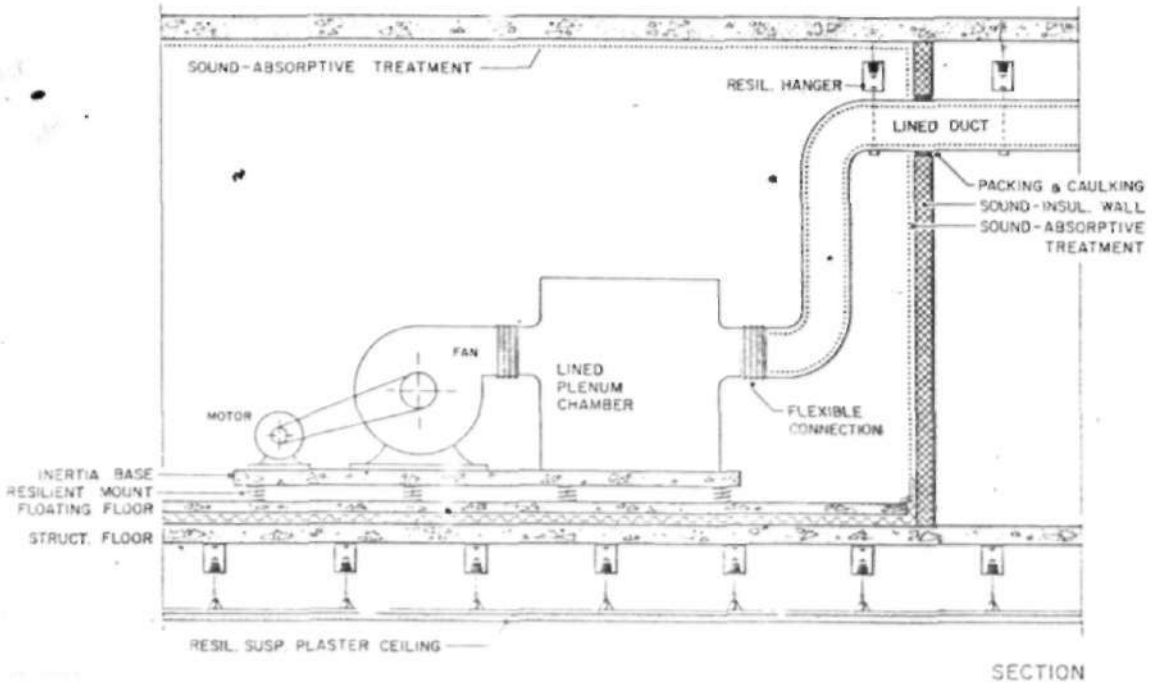


FIGURE 3·25 SOUND INSULATION CONSTRUCTION FOR A MACHINERY ROOM.

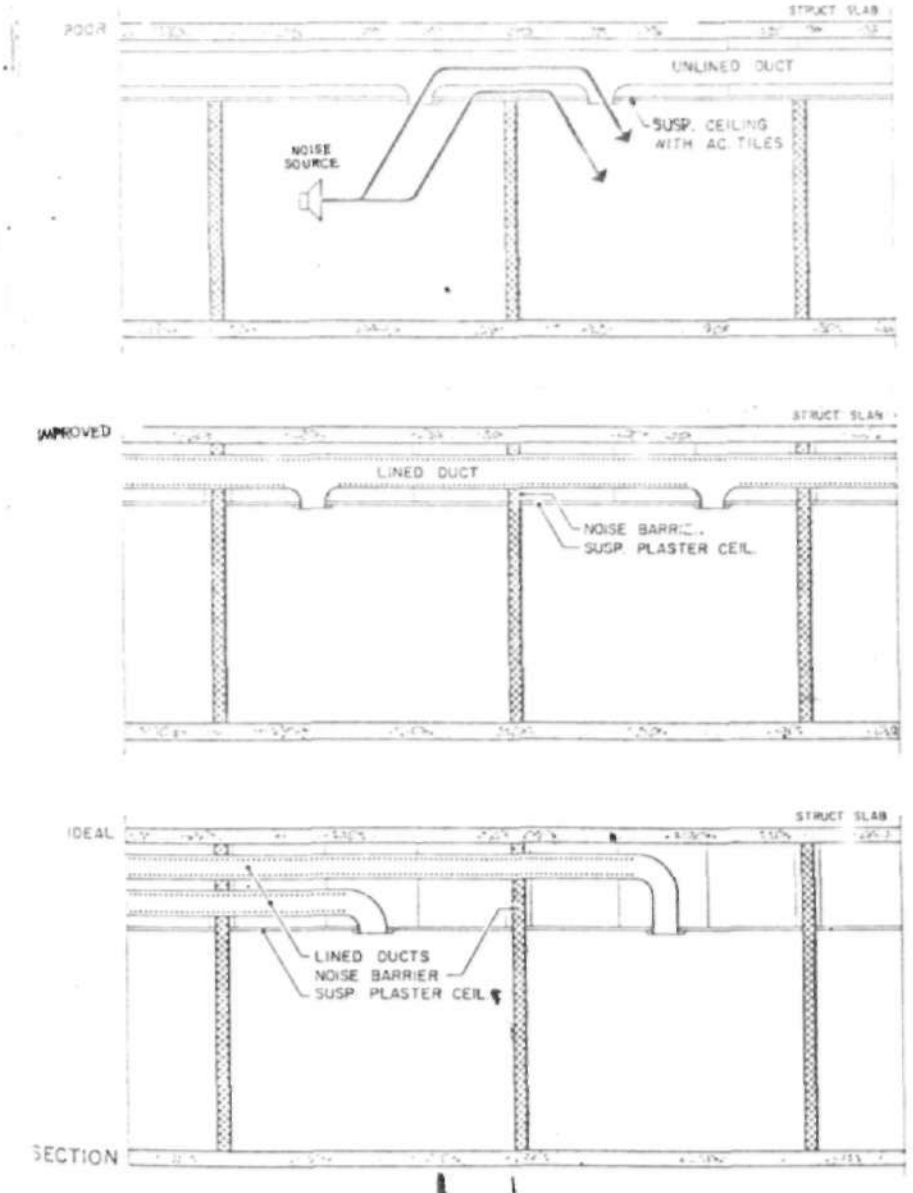


FIGURE 3·26 METHODS OF INSTALLING DUCTS INTO ROOMS.

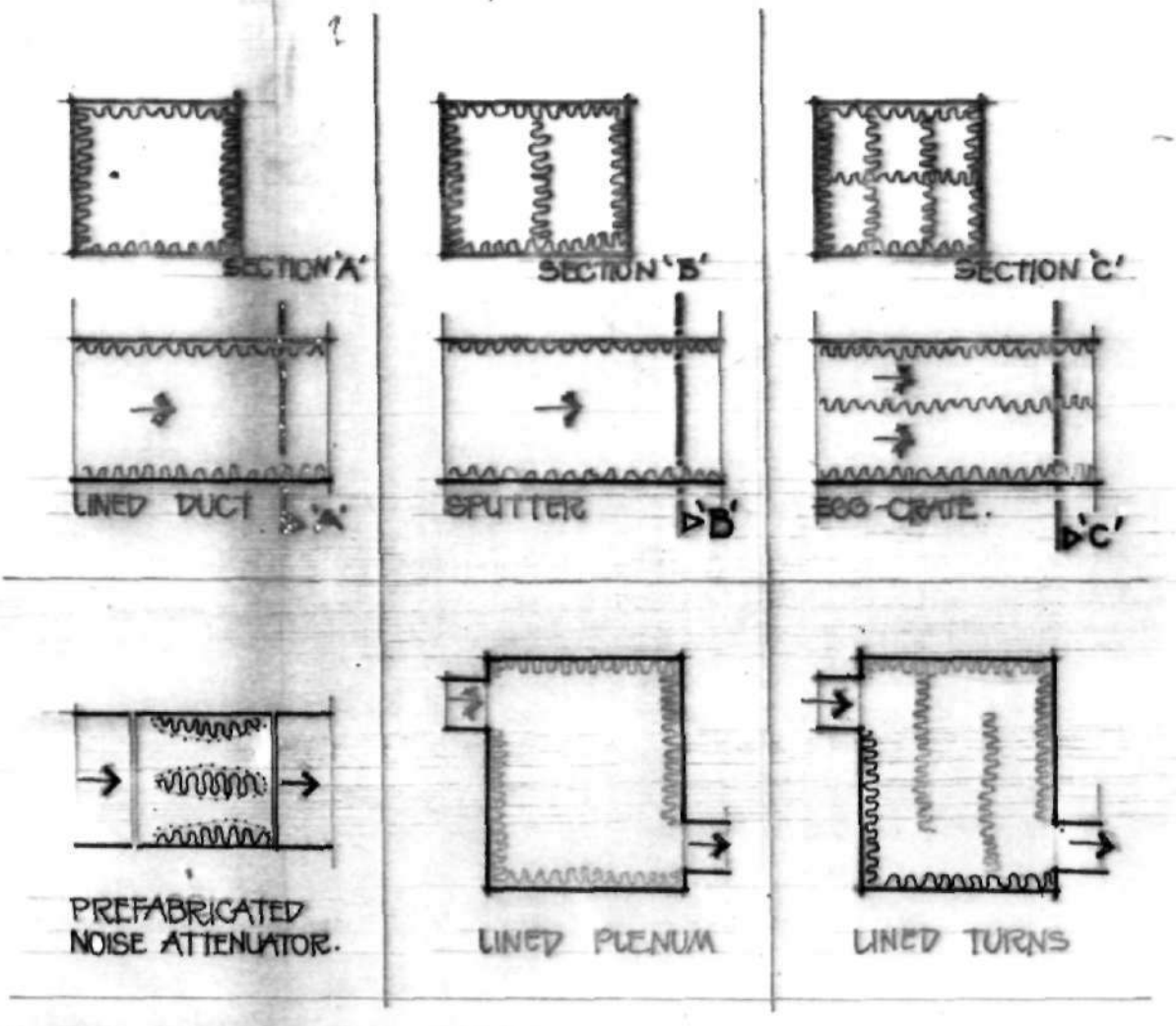


FIGURE 3·26.A. SOUND ABSORPTIVE LINING IN DUCTWORK.

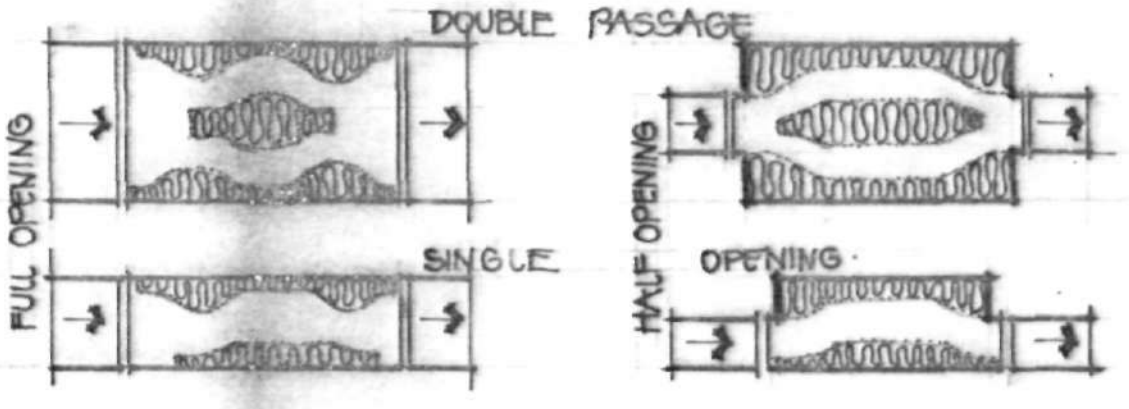


FIGURE 3·27 SILENCERS USED IN SOUND INSULATION.

3.11 Vibration

Vibration is the movement of a structure brought about by some alternating force. This can be transmitted to distant parts of the structure and reradiated from the surface of the structure.

Vibration may, damage a building, annoy the occupants, interfere with work and harm precision instruments, and it may cause noise if the rate of vibration is within the audio frequency range.

Vibration isolation could be achieved by either the two systems mentioned below, active or passive isolation. In active isolation the transmission of vibrations from unbalanced forces from a machine to its foundation is prevented while in passive isolation the vibrations from the substructure is prevented from reaching the machine mounted on it, this is the system used in the installation of precision instruments.

The sources of vibration has a driving frequency, while the isolator has its own resonant frequency. The degree of insulation to be achieved depends on the ratio of the driving frequency and the natural frequency. It should be noted that no isolation will be achieved if the resonant frequency is greater that the driving frequency, and the situation will be worsen if the frequencies are equal or near equal.

The vibration isolator is either of the following.

(i) A resilient floor mount (steel spring, air springs, rubber, cork, felt, neoprene, precompressed fibrous glass and so on).

(ii) Resilient ceiling hanger (spring, neoprene and so on)

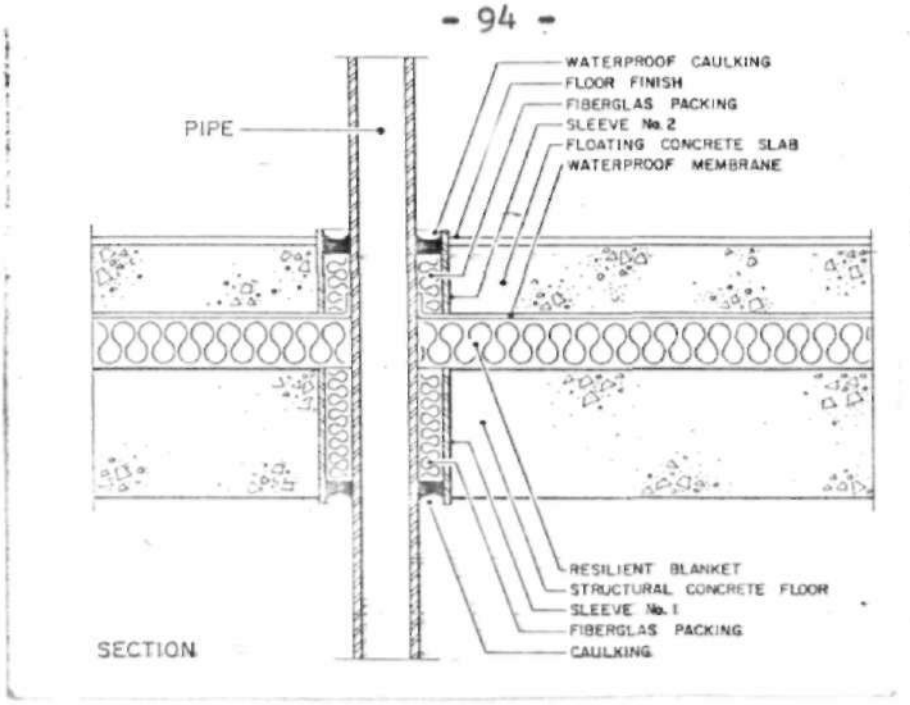


FIGURE 3·28 SOUND INSULATION AGAINST NOISE FROM PIPES.

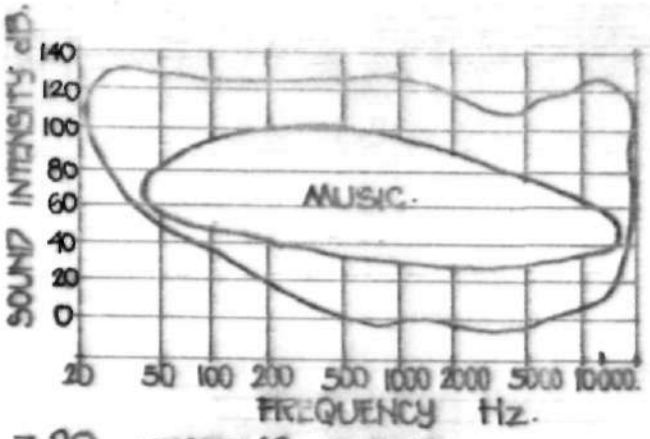


FIGURE 3·29 HEARING CURVE.

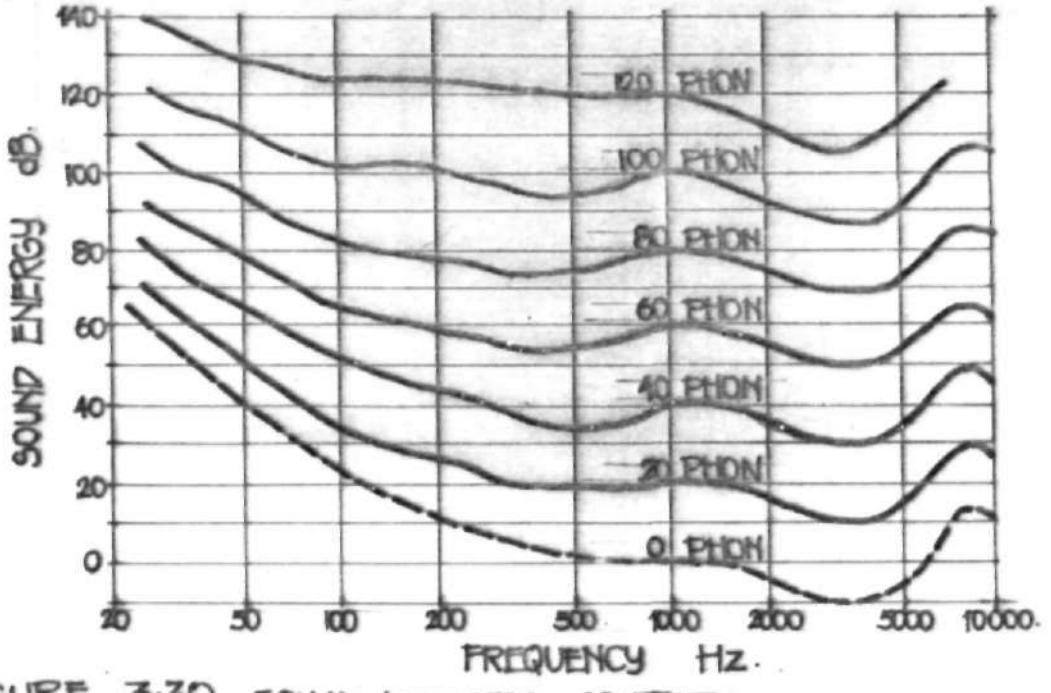


FIGURE 3·30 EQUAL LOUDNESS CONTOURS.

(iii) Resilient wall isolator (isolation clip, resilient wall brace).

(iv) Flexible hose (stainless steel, reinforced rubber, molded teflon, flexible butyl and so on).

3.12 Noise Criteria

These are the limits set to the acceptable levels of intruding noise for various occupancies.

3.12.1 Damage to Hearing

The ear is sensitive to sounds within the audio frequency range of $20H_z$ to $20{,}000H_z$. The normal hearing curve is between $25H_z$ and $18{,}000H_z$ for frequencies and between 0dB and 130dB for sound intensity (figure 3.29). Above this range the ear is subjected to damage, that is when the sound pressure level is upto the threshold of pain (figure 3.30). It should be noted that this level of noise do not normally occur in buildings, but levels high enough to cause temporary or permanent deafness do occur in industries.

Various noise criteria have been established so as not to expose people to the danger of the commulative effect of loud noise. One of these criteria is the Walsh-Healey public contracts Acts (revised in 1969) of the United States, established the maximum level of industrial noise that employees could be subjected (figure 3.31).

The dose (D) can be calculated using this formula.

$$D = \frac{C1}{T1} + \frac{C2}{T2} + \frac{C3}{T3} + \frac{Cn}{Tn}$$

Where C1..Cn = expected exposure time in hours

T1...Tn = Permissible exposure time in a day in hours.

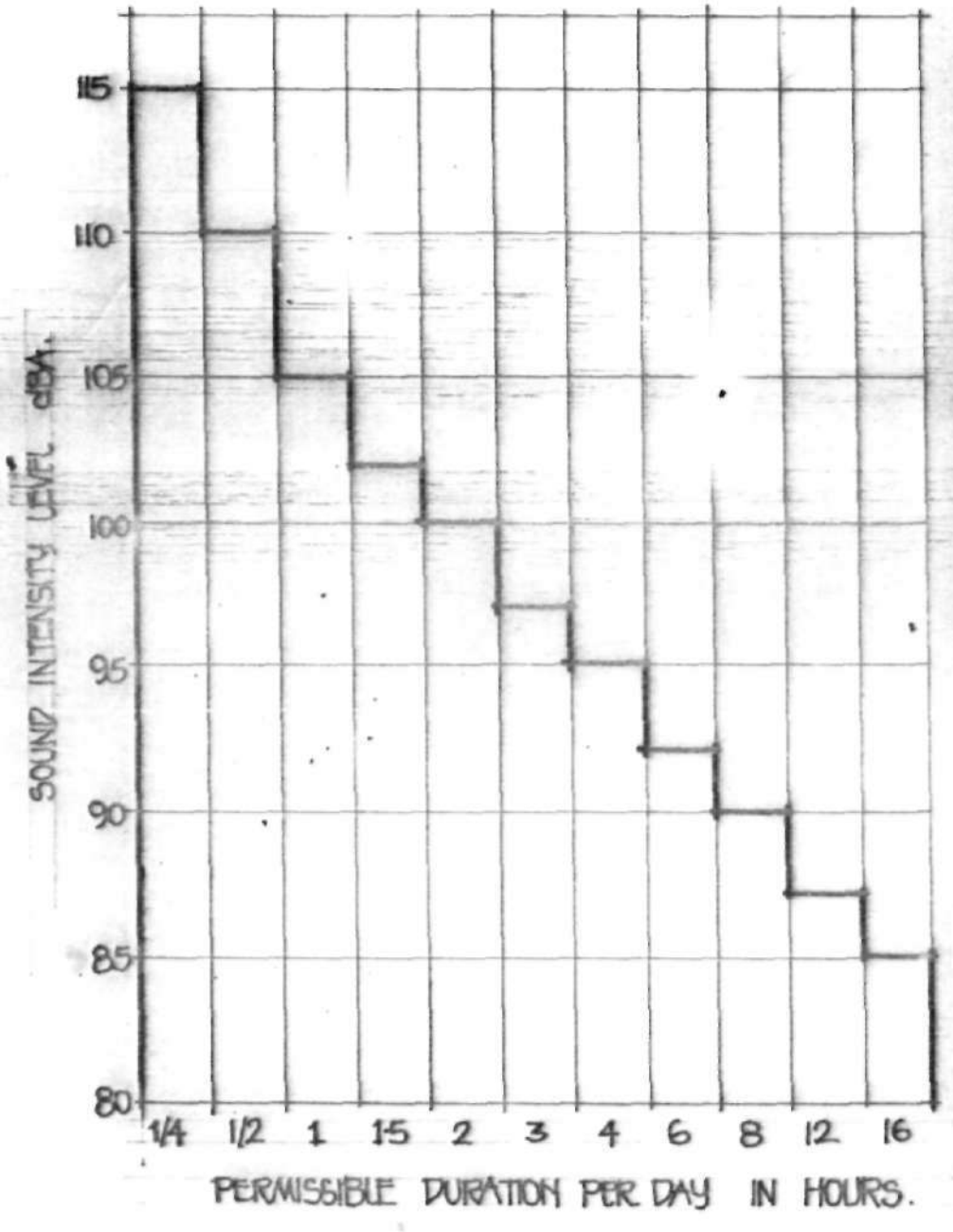


FIGURE 3·31 PERMISSIBLE LEVELS OF INDUSTRIAL NOISE.

3.12.2 Maximum Permissible Background - Noise Levels

These are the permissible levels of background noise that will not interfere with an activity. They are normally specified in terms of noise criterion (NC) curves, illustrated in figure 3.32.

Table 3.1 gives the value of the recommended background noise for specific activities. The noise criterion is similar to the noise rating curves which was established by the international organisation for standardization, used mostly in European practice. It is noteworthy to know that the intruding noise should be meaningless, but if it carries an information then other criteria apply.

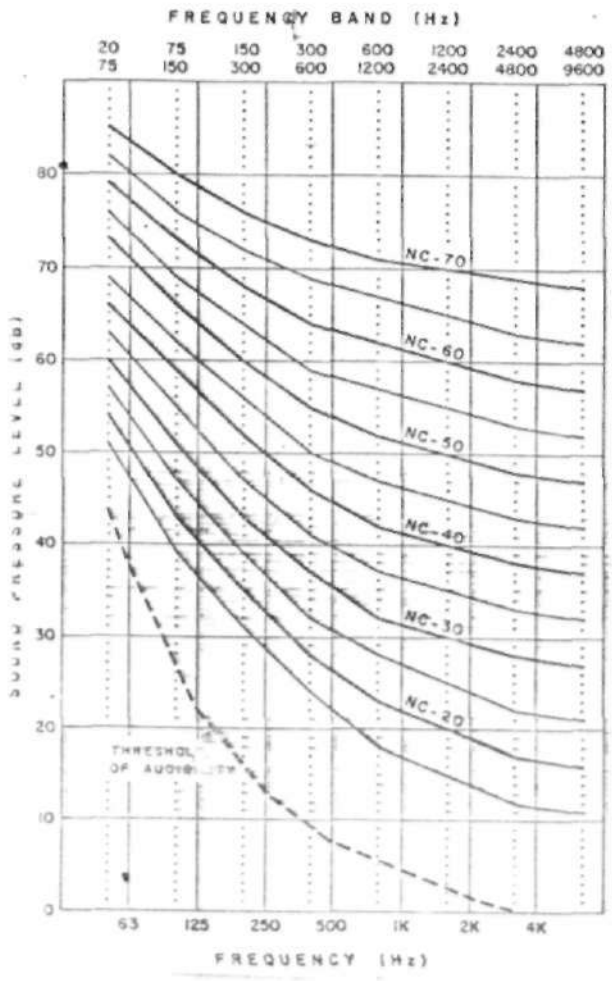


FIGURE 3·32 NOISE CRITERION CURVE.

Type of room	NC number
Concert hall	15–20
Radio or recording studio	15–20
Opera house	20
Legitimate theater	20–25
Music room	20–25
Television studio	20–25
Executive office	20–30
Classroom or lecture hall	25
Motion-picture studio	25
Conference room	25–30
Church or synagogue	25–30
Courtroom	25–30
Assembly hall or school auditorium	25–35
Home (sleeping areas)	25–35
Hotel or motel	25–35
Motion-picture theater	30
Hospital	30
Semiprivate office	30–35
Library	30–35
Business office	35–45
Restaurant	35–50
Drafting room	40–45
Gymnasium	45–50
Typing or accounting office	45–60
Coliseum	50

TABLE 3·1 PERMISSIBLE BACKGROUND NOISE FOR VARIOUS ACTIVITIES.

CHAPTER FOUR

CASE STUDIES

4.1 Criteria for Choosing Case Studies

The following points were taken into consideration before embarking on the case studies.

(i) Type of construction used.

(ii) Zoning of activities on the whole layout.

(iii) Accessibility to the public.

(iv) Source of power and water.

(v) Number of recording studios in the industry and the methods of control employed.

(vi) Type of insulators and absorbers employed in the recording studios.

(vii) Expansion possibilities on site.

(viii) Parking facilities available on site.

(ix) Welfare service on site.

4.2 EMI Nigeria Limited

It is a company that specialises in the recording of Music and the production of prerecorded cassettes.

4.2.1 Site/Zoning

The site is found along Oregun road in the Ikeja area of Lagos, and is about 1400m^2 out of which 396m^2 is built up. There is an attempt at zoning of the activities on the site. The recording studio was placed far from the road, offices were not placed on the studios. The zoning was destroyed by attaching the central air conditioning plant to the wall near the recording studios.

CASE STUDY.

EMI NIG. LTD. OREGUN ROAD, LAGOS.

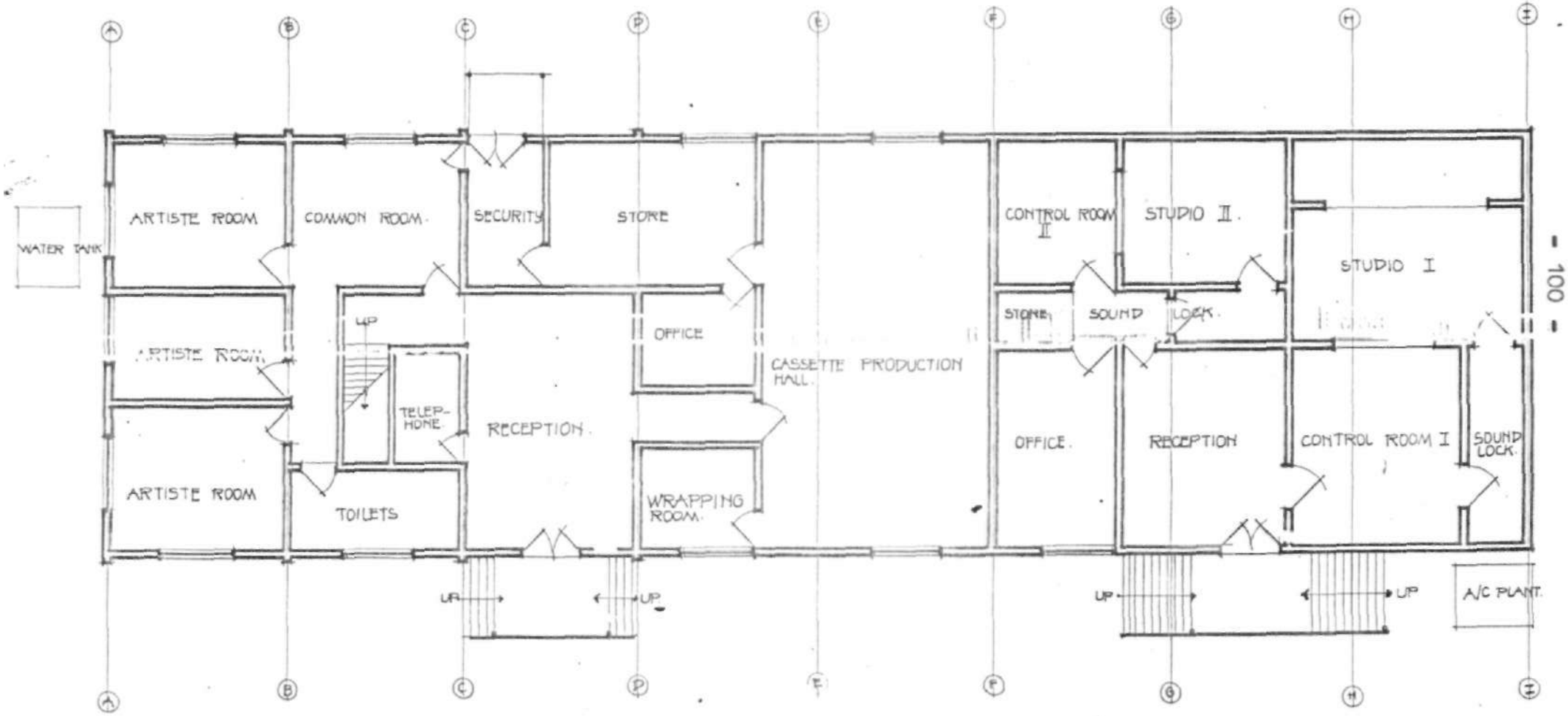


FIGURE 4·1 EMI NIGERIA LIMITED.

4.2.2 Construction Methods

The building is on two floors, and the structural system used is a beam-column construction roofed with corrugated metal sheets. The walls are of sandcrete blocks 230mm thick and plastered both internally and externally. The building needs renovation, due to the fact that cracks are very visible in some parts of the building. Repainting of the whole building is needed.

4.2.3 Accessibility

The site is accessible from Gregun road. Before going into the company a Security check is performed on you.

4.2.4 Power and Water Supply

Electricity is supplied to the company by the National Electric Power Authority but the company has its own standby generator. There is a water tank on the site. Overflow of water from the tank has defaced the structure carrying the tank. The tank company is linked to the outside world with the telephone line, this is needed for easy communication.

4.2.5 Recording Studios

There are two recording studios in this company, an eight and a 24 track studios. The eight track studio is also being used for auditioning. Each studio is linked to a control room, and entrance to the studio is through a sound lock. There is a problem of storage area for studio equipments and the number of studios are not enough.

4.2.6 Acoustical Considerations

The walls of the recording studios and control rooms are all lined with sound absorbing materials. Variable reverberation requirements are achieved by the use of movable partitions and electromically. The ceilings of the studios are not parallel to the floor slab. Noise insulation value is upto an acceptable value.

4.2.7 Parking

There are no defined parking spaces and as such parking is not well organised.

4.2.8 Welfare Facilities on site

The number of staff are few and as such a canteen was not provided. There is a sleeping area for overnight Artistes who can not afford the high hotel bills. The toilets are very few and far from the people it is serving.

4.3 Record Manufacturers Nigeria Limited

They are concerned with only the manufacture of record discs.

4.3.1 Site/Zoning

The site is about 2450m^2 and a built up area of 950m^2. The administration area is structurally seperated from the production area, with the welfare areas further away. Zoning was done, though it was based on function.

4.3.2. Construction Method

The administration area is on a two storey building. The elevation is a skeletal rectilinear one, a beam-column construction. The production area is constructed of steel columns, supporting steel frames with a corrugated metal sheet covering.

TURALLY SEPARATE.

ATERIALS.

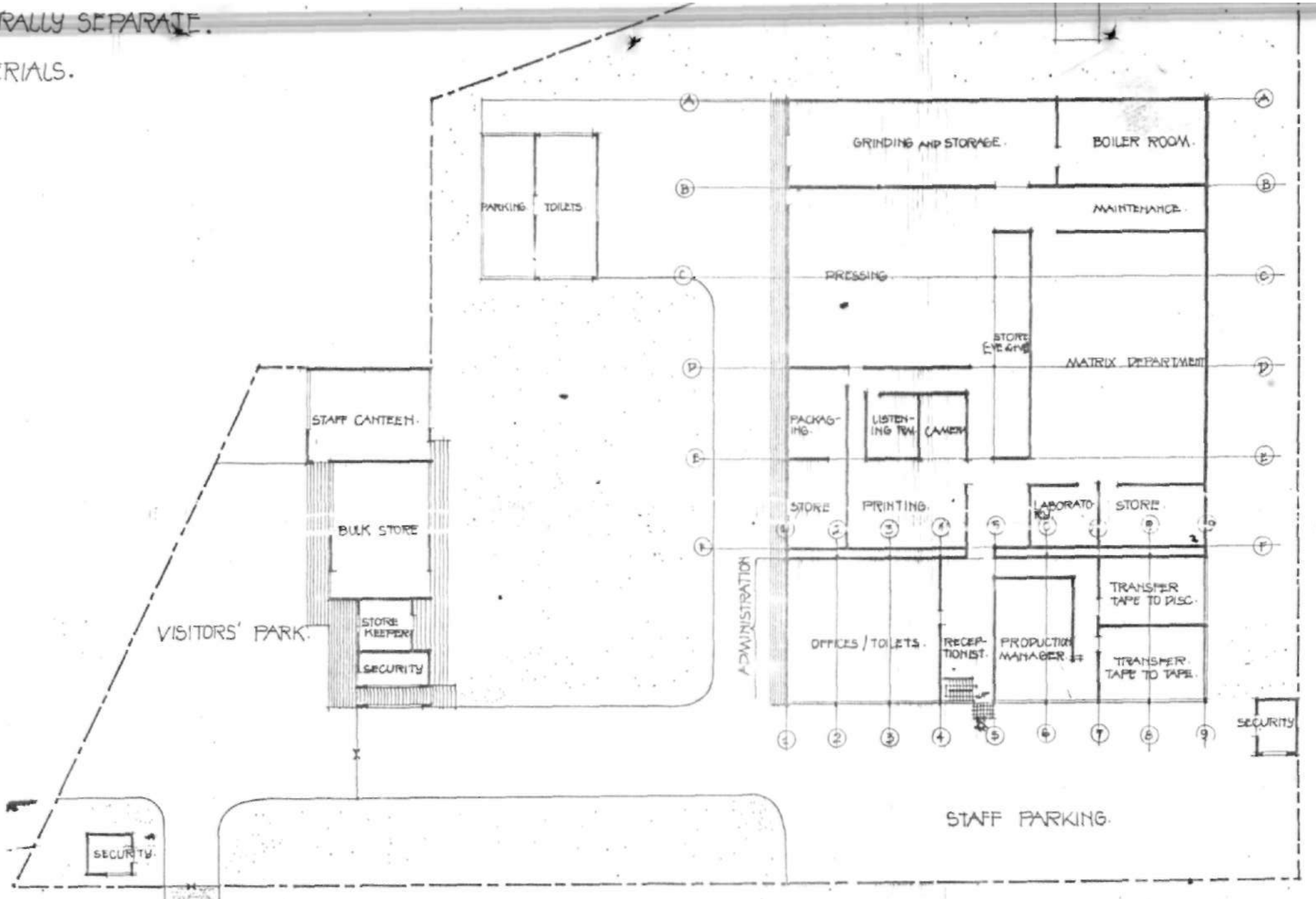


FIGURE 4.2 RECORD MANUFACTURERS NIGERIA LIMITED.

4.3.3 Accessibility

The site is accessible from the ACME road.

4.3.4 Power and Water Supply

The pompany has its own stand by generator, but the major electricity supplier is the National Electric Power Authority. There is a large water storage tank on the site, to cater for the large quantity of water needed for the production of record discs.

4.3.5 Parking

There is a seperate parking for the staff and visitors. The visitors are restricted to the entrance area of the industry.

4.3.6 Welfare facilities on site

A staff canteen is provided for the employees. Toilets and changing rooms are also provided on the site.

4.3.7 Inspection areas.

The room used for the visual control of records is not well lighted, while the listening room is not adequate. There is no mother control room in the industry.

4.3.8 Matrix department

The area near the electrolytic bath is waterlogged. Methods of draining water should have been incorporated in the design.

4.3.9 Ventilation and Lighting

The design was done without considering the possibilities of using natural ventilation or lighting, this is to say that the design is insensitive to environment.

4.4 Australian Broadcasting Corporation (ABC)

Radio Accommodation in Hobart, Tasmania

4.4.1 Site/Zoning.

Zoning of functions was done, the sub station is placed away from the acoustically sensitive rooms. The Auditorium rooms are also placed away from the recording rooms. Offices are on the first floor while the 2nd floor is occupied by the central air conditioning plant.

4.4.2 Construction Method

The structural elements are the beams and columns. Most of the partitions are of timber construction.

4.4.3 Accessibility

The site is accessible to the public. There are seperate staff and visitors entrances.

4.4.4. Power Supply and Telephone

The radio station have its own sub station. Telephone as a means of communication is important in a radio station and as such this station have this link.

4.4.5 Recording Studios

All the recording studios are linked to a control room. Entrance into them is through a sound lock. Some of the recording studios are used as control rooms also. There is a large production studio for accommodating a large audience. The noise in the music studios is 20.

4.4.6 Acoustical Considerations

All the floors in the building are carpetted, This is done so as to insulate them against impact noise. The ceilings are of acoustic tiles. Walls of acoustically sensitive rooms

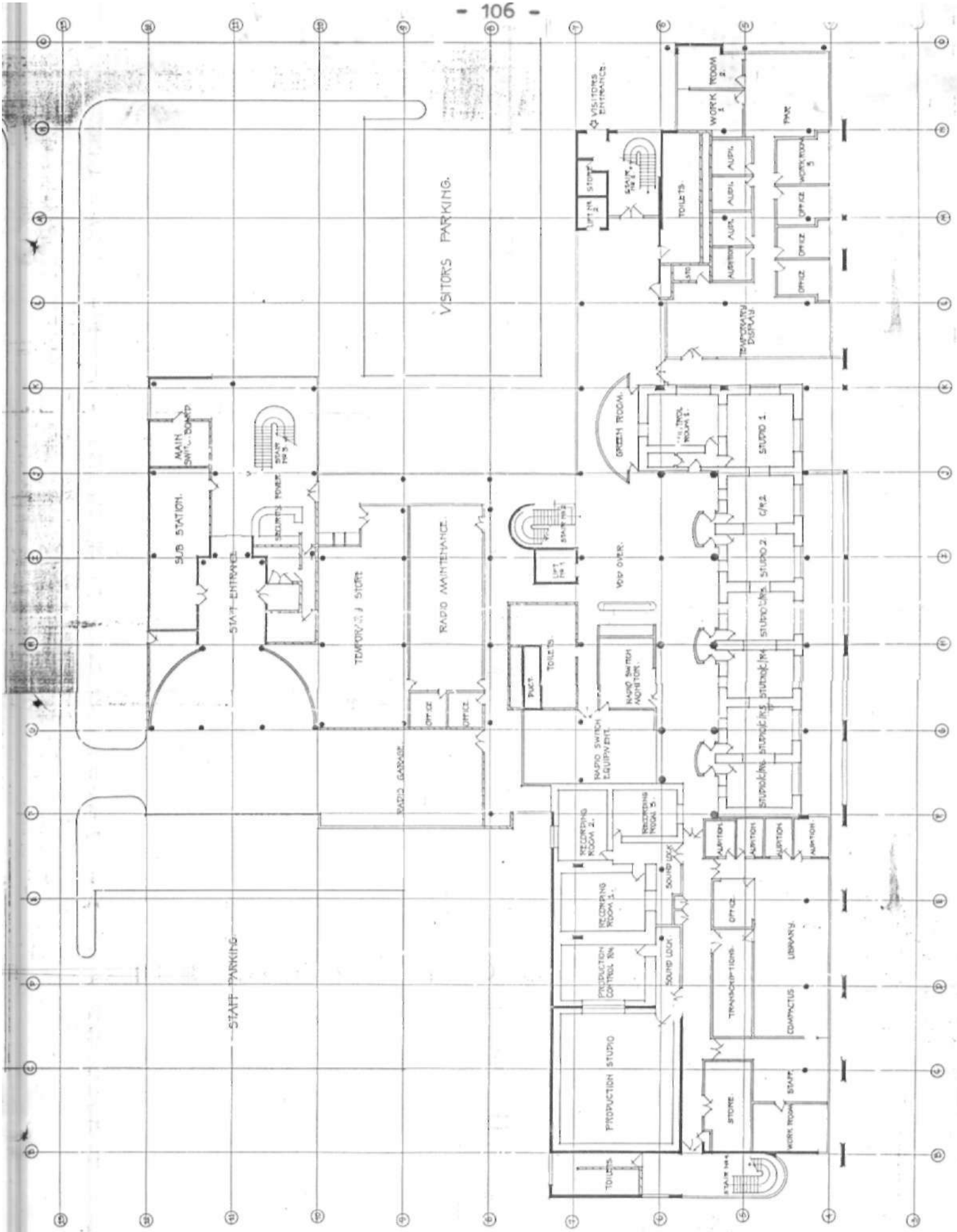


FIGURE 4·3 AUSTRALIAN BROADCASTING CORPORATION.

were finished with sound absorption materials on both sides. The doors have high acoustical value, their perimeter is sealed with sound absorption materials. There are windows to the outside of the studio, and they are of sound insulating glass. The advantage gained in saving lighting cost is lost in sound insulating the windows. The partitions are of timber construction, this is why the thickness is more so as to give the required sound insulation needed.

There are offices on the recording studios this has increased the cost of building due to insulation costs, This was necessary due to the fact that the site allocated for this purpose was limited.

4.4.7 Parking

Staff parking is seperated from the visitors parking this is good due to the fact that a large number of people visit the station for various programmes, and as such traffic if not controlled will be confusing.

4.4.8 Welfare facilities

The toilets are placed on the remote side of the building and have a brick wall around them. There is a staff canteen on the first floor of the building away from the recording studios.

4.4.9 Others

The positioning of walls and some columns did not follow the grid pattern of the design, this is an uneconomical way to design. Ambient noise is increased in rooms where the recording instruments and session take place in the same place.

4.5 RCA LIMITED, AUSTRALIA

4.5.1 Site/Zoning

The buildings cover 3260m^2 of the site, but the gross floor area is 3500m^2 of which the production and storage comprises 2200m^2, administration and service offices 940m^2, technical services 360m^2. The administrative and production wings are structurally seperate.

4.5.2 Construction Method

The walls are of sandcrete blocks. The roof is of a hollow core slab suspended from the column. This material makes the roof lighter than it would have been, if the it were the normal concrete slab that is in use.

4.5.3 Accessibility

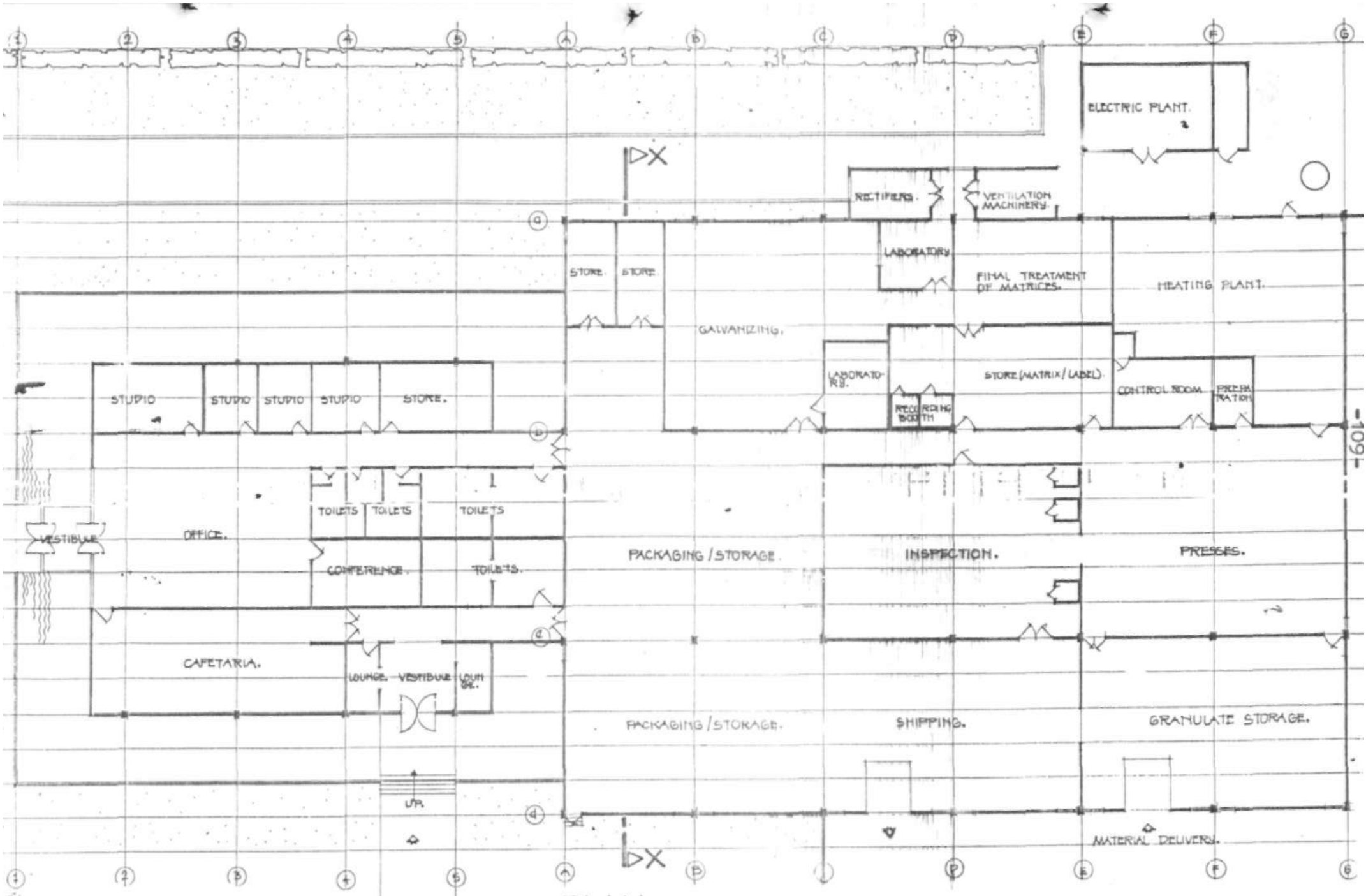
The entrance to the site leads one to the administration area, from here the other sections could be reached. The raw materials and finished goods are shipped in and out through the side bounded by the sea respectively.

4.5.4 Power and Water Supply

Being a large industry it has its own electric plant. There is a water storage tank, which is necessary for the running of the industry.

4.5.5 Recording studios

There are four recording studios and two recording booths. Each studio has its own reverberation characteristics to suit different acoustical requirements. There is a single control room. Control is through the use of audio-visual aids. This is good because it eliminates the cost to be incurred in building control rooms for each studio.



PLAN.

FIGURE 4-4 RCA LIMITED AUSTRALIA.

The studio are accessible from an office area, this is not good because of the need for an expensive sound insulating door.

4.5.6 Acoustical Considerations

The walls of the recording studios are lined with sound absortive materials. There is the avoidance of parallerism between the walls of the biggest of the studio. The wall of the recording booth facing the press room is of a double thickness, this is done so as to increase its sound insulation property. There is a wet moat around the area used for recording, this restricts the distance of vehicles and people to the walls of the studios and as such save money to be used in sound insulating them.

4.5.7 Parking

Most of the parking is done in front of the Administrative building, which is a structurally seperate building from the production building.

4.5.8 Welfare facilities on site

There is a staff cafetaria for serving meals. There are toilets and changing rooms in a near central portion. The toilets are sharing a wall with the conference room, This is not good due to acoustical reasons.

4.5.9 Others

On the whole the design is aesthetically sound and is sensitive to the site conditions.

4.6 A Typical radio Studio suite of Place de Radio Canada, Montreal.

Entrance to the radio studio is through a sound lock, this helps in eliminating the use of expensive sound doors.

The walls are treated accoustically and the control window is of a sound insulating construction. A storage area is attached to the studio. See accompanying figure 4.5

4.7 Television Audience studio of Place de Radio Canada, Montreal

Most of the wall is of a multiple partition and the interior walls are treated with a sound absorption material. The studio is linked to three seperate control rooms, through control windows. The reverberation characteristics is controlled by use of movable partition (used for creating scenery) and by use of a flexible thick curtain. See the accompanying figure 4.6

4.8 Conslusions

From the studies done above certain conclusions could be reached and these are as follows.

4.8.1 Zoning

The activities should be divided into those requiring a high degree of noise insulations and those that dont. The design should locate areas that are sensitive to noise on the remotest part of the site.

4.8.2 Walls

Materials that are dense should be used because, they offer a high degree of insulation against noise, and could be used as sound reflecting surfaces within the studios.

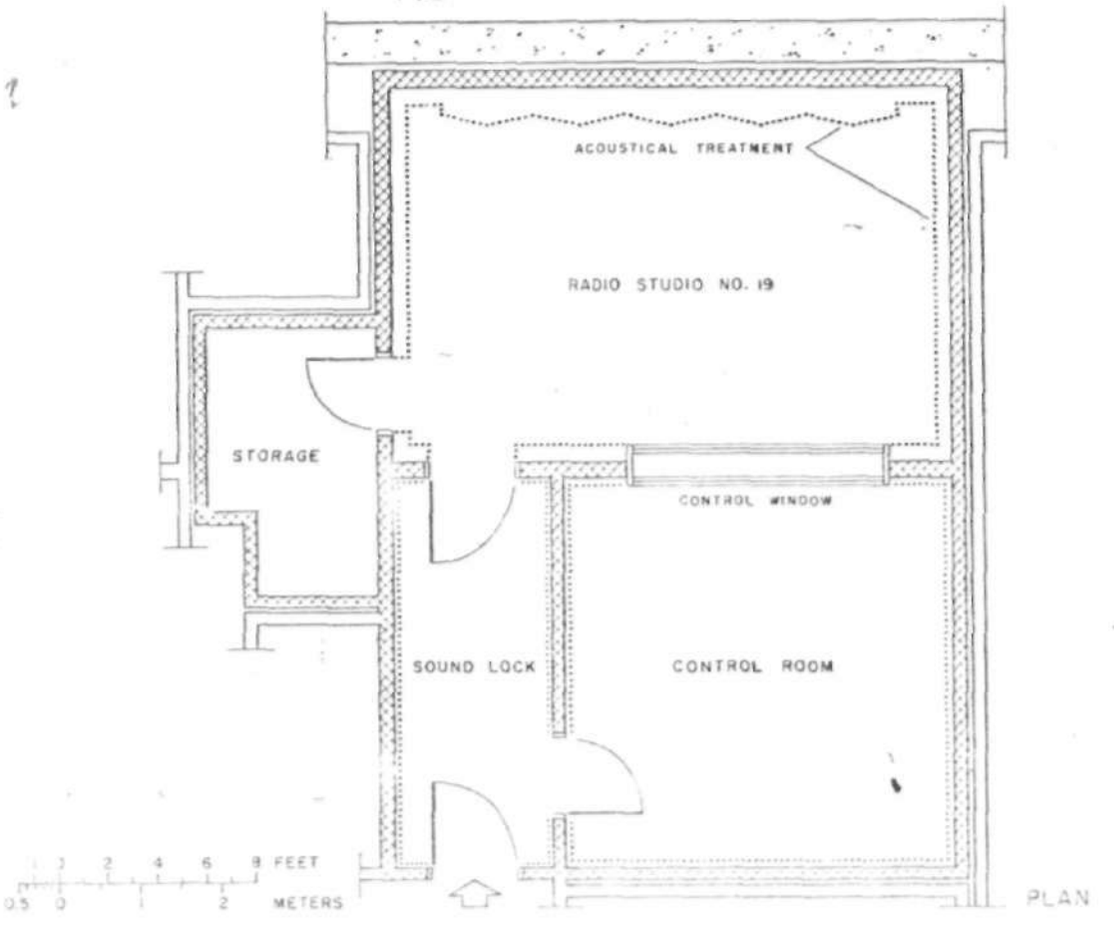


FIGURE 4.5 TYPICAL RADIO SUITE OF PLACE DÉ RADIO CANADA, MONTREA

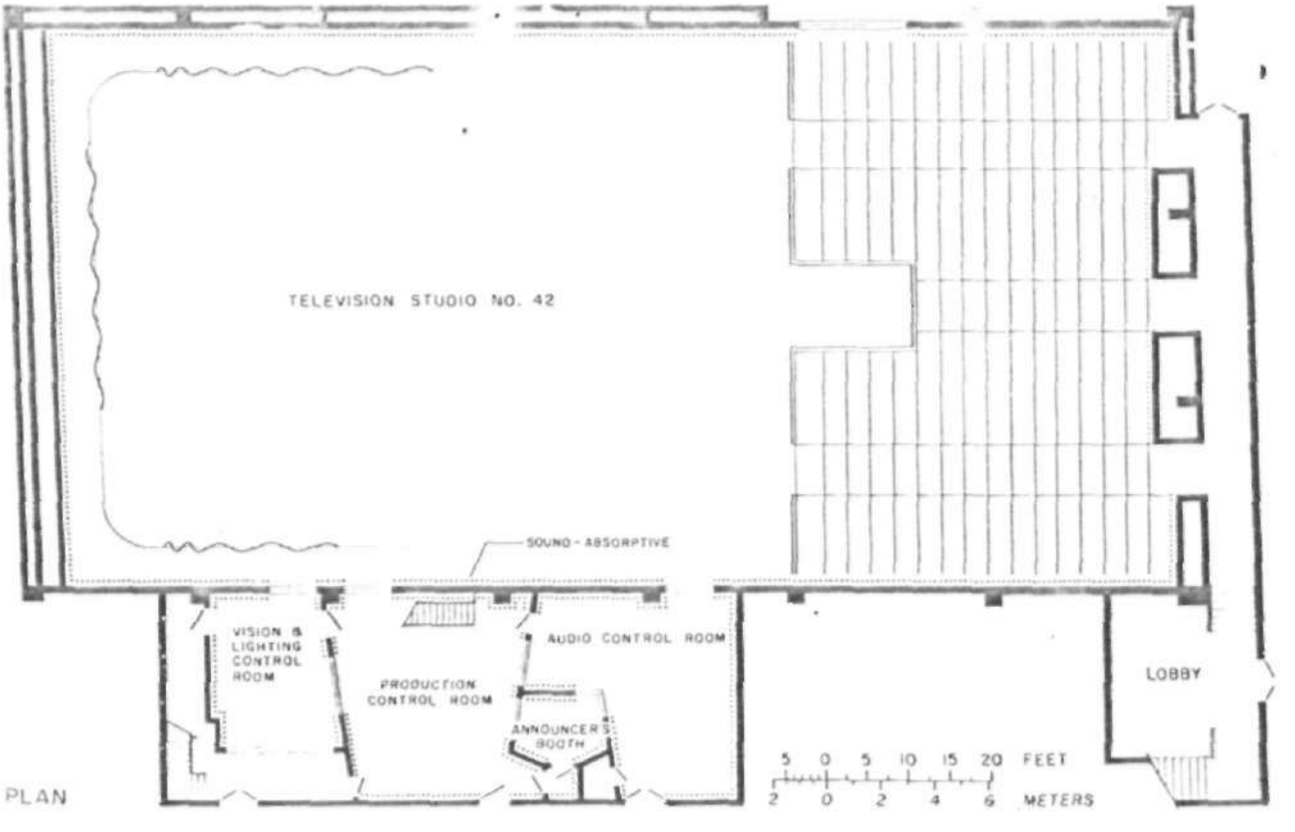


FIGURE 4.6 TELEVISION AUDIENCE STUDIO OF PLACE DE' RADIO CANADA, MONTREAL

4.8.3 Services

There should be a standard Electric generating plant on site in case of Electricity failure or inadequacy. Water storage facilities should be provided also. Telephone should be provided also. Telephone should be provided to the industry and there is the need for a central Air conditioning plant for the recording studio. Artificial lighting is also more favourable than the natural one in the recording studio.

4.8.4 Acoustical treatments

The recording studios should be treated generously with sound absorptive materials. The reverberation characteristics can be changed by designing either, different studios with differing reverberation characteristics, same studio with variable acoustical treatments, studio with movable screens to be used for different requirements or electronically if the designed studio is a "dead one".

4.8.5 Control rooms

Each studio should have its own control room, and access should be through a sound lock. In across areas with advanced technology, one control room could be used, with audio-visual aids linking all the studios to it. The control rooms should be treated with sound absorption materials.

4.8.6 The Site

It should have an expansion area, since all industries tend to expand after some years. The site should be one where acoustical insulation construction will not be needed, this is to say it should naturally provide the insulation itself.

4.8.7 Constructions

The administrative, Production and recording buildings should be structurally seperate. This will help in removing the cost of to be incurred in vibration isolation. Inexpensive constructional solutions should be provided , but economical ones are better. There should be a strong functional link between the recording studios and the production area. The recording studios can be termed as an auxilliary production area.

4.8.7 Security

A workable Security network should be incorporated in the design. It could be from the entrance, where Security checks could be performed or within the industry with Security posts designed.

4.8.7 Welfare Services

A resraurant and toilet facilities should be provided for the employees.

CHAPTER FIVE

5.0 SITE.

5.1 Location (General)

The site is in Kaduna. Kaduna is located on latitude 10°30'N and longitude 7°30'E. Kaduna town was chosen for locating the music industry because of the following reasons:

(i) It is slightly north of the centre of gravity of the northern Nigeria, and as such the music industry could serve the region efficiently.

(ii) There is a good communication network between Kaduna and other major towns in the country. This communication network includes the, telephones, air, road and railway (figure 5.1)

(iii) Isolated from existing cities, thus free from local political and religious complications. This is needed for music production which is a reflection of the types of society.

(iv) Availability of Services

The town is linked with the National Electricity supply grid, this is needed for the running of the industry.

The town is adequately supplied with water.

(v) Industrial nature of the town. Kaduna is more of an industrial town than a commercial one. There are advantages gained in siting an industry in an industrial town, and these advantages are meant to be exploited by this proposal.

5.1.1 Site Location

The site is located in the southern part of the Kaduna capital territory, called Kaduna south. Kaduna south consist of two indigenous villages, Barnawa and Kakuri. The site is in the industrial zone of Kakuri village along the Nassarawa road. Figure 5.2 illustrate the location of the site.

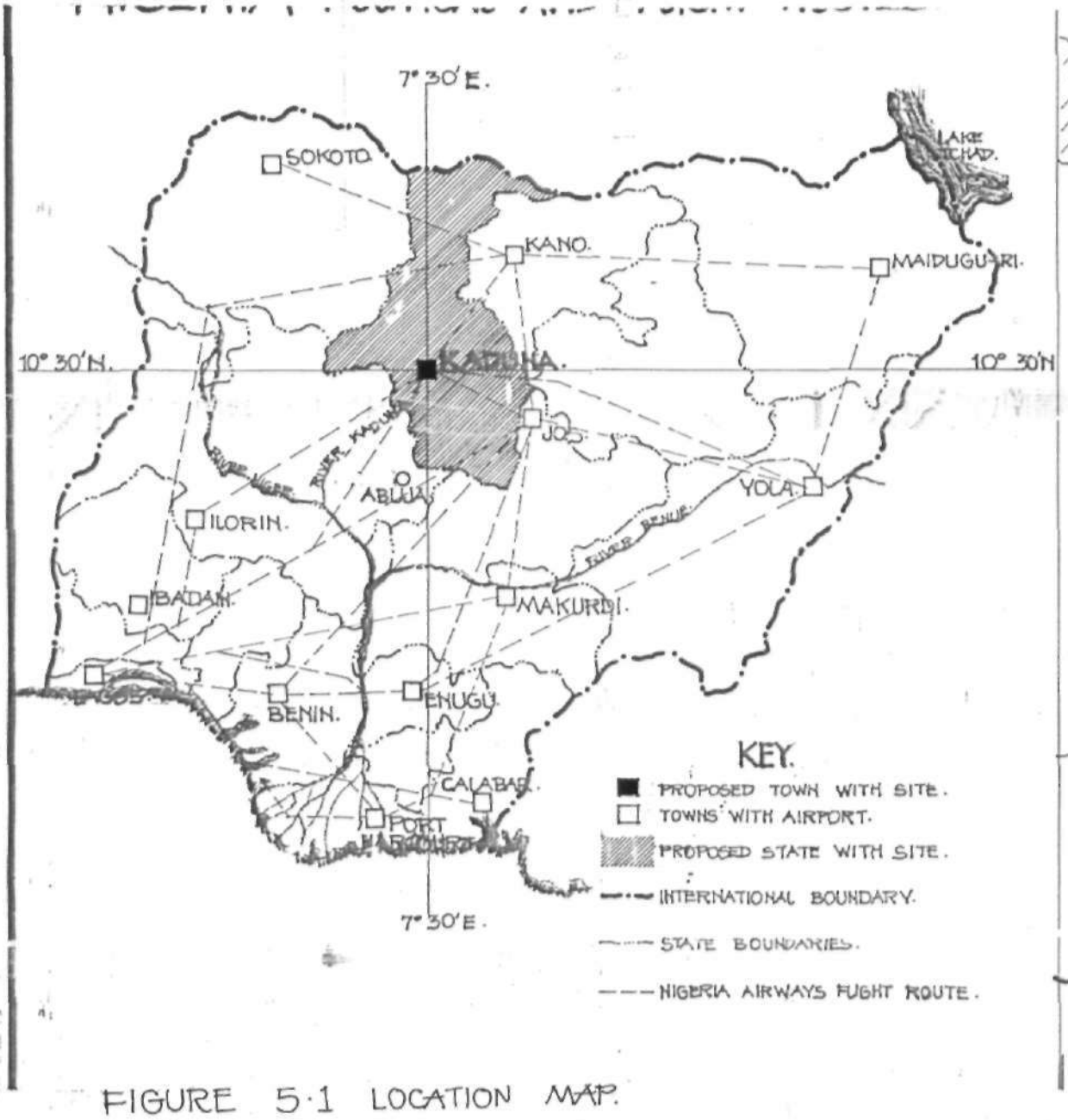


FIGURE 5·1 LOCATION MAP.

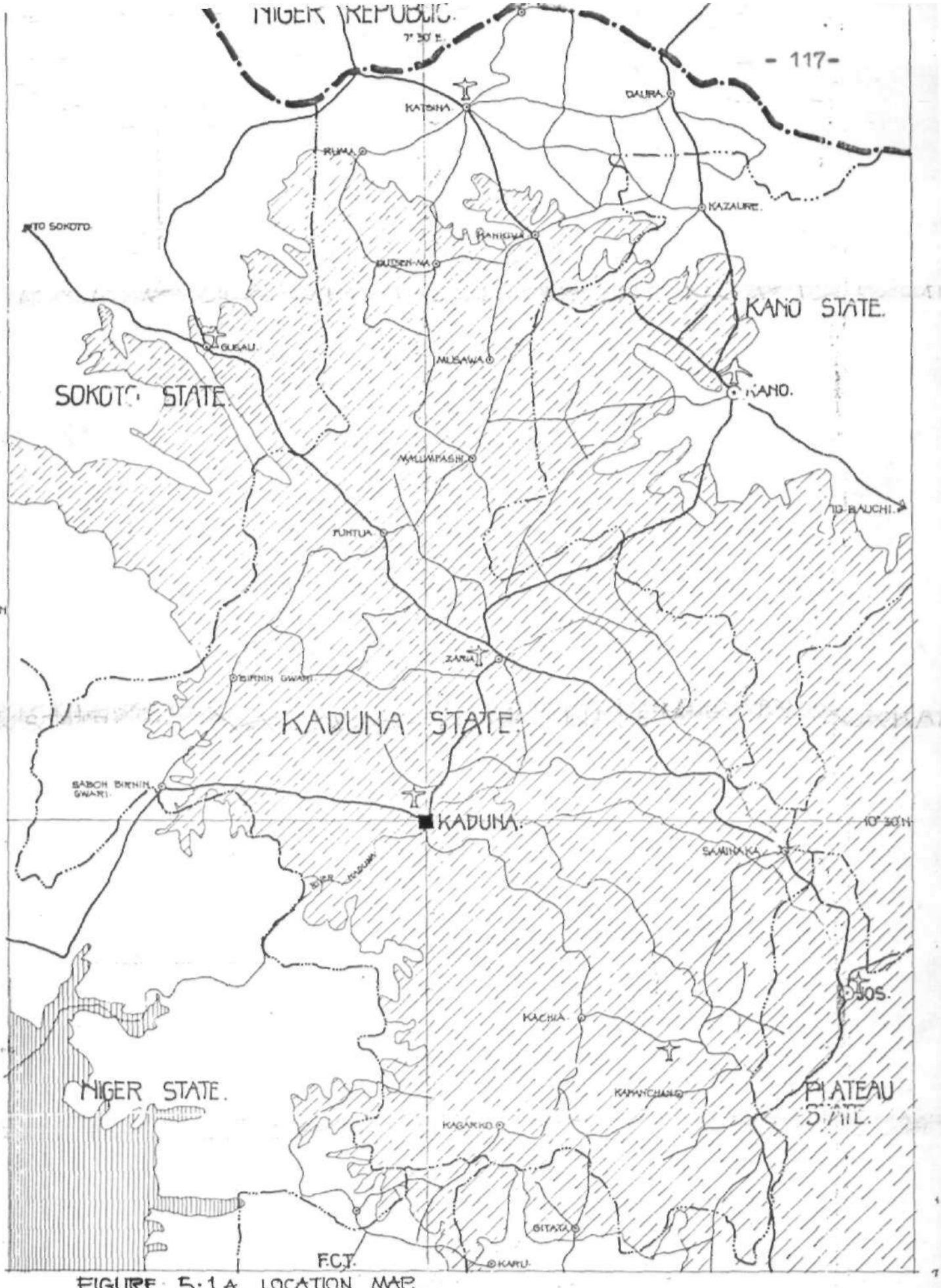


FIGURE 5·1A LOCATION MAP.

KEY.

- MAJOR TOWNS ON THE ROAD NETWORK.
- PROPOSED TOWN WITH SITE.
- INTERNATIONAL BOUNDARY.
- AIRPORT OR AIRSTRIP.
- STATE BOUNDARIES.
- AREAS BETWEEN 800 AND 1000 FT ABOVE SEA LEVEL.
- MAJOR ROAD NETWORK.
- AREAS BETWEEN 200 AND 500FT ABOVE SEA LEVEL.
- MINOR ROAD NETWORK.
- AREAS BETWEEN 0 AND 200FT ABOVE SEA LEVEL.

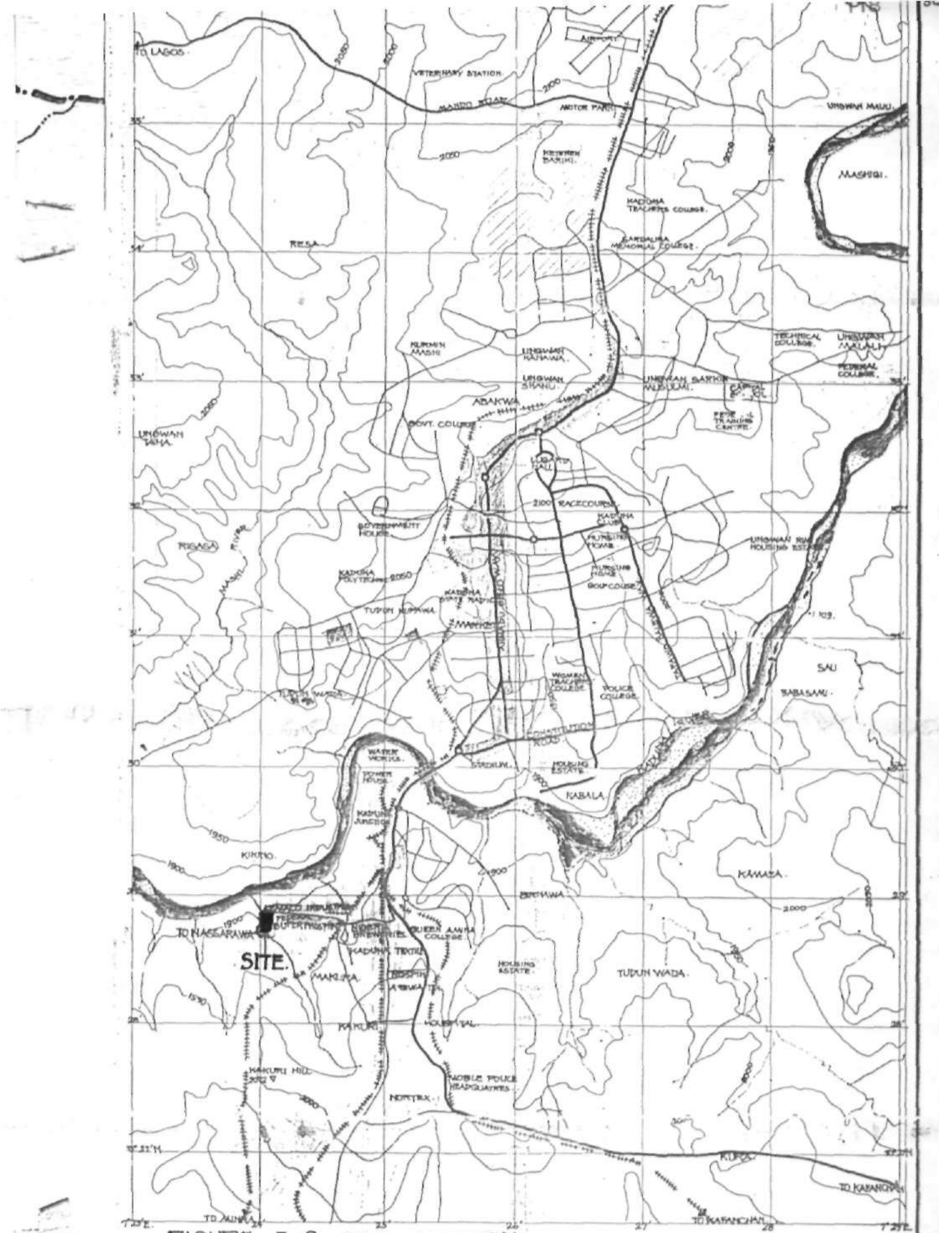


FIGURE 5·2 · SITE LOCATION.

KEY.

SCALE: 1:50,000.

- RAILWAY LINE.
- ROAD NETWORK. [MAJOR].
- SITE FOR PROJECT.
- INDUSTRIAL LAND.
- COMMERCIAL LAND.
- EDUCATIONAL BUILDINGS.
- PUBLIC BUILDINGS.
- HOUSING AREAS.
- AMENITY LAND INCLUDING OPEN SPACES.
- ROCK OUT CROP.
- RIVERS AND STREAMS.

5.2 Physical features

The most dominant physical feature in Kaduna is the River Kaduna, it is an important tributary of the River Niger. Kaduna is founded on a rolling Plateau about 2,000 feet above sea level with a monotomous open grassland rolling country broken in many places by solid granite domed inselbergs which are several hundred feet above the surrounding plain.

Broad shallow valleys dissect much of the Plateau surface with some of them being dry for most part of the year. The valleys are the only areas of extensive woodland, apart from the small forest reserves located in the west and north of the town. Continous cultivation and bush fire deforested most part of the town.

The Kaduna district is underlain by granite rocks of the basement complex which have weathered in most areas forming layers of time textured soil. There is a physical limit to development in Kaduna by land liable to flood, many small streams and numerous rock outcrops.

5.3 Morphology

The plan of Kaduna was drawn in 1913 before the beginning of the major construction works. The main residential, administrative, commercial and military areas are in the northern district of the town, while the industrial area is located in the southern district consisting of two indegenous villages.

5.4 Commerce and Industry

Kaduna town is more of an industrial than a commercial city. The industries are the largest employers of labour, notably, the textile industries, Breweries and so on.

The main commercial area is in the Kaduna North. The central business district is along the Ahmadu Bello Way, and the major thoroughfare of Sabon gari.

5.5 Soil

The soil type in Kaduna belongs to what is known as the "Zaria" soil group. It have a covering material which may be upto 4.2 metres deep. It is formed of a fine texture and tends to become waterlogged with a heavy downpour on the one hand and cracks during the dry season. This type of soil favours the growth of cotton. There is no known mineral deposits in Kaduna.

5.6 Climate and Vegetation

5.6.1 Vegetation

The vegetation in Kaduna is the type generally found in the North guinea zone. It consists of "orchard bush" a continous cover of well developed trees some may reach 9 to 15m high often dense. This suppresses the grass around it. The various activities of man has modified the vegetation now, most places in the town are either open or have park-like grassland, with only a few patches of forest reserves.

5.6.2 Temperature

There is a marked degree of fluctuation between the day and night temperatures in Kaduna. After a very hot day, the night can be very cold. The hottest months are between March and May with a peak in April. The temperature then becomes relatively stable upto October, then it falls down to form the cold months of the year (figure 5.3).

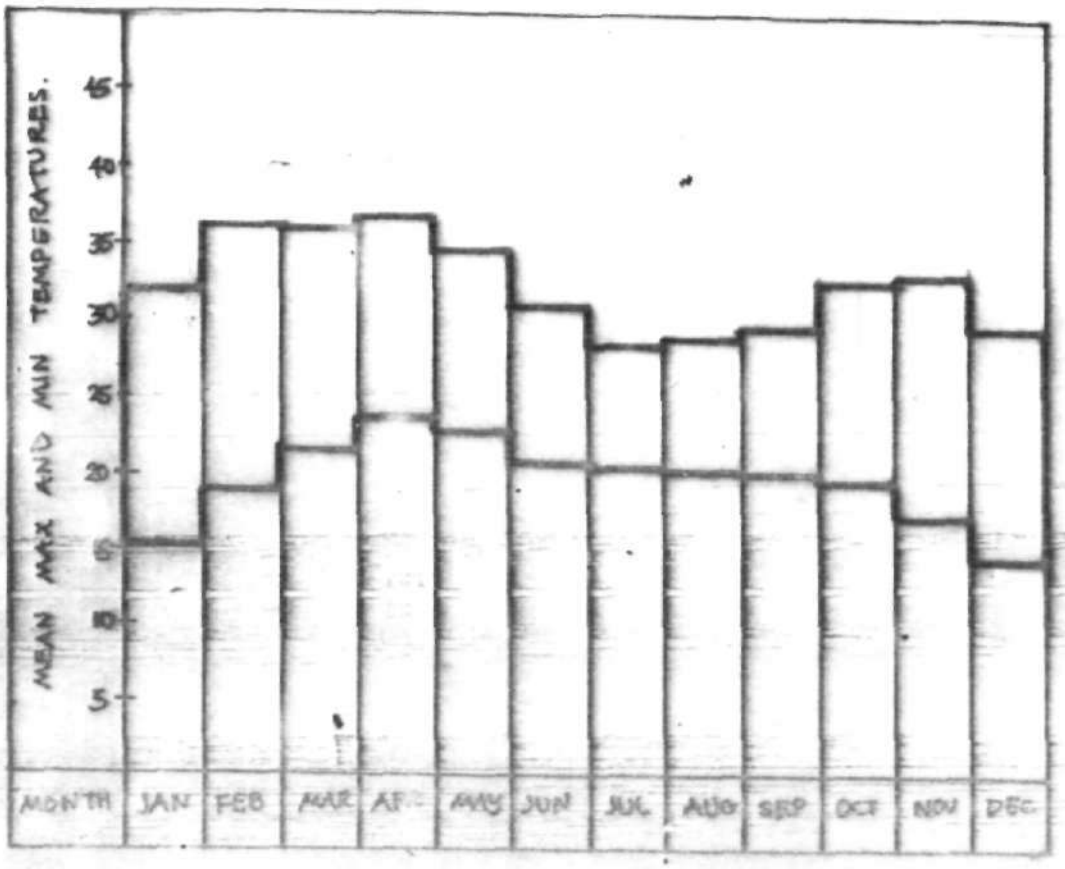


FIGURE 5.3 MEAN MONTLY TEMPERATURES.

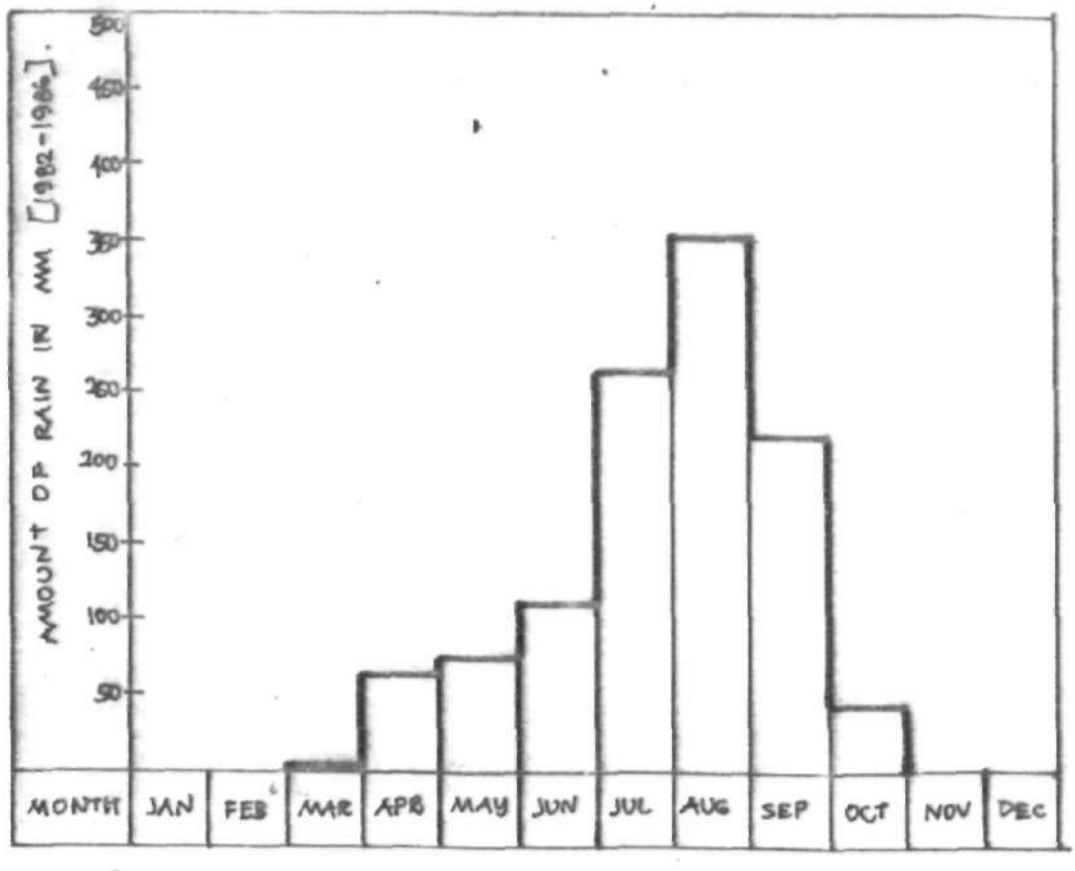


FIGURE 5.4 MEAN MONTHLY RAINFALL.

5.6.3 Rainfall

There are two distinct seasons in Kaduna, the dry season from November to March and the wet (rainy) season between April and October. The dry season brings the harmattan wind, which is ladden with dust, cold and dry, blowing from the north east. Moisture ladden wind blowing from the southwest brings along the rains. Paradoxically rainstorms which are preceded by driving wind and are usually violent with thunder and lightning comes from the North east. Figure 5.4 illustrates the mean rainfall data over a year.

5.6.4 Wind

The wind direction is not constant, it keeps changing and so does the velocity. The wind moves fastest during the peak periods of harmattan. This is to say between December and February (Figure 5.5). During rainstorms the direction of the wind is from the North east, so also is it during harmattan.

5.6.5 Relative humidity

This is a measure of the moisture content in the air, Figure 5.6 illustrates this point. The maximum humidity period is during the months with the highest rainfall value.

5.7 Criteria for Choosing site

(i) The site should be one that would be easily reached (accessibility)

(ii) It should be one where minimum sound insulation will be required.

(iii) It should be large enough to take care of expansions, most especially in the production areas.

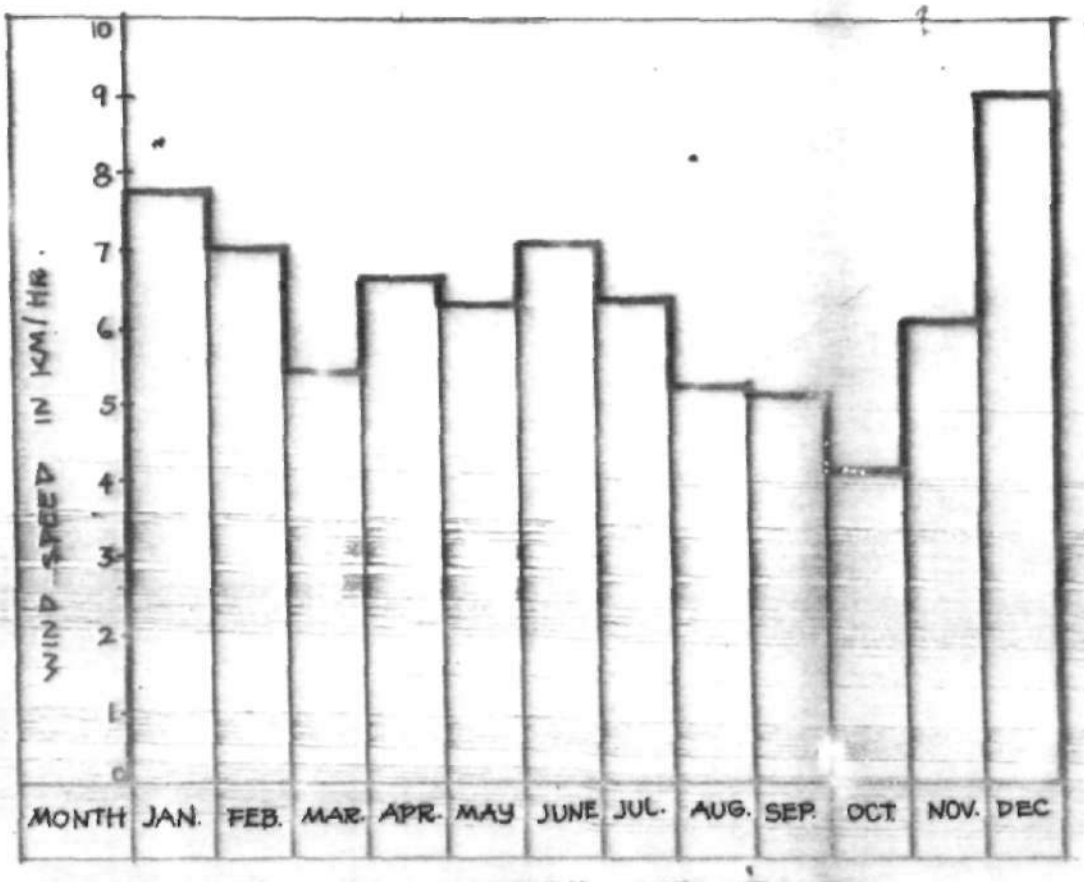


FIGURE 5·5 MEAN MONTHLY WIND VELOCITY.

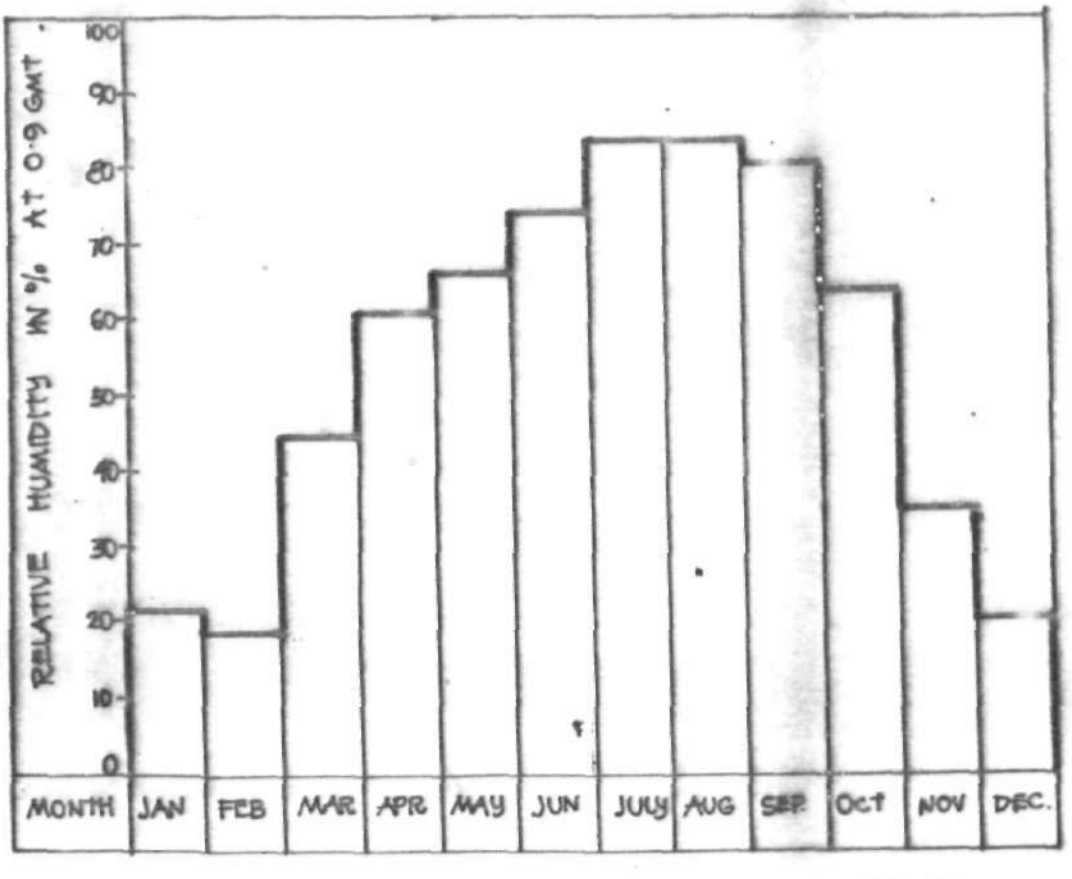


FIGURE 5·6 MEAN MONTHLY RELATIVE HUMIDITY.

(iv) Services like Electricity, water and telephones should be found near the site for easy tapping.

(v) The site should be flat or relatively flat and the ground should be strong enough to be able to carry the substructures.

(vi) Site should be one that could be easily acquired.

5.8 Site Analysis

The site is bounded on the west by the stream on the North by lemaco enterprises Limited and by Nassarawa road on the east and south. The area is about two hectares. The major source of noise near the site is from the road. There are two major footpaths on the site one links Nassarawa village to the road and the other running from North to south. The site is bare with no tree on it, although the soil is good for agriculture evidenced by the fact that it is used for this purpose now. The site slopes towards the stream with an easy grade of 1.0%. This can be exploited for drainage purposes. There is a mechanic shed and a small portion used by fish sellers on the southern part of the site. Refuse in the form of scrap metal is being dumped on the site. The untarred part of the Nassarawa road is now under construction so it would be treated as a tarred road in the design. See figure 5.7 for the complete site analysis's diagramme.

5.8.1 Site advantages

(i) The site has an easy access from the Nassarawa road, This road is not a busy road due to the fact that it leads to a squatter settlement.

(ii) There is the availability of services near the site, they include the telephone line, electricity and water.

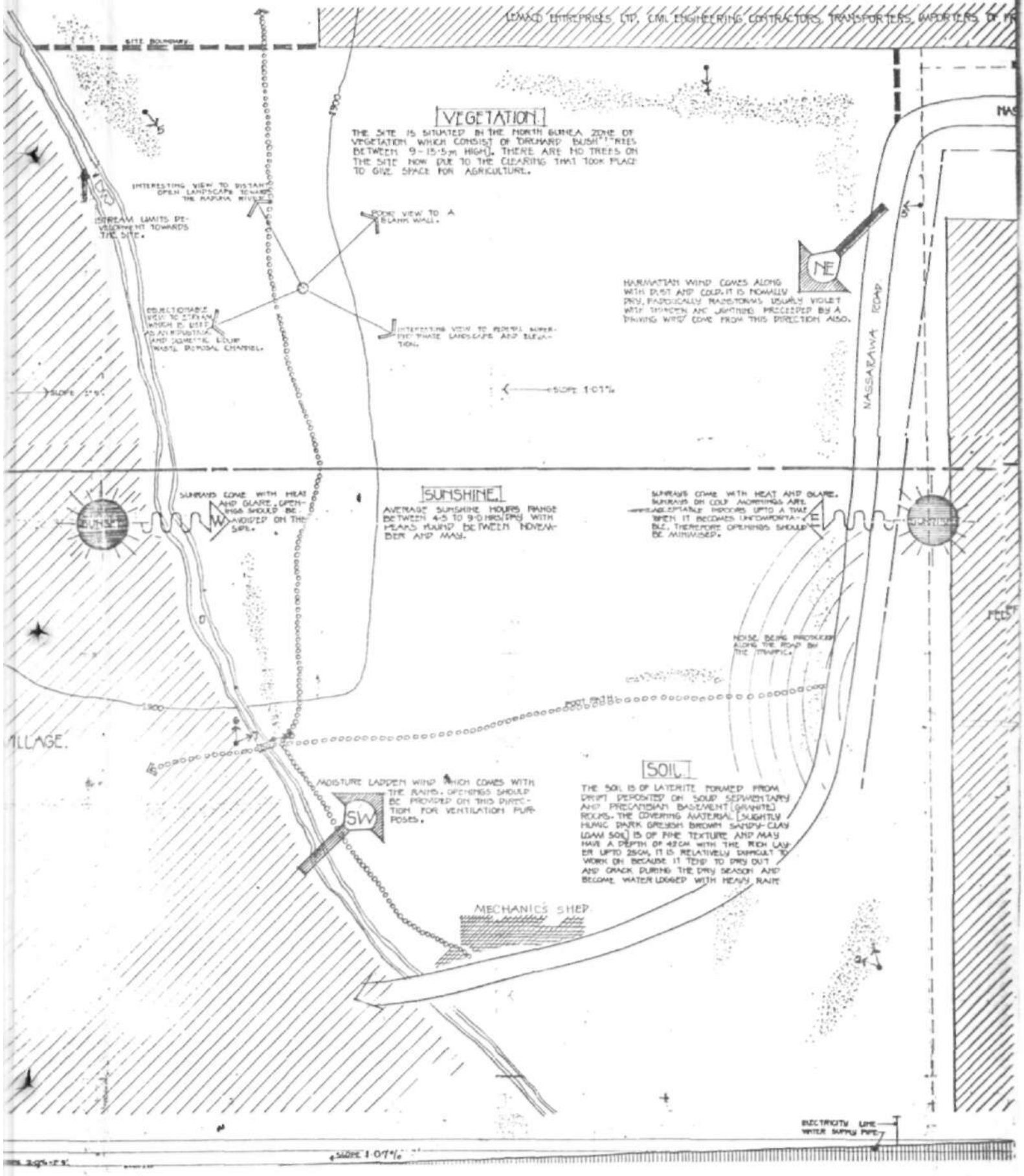


FIGURE 5·7 SITE ANALYSIS.

(iii) The site is relatively quite. The activities around it are not noisy ones.

(iv) The site slopes towards the stream. This helps in the natural drainage of the site, and could be used in designing an economical and efficient drainage for the industry.

(v) The stream naturally restricts the development of other activities towards the site. This is good in that we can be certain that the other activities to be sited around it will not intefere with the functioning of the studios.

(vi) The soil type is good and stable, and as such will not require an expensive substructure.

(vii) Bush clearing will not be required here due to the fact that there are no trees on the site.

5.8.2 Site disadvantages

(i) The lack of trees, means that all the ones that would be required have to be planted. The planting can be done before starting the construction work or they could be started at the time.

(ii) The refuse and scrap metal dumped on the site has to be cleared before construction work begins.

5.9 Conclusion

The advantages to be gained by using the site outweigh the disadvantages, therefore it would be a wise decision if the project is implemented on this site. Without saying it, the site fulfils most of the conditions needed for the choice of site for acoustically sensitive projects.

CHAPTER SIX

6 PROJECT REPORT

6.1 Architects Brief

The design of a music industry is required in Kaduna. Music is going to be recorded and the production of record disc and cassettes is envisaged. The following departments are needed in the industry: Administration, Marketing, Welfare, Recording and Production.

6.1.1 Administration

Offices are needed for the daily running of the industry. A conference room and a library should be incorporated here. The staff and activities to be accommodated with their required areas are as follows:

Staff Office	Area
Entrance lobby/Security	$18m^2$
Receptionist/Waiting room	$36m^2$
Telephone room	$18m^2$
Public relations officer	$36m^2$
Library	$54m^2$
Compactus	$12m^2$
Registry	$36m^2$
General Officer	$18m^2$
Personnel Manager	$36m^2$
Secretary Typist for above	$18m^2$
General Manager	$36m^2$
Secretary Typist for above	$18m^2$
Photocopy room	$12m^2$
Conference room	$40m^2$
Total Area	$388m^2$
Add 10% for circulation	$38.8m^2$
Grand Total Area	$426.8m^2$

6.1.4 Recording Department

Rooms requiring different acoustical qualities are needed for the recording or rehearsal of music. It will also include storage area for equipments and tapes.

ROOM/ACTIVITY	AREA
Security Office	$12m^2$
Receptionist/Waiting room	$54m^2$
Producer's Office	$24m^2$
Store for tapes	$15m^2$
Recording Studio I	$42m^2$
Recording Studio II	$42m^2$
Control room I	$30m^2$
Control room II	$30m^2$
Rehearsal/Orchestra Studio	$54m^2$
Control room for above	$24m^2$
Rehearsal Studio II	$24m^2$
Editing room	$12m^2$
Auditorium/Recording Studio	$24m^2$
Control room for above	$12m^2$
Sound Locks	$36m^2$
Equipment store	$15m^2$
Demos Store	$15m^2$
Tape-Tape transfer room	$36m^2$
Tape - Disc transfer room	$36m^2$
Total Area	$540m^2$
Add 10% for circulation	$54m^2$
Grand Total Area	$594m^2$

6.1.5 Production Area.

ACTIVITY	AREA
Production Managers office	$36m^2$
Laboratory	$36m^2$
Matrix department	$108m^2$
Raw Materials store	$108m^2$
Press room/Maintenance	$180m^2$
Inspections	$36m^2$
Finished goods (records) store	$108m^2$
Stamper/Tape store	$18m^2$
Raw materials (cassettes) store	$48m^2$
Production hall	$60m^2$
Wrapping and packaging	$30m^2$
Finished goods (cassettes store	$48m^2$
Total Area	$816m^2$
Add 10% for circulation	$81.6m^2$
Grand total	$897.6m^2$

6.1.6 Auxiliary Areas

These are areas designated for vehicular parking and technical services.

Activity	Area
Vehicular Parking (uncovered)	$704m^2$
Vehicular Parking (covered)	$156m^2$
Generator house	$15m^2$
Air conditioning Plant	$30m^2$
Gate House	$12m^2$
Manouvering areas	$1,452m^2$
Total Area	$2,369m^2$

6.2 Design Concept

The best concept used in industrial design is the functionality concept. In this type of concept, the functional flow is given more consideration than the others. But in the design of acoustically sensitive buildings, the zoning concept based on the noise criteria for the activities is used. Therefore, a marriage between these two concepts is needed for a functional and economic design.

6.2.1 Functional Diagrams

Figure 6.1 illustrates the general flow of people and vehicles in the industry. Figure 6.2 is an illustration of the production process from the artiste to the record disc or cassette as the case may be.

6.2.2 The Noise criteria for the different activities on the site is as follows. The noise criteria for the conference hall, library and offices of the senior staff is from 30 to 40 dB and it is higher in the typing offices (40 to 50dB). Recording studios should be placed at the quietest part of the site, because their noise criteria value is the lowest, between 10 and 20dB is acceptable. It is a little bit higher for rehearsal studios, about 30dB is acceptable. In the welfare department a noise criteria value of between 35 and 45 dB is acceptable. The production areas should be placed away from the studios because the presses used in record production produce noise. A noise criteria value of between 50 and 75dB is allowed.

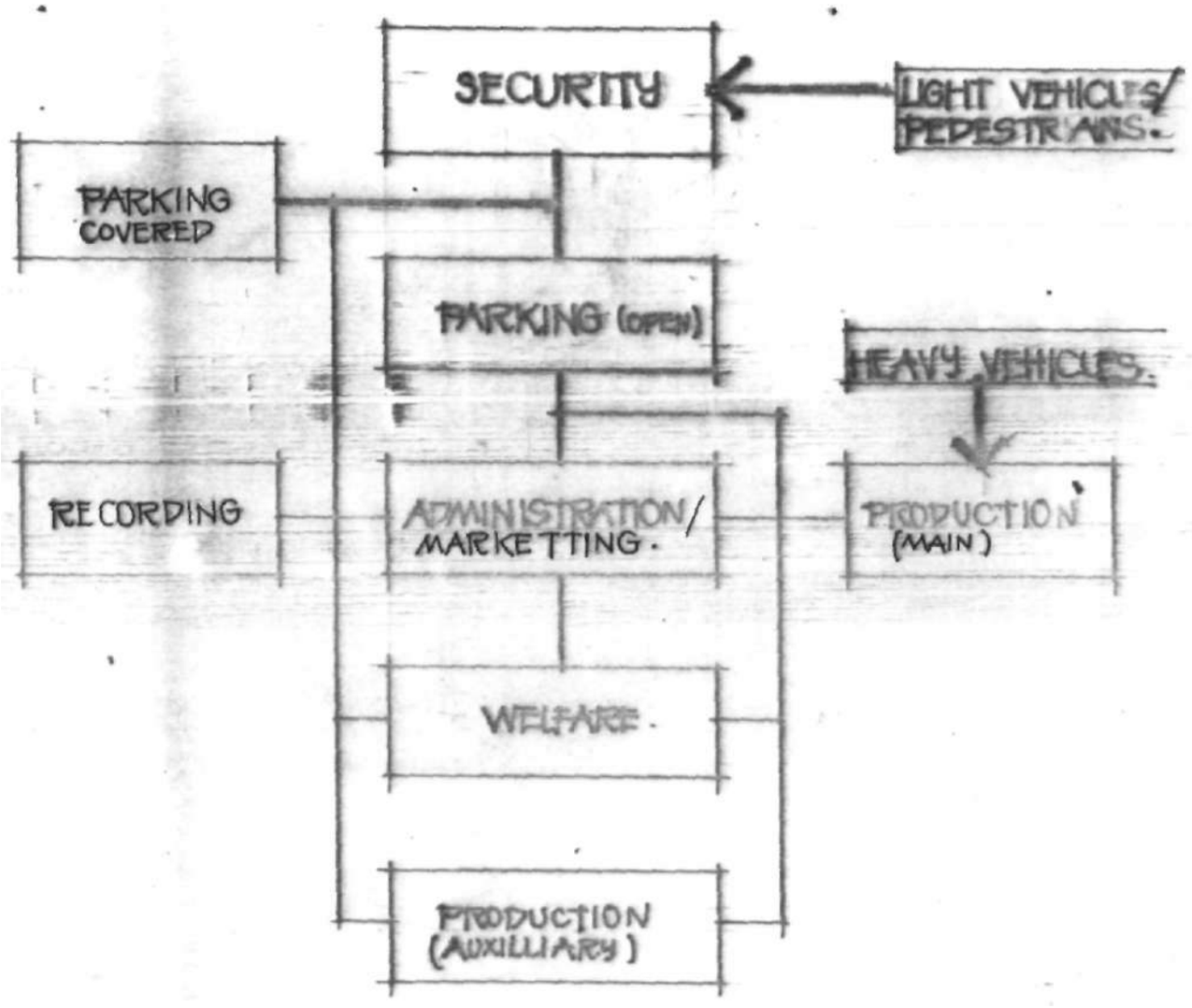


FIGURE 6.1 FLOW DIAGRAM.

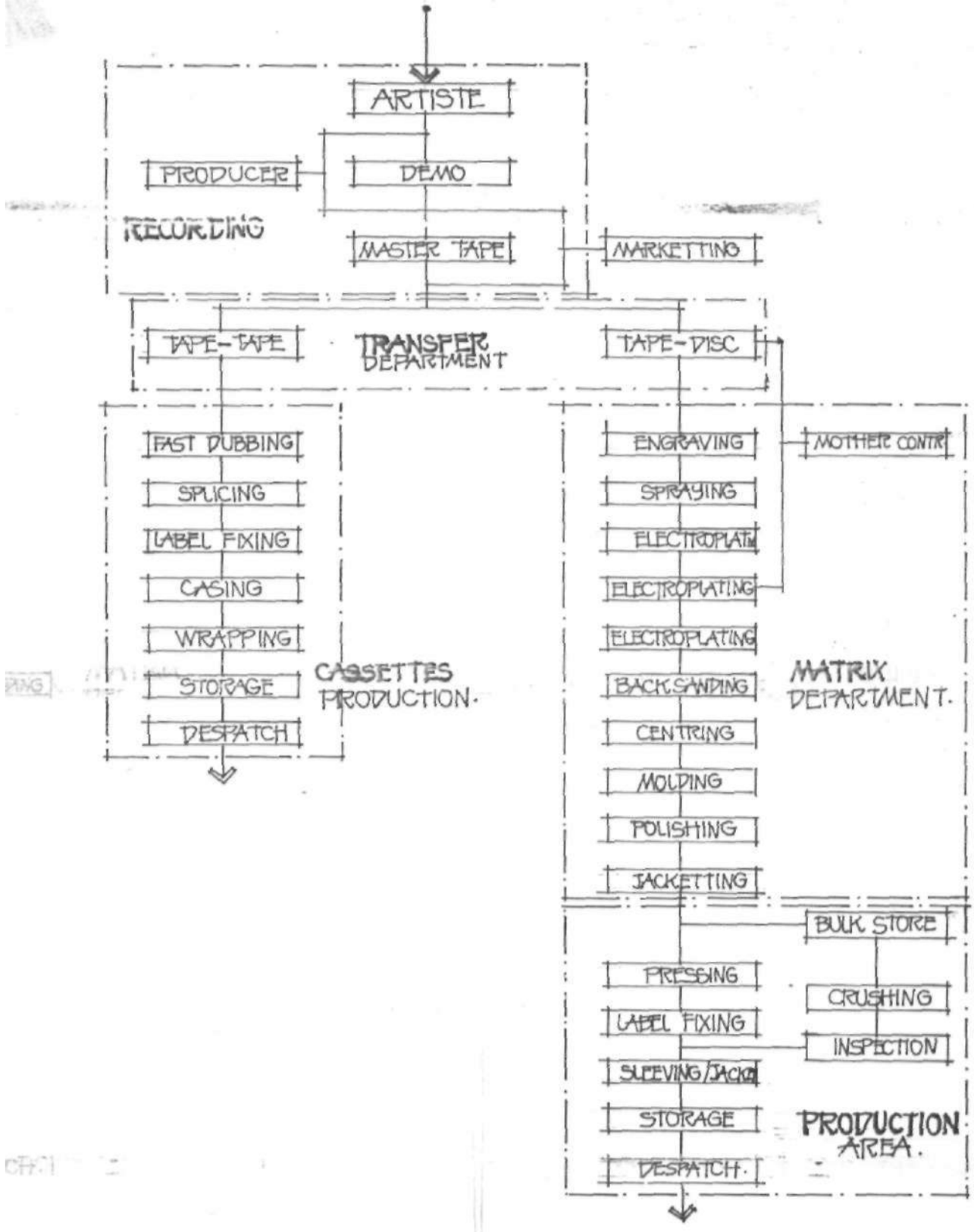


FIGURE 6·2. PRODUCTION DIAGRAM.

It is advisable to site the production area in a place on the site where it can shield the recording areas from external noise.

6.2.3 Concept chosen

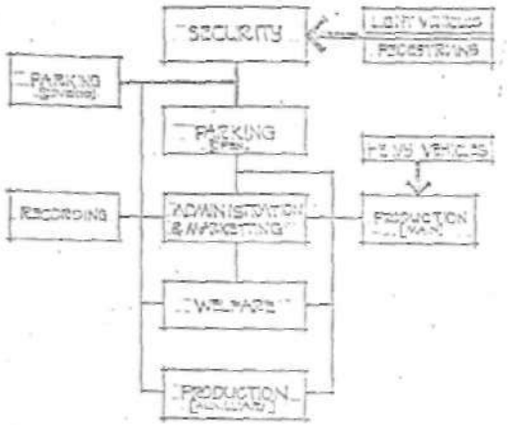
Figure 6.3 illustrates the concept that was chosen for this design. The production area was sited near the road for easy accessibility to trucks and for it to shield the studios from the traffic noise. The pedestrian, small vehicles and trucks traffic are seperate and controlled from the gate house. The welfare section is placed in a central position so that all sections would enjoy its services.

6.3 Design

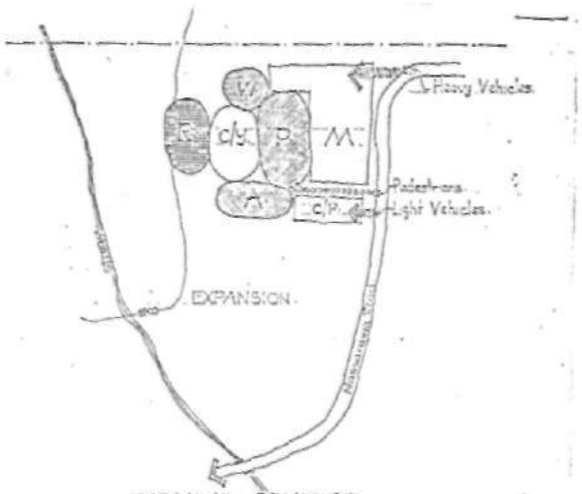
6.3.1 Site Plan

The design was done in such a way as to fit into the site. The site has a gentle slope towards the western part, this means that, the buildings should be sited in such a way as to allow the longer sides to face East and West for drainage purposes and to avoid cutting and filling. The administration block could have been made one long block, but this was not done, so as to cut down the distances between offices at the two extremes.

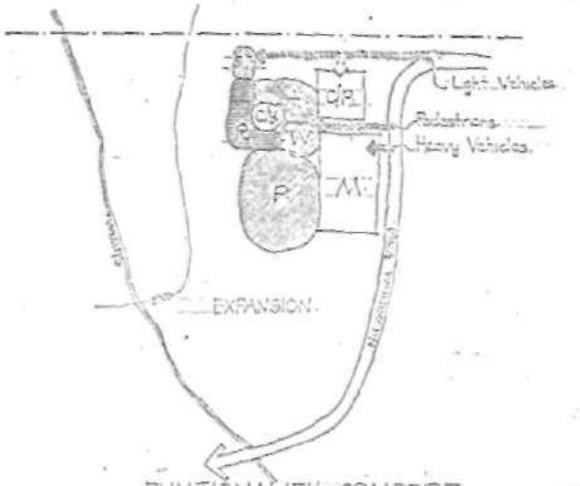
Three courtyards are designed for the industry. Two of them are principally for ventilation and lighting purposes, while the third one is a landscaped one, to be used for outdoor eating and seating area. Figure 6.4. gives the details of the site plan.



FLOW DIAGRAM.



ZONING CONCEPT



FUNTIONALITY CONCEPT

LEGEND

P	PRODUCTION AREA.
R	RECORDING AREA.
A	ADMINISTRATION AREA.
W	WELFARE AREA.
M	MANUFACTURING AREA.
CY	COURTYARD AREA.
CP	CAR PARKING AREA.
S/A	SERVICES/ARTISTES PARKING

ADVANTAGES

- INEXPENSIVE SOUND INSULATION CONSTRUCTION CAN BE USED.
- EXPANSION IS POSSIBLE IN THE RECORDING AND ADMINISTRATION AREAS.
- UNINTERRUPTED LARGE CENTRAL COURTYARD.
- TOTAL SEPARATION OF TRAFFIC ROUTES TO ELIMINATE ACCIDENTS.
- VEHICULAR TRAFFIC IS RESTRICTED TO A SECTION OF THE SITE.

DISADVANTAGES

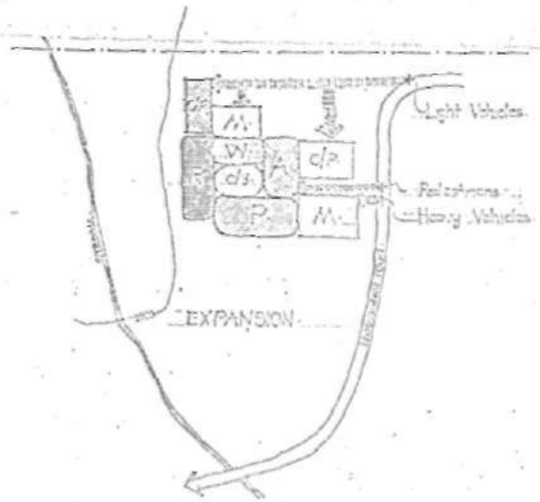
- RECORDING AREA IS NOT LINKED TO THE OTHER SECTIONS.
- WELFARE SECTION IS FAR FROM THE ADMINISTRATION AREA.
- EXPANSION IS NOT POSSIBLE IN THE PRODUCTION AREA.
- RECORDING AREA IS NOT LINKED TO THE ROAD.
- MAINTENANCE OF COURTYARD MIGHT BE UNECONOMICAL.

ADVANTAGES

- THE WELFARE SECTION IS POSITIONED FOR EASY ACCESSIBILITY BY THE USERS.
- TOTAL SEPARATION OF TRAFFIC ROUTES.
- SMALLER COURTYARD FOR EASY MAINTENANCE.
- VEHICULAR TRAFFIC IS RESTRICTED TO A PARTICULAR SECTION OF THE SITE.
- EXPANSION IS POSSIBLE IN RECORDING AND PRODUCTION AREAS.
- ALL SECTIONS ARE INTERLINKED.

DISADVANTAGES

- VIBRATIONS OF MACHINES FROM THE PRODUCTION AREA COULD BE TRANSMITTED TO THE RECORDING AREA.
- ARTISTES' PARKING AREA COULD BE A SOURCE OF NOISE TO THE RECORDING AREA.



ADOPTED CONCEPT.

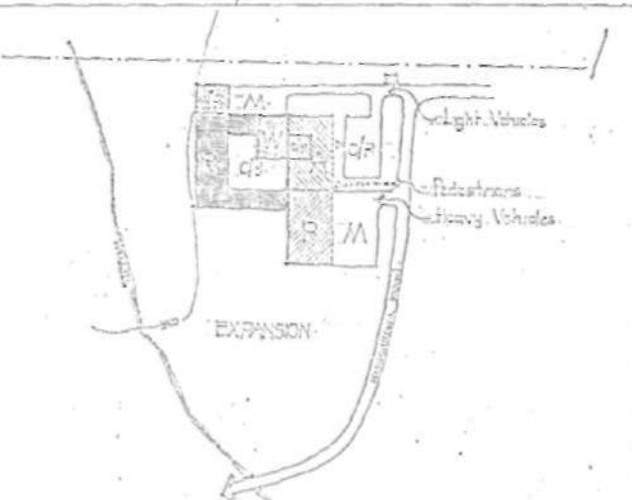
adopted Concept

advantages.

- SEPARATION OF VEHICULAR TRAFFIC FROM PEDESTRIANS' ROUTE.
- EXPANSION IS POSSIBLE IN BOTH PRODUCTION AND RECORDING AREAS.
- 'ARTISTES' PARKING AREA IS NEAR THE RECORDING AREA.
- WELFARE AREA IS LINKED WITH THE ROAD.
- THE PRODUCTION AREA IS LINKED TO THE RECORDING AND ADMINISTRATION AREAS.
- THE PLANNING FORMS A "CLOSE CIRCUIT".
- THE RECORDING AREA IS PLACED ON THE QUITE SIDE OF THE SITE.
- THE PRODUCTION, ADMINISTRATION AND WELFARE AREAS SHIED THE RECORDING AREA FROM THE TRAFFIC NOISE FROM NAIROBI-WA ROAD.

disadvantages.

- THE PRODUCTION AND WELFARE AREAS ARE NOT DIRECTLY LINKED TO EACH OTHER.
- COURTYARD MIGHT BE TOO LARGE AND AS SUCH UNINTERESTING AND DIFFICULT TO BE MAINTAINED EFFECTIVELY.



CONCEPTUAL SITE PLAN.



FIGURE 6·4 SITE PLAN

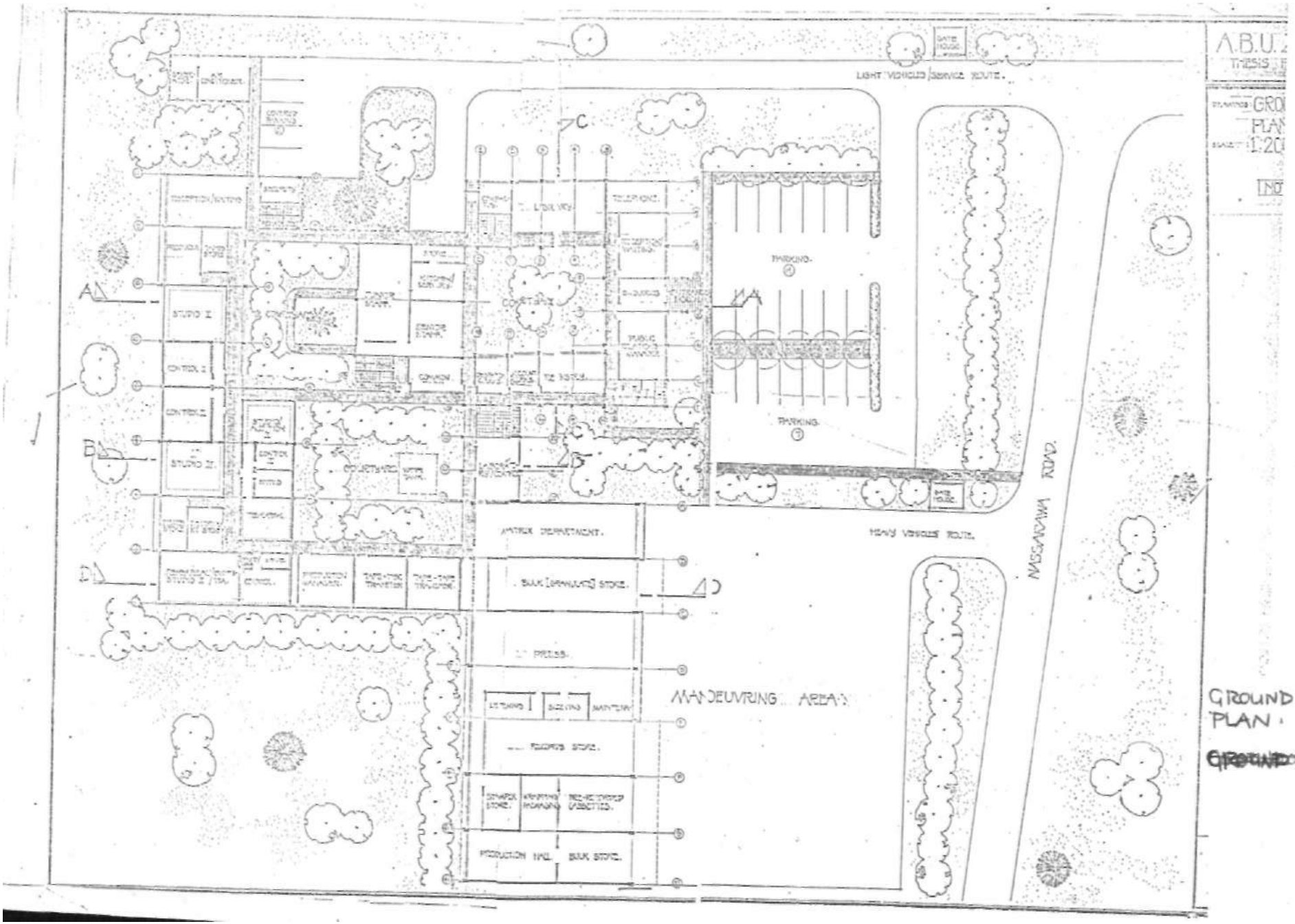
6.3.2 Plans and Elevations

The administration building being the "power block" is housed on two floors, while the other departments are on a single floor. This design solution helped in maintaining the general townscape around the site. The plans are all retilinear in nature, the elevations (Front, back and right side) are skeletal rectilinear with the left side elevation being planer rectilinear (see figure 6.5 and 6.6).

6.3.3 Structures

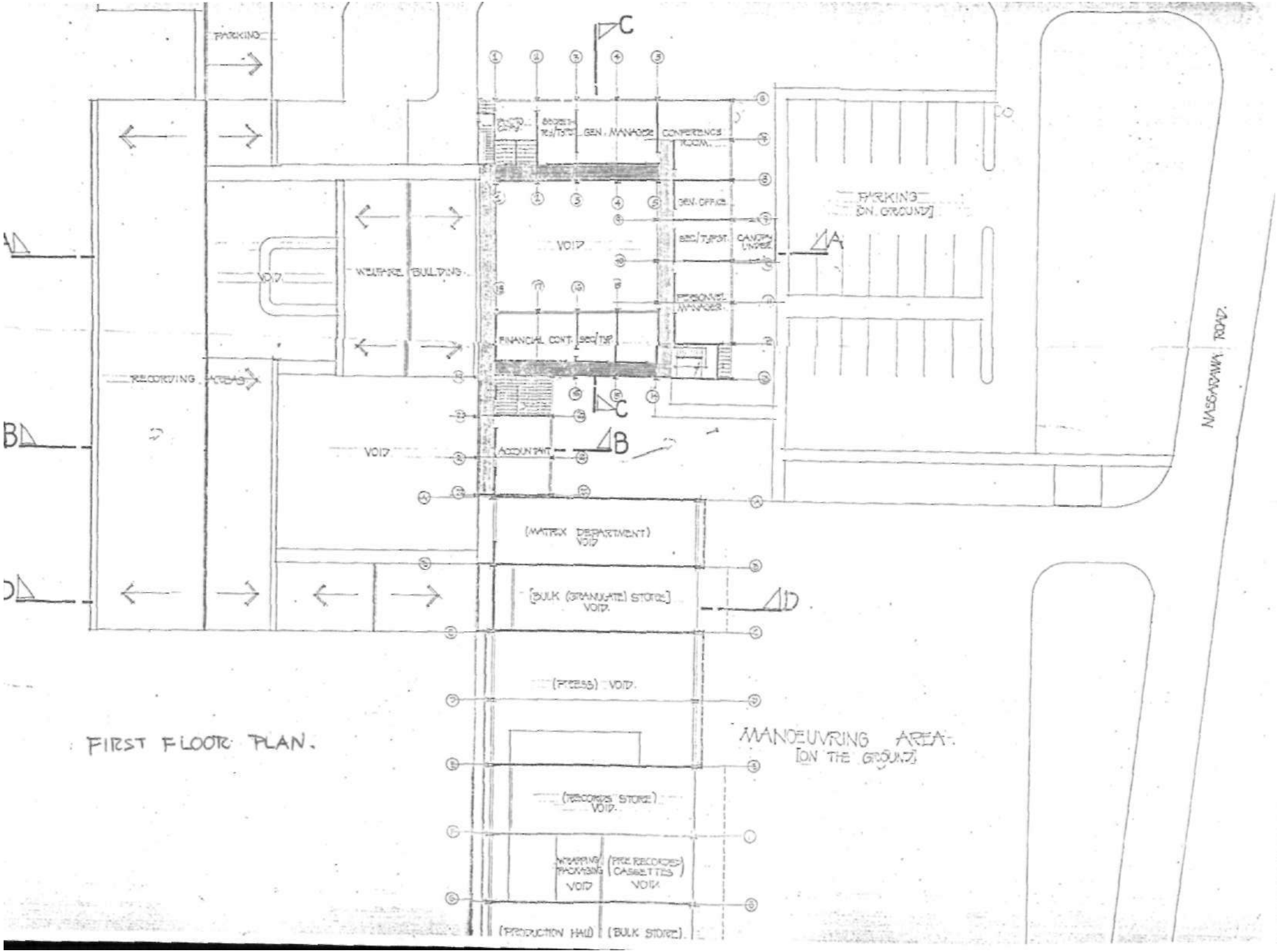
The structural elements in the administration block are the columns and beam spaced at a distance of 3.6m. The roof is of a timber truss and the covering is of Aluminium roofing sheets, with a gutter to collect the rain during rain. The production area have concrete columns and spaced at 6m distance with steel long span joists (top chord pitched two ways, underslung) forming the roof structure. The roofing sheets are also of corrugated aluminium. The walls are of 230mm bricks, plastered both sides and painted.
The ceiling is attached to the underside of the bottom chord .
In the recording studio concrete portal frames are used, they are spaced at 6m. A concrete slab is used for roofing the recording studios due to its superior acoustical quality over metal roofing sheets. A suspended ceiling is designed for the recording studios for acoustical reasons also.
The walls in the studios are 230mm thick, made of brick.
The welfare section has a similar structural solution as the production area, but is slightly different from it, in that its walls are 180mm.

The administration, production, Recording and welfare blocks are structurally seperated but functional linked.

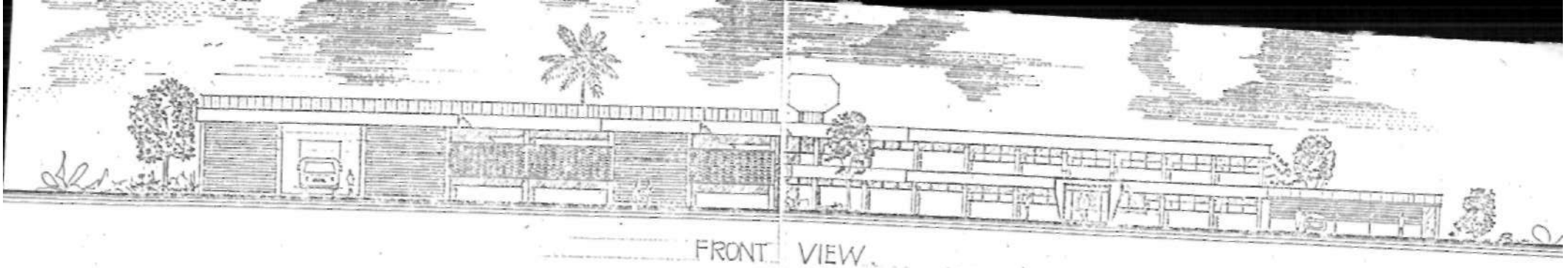


GROUND FLOOR PLAN.

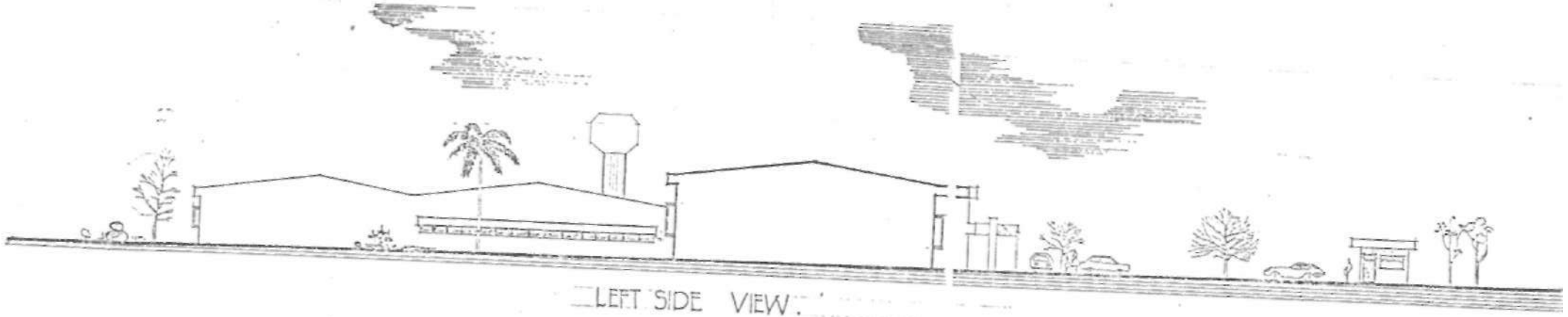
~~GROUND~~ FLOOR PLAN.



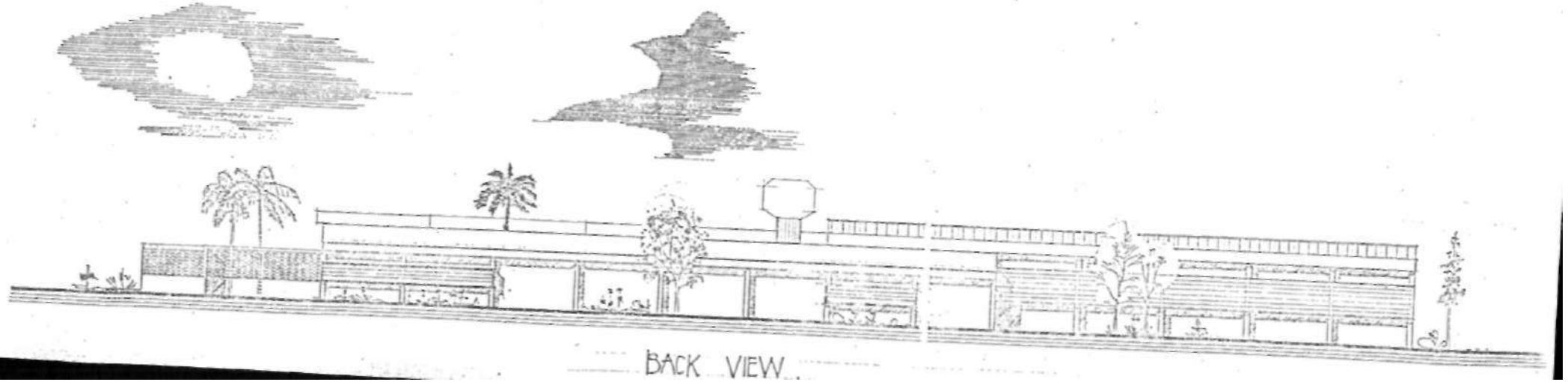
FIRST FLOOR PLAN.



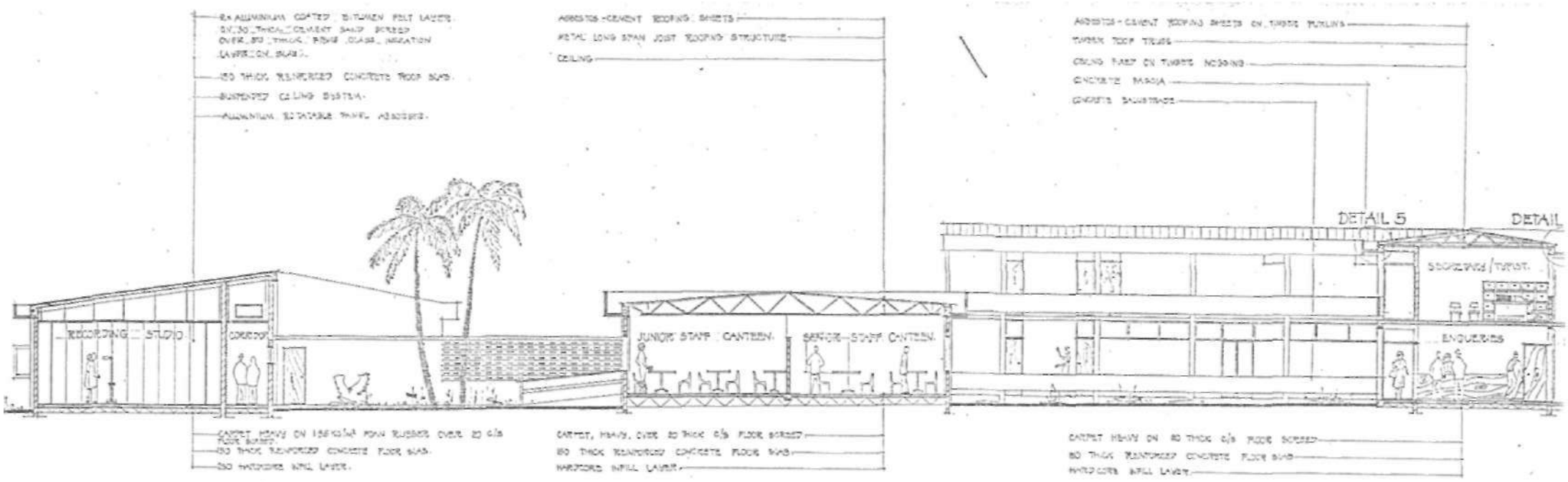
FRONT VIEW.



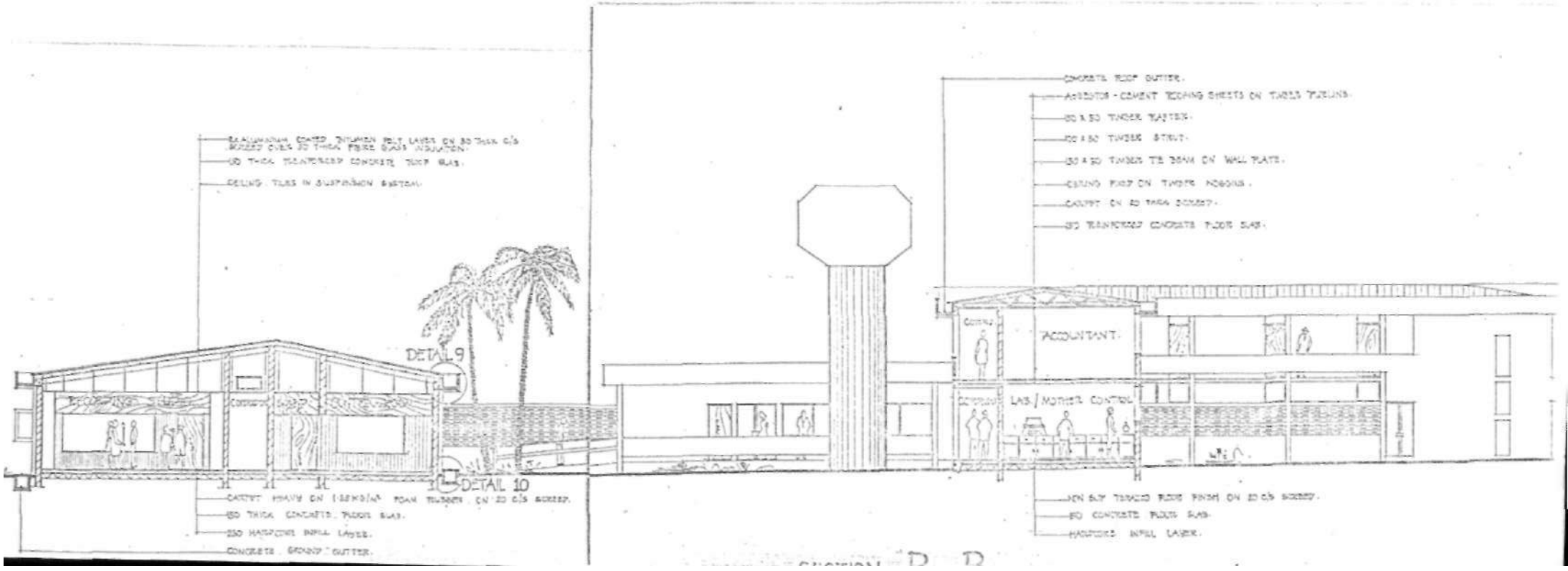
LEFT SIDE VIEW.



BACK VIEW.



SECTION A-A.



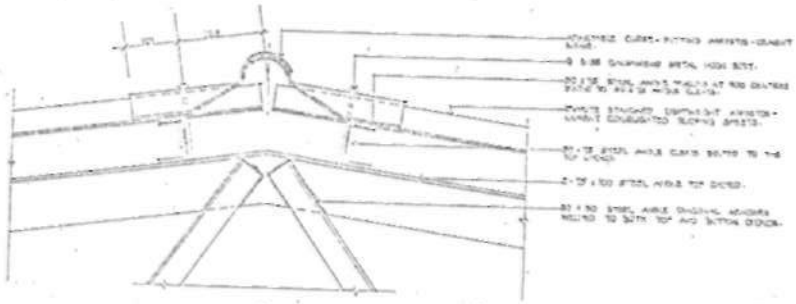
SECTION B-B

A.B.U. ZARIA
THESIS PROJECT.

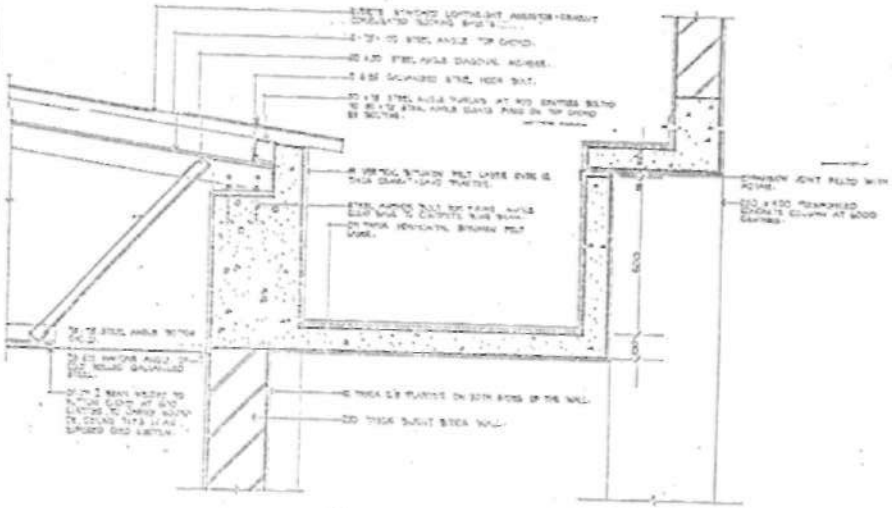
FEATURE: DETAILS.

SCALE: 1:5 & 1:10.

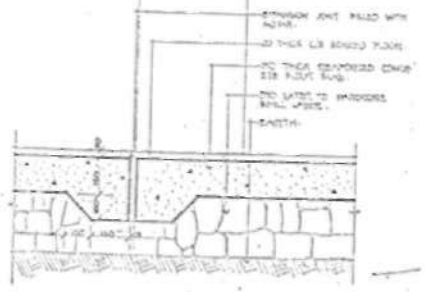
NOTES



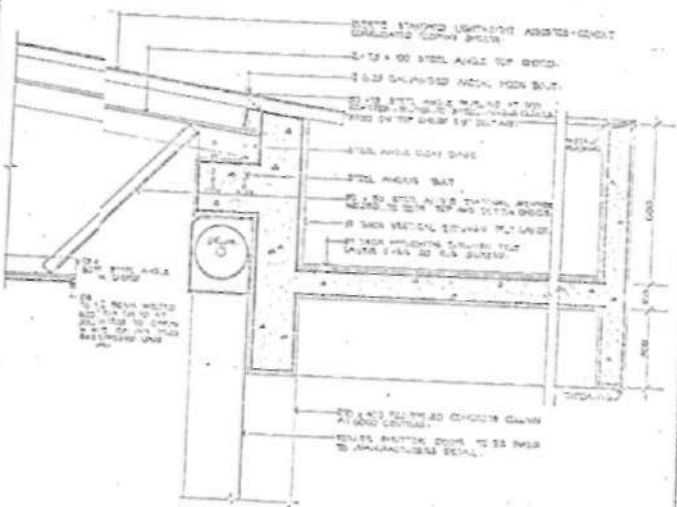
DETAIL 1. SCALE 1:5.



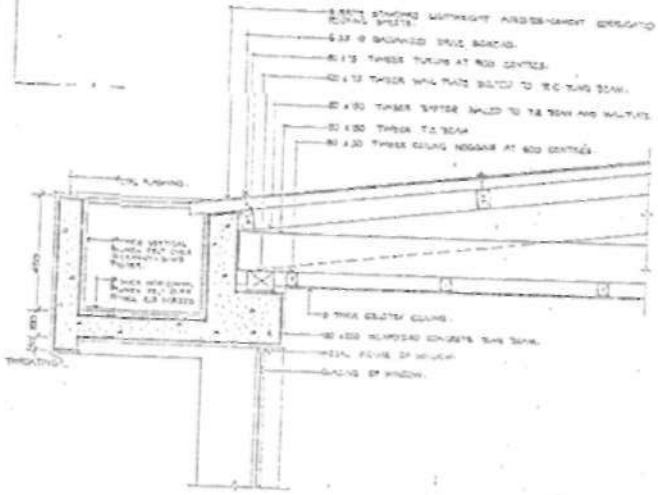
DETAIL 2. SCALE 1:10.



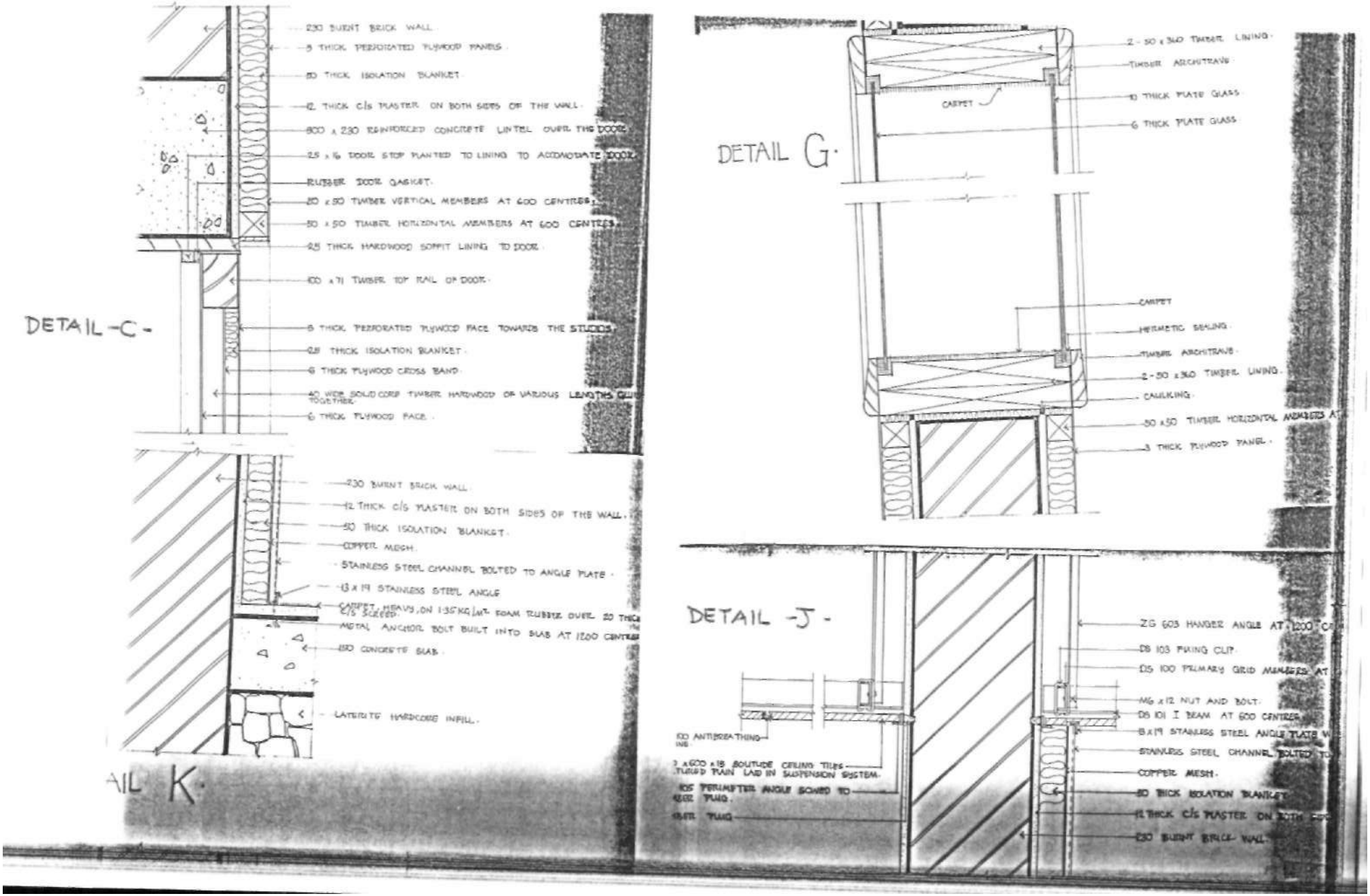
DETAIL 3. SCALE 1:10.

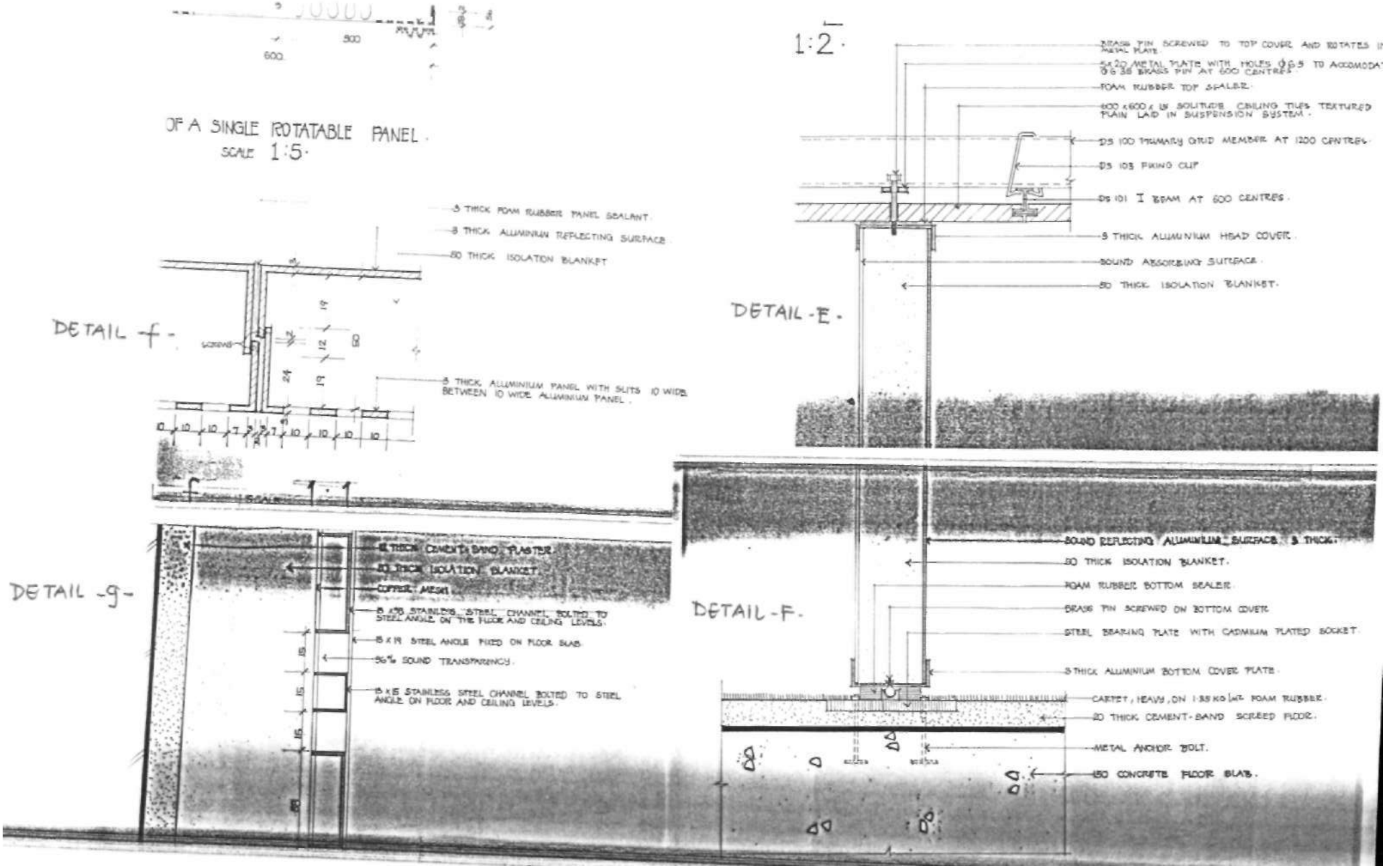


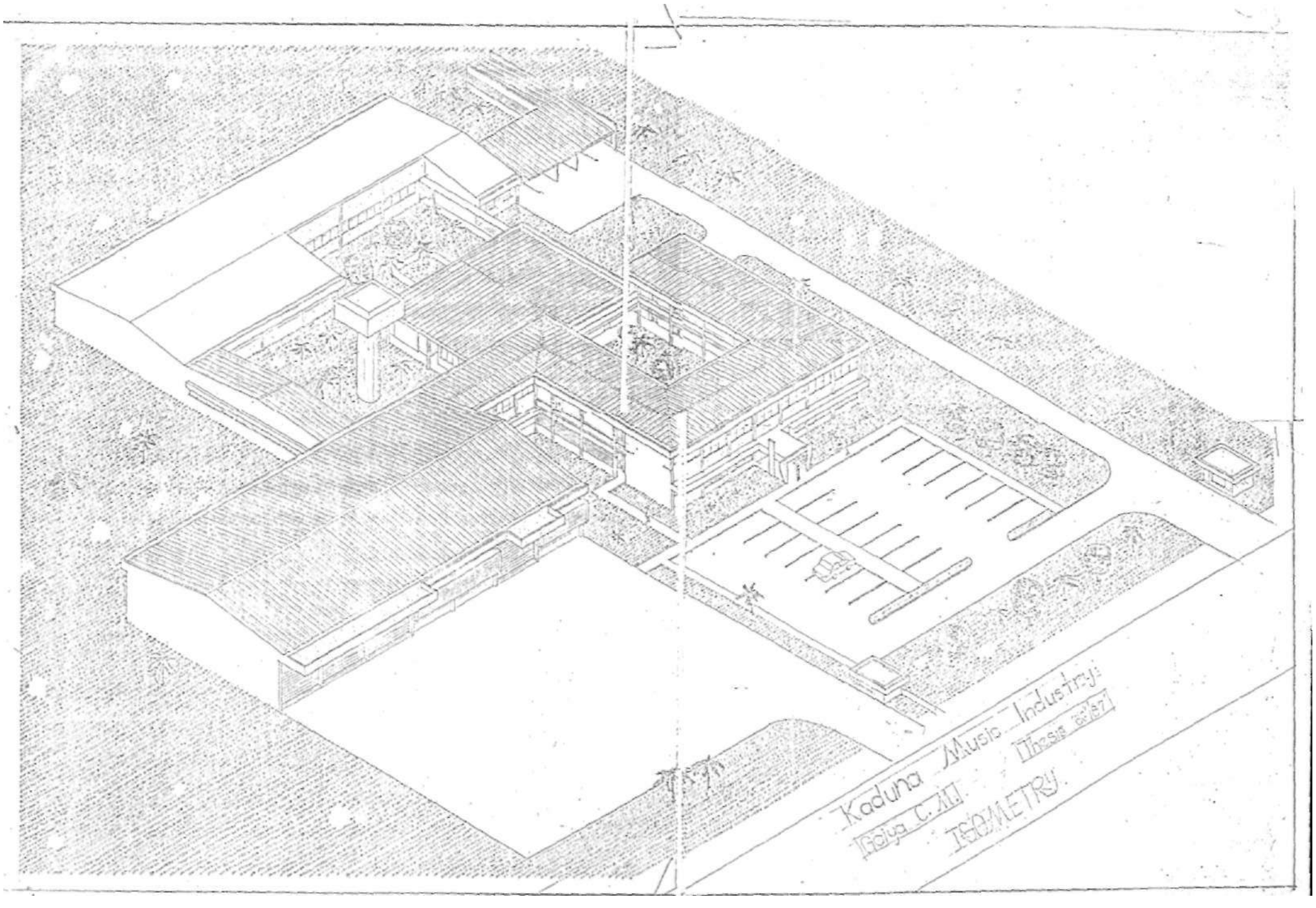
DETAIL 4. SCALE 1:10.



DETAIL 5. SCALE 1:10.


DETAIL -C-
230 BURNT BRICK WALL.
5 THICK PERFORATED PLYWOOD PANELS.
50 THICK ISOLATION BLANKET.
12 THICK C/S PLASTER ON BOTH SIDES OF THE WALL.
600 x 230 REINFORCED CONCRETE LINTEL OVER THE DOOR.
25 x 16 DOOR STOP PLANTED TO LINING TO ACCOMODATE DOOR.
RUBBER DOOR GASKET.
50 x 50 TIMBER VERTICAL MEMBERS AT 600 CENTRES.
50 x 50 TIMBER HORIZONTAL MEMBERS AT 600 CENTRES.
25 THICK HARDWOOD SOFFIT LINING TO DOOR.
100 x 71 TIMBER TOP RAIL OF DOOR.
6 THICK PERFORATED PLYWOOD FACE TOWARDS THE STUDDS.
25 THICK ISOLATION BLANKET.
6 THICK PLYWOOD CROSS BAND.
40 WIDE SOLID CORE TIMBER HARDWOOD OR VARIOUS LENGTHS GLU
TOGETHER.
6 THICK PLYWOOD FACE.
230 BURNT BRICK WALL.
12 THICK C/S PLASTER ON BOTH SIDES OF THE WALL.
50 THICK ISOLATION BLANKET.
COPPER MESH.
STAINLESS STEEL CHANNEL BOLTED TO ANGLE PLATE.
13 x 19 STAINLESS STEEL ANGLE
CARPET, HEAVY ON 1.35 KG/M² FOAM RUBBER OVER. 20 THICK
C/S SCREED.
METAL ANCHOR BOLT BUILT INTO SLAB AT 1200 CENTRES
150 CONCRETE SLAB.
LATERITE HARDCORE INFILL.
AIL K.
DETAIL G.
2 - 50 x 340 TIMBER LINING.
TIMBER ARCHITRAVE
10 THICK PLATE GLASS
CARPET
6 THICK PLATE GLASS
CARPET
HERMETIC SEALING.
TIMBER ARCHITRAVE.
2 - 50 x 340 TIMBER LINING.
CAULKING.
50 x 50 TIMBER HORIZONTAL MEMBERS AT
3 THICK PLYWOOD PANEL.
DETAIL -J-
ZG 603 HANGER ANGLE AT 1200 C
DS 103 FIXING CLIP
DS 100 PRIMARY GRID MEMBERS AT
M6 x 12 NUT AND BOLT.
DS 101 I BEAM AT 600 CENTRES
13 x 19 STAINLESS STEEL ANGLE PLATE W
STAINLESS STEEL CHANNEL BOLTED TO
COPPER MESH.
50 THICK ISOLATION BLANKET
12 THICK C/S PLASTER ON BOTH
230 BURNT BRICK WALL
600 ANTIBREATHING
LINE
600 x 18 BOLITUDE CEILING TILES
TURNED PLAIN LAID IN SUSPENSION SYSTEM.
DS5 PERIMETER ANGLE BOWED TO
CEILING PLANE.
MASTER PLANE


600
500
OF A SINGLE ROTATABLE PANEL.
SCALE 1:5.
DETAIL -f-
5 THICK FOAM RUBBER PANEL SEALANT.
5 THICK ALUMINIUM REFLECTING SURFACE.
80 THICK ISOLATION BLANKET.
5 THICK ALUMINIUM PANEL WITH SLITS 10 WIDE BETWEEN 10 WIDE ALUMINIUM PANEL.
DETAIL -g-
15 THICK CEMENT-SAND PLASTER.
80 THICK ISOLATION BLANKET.
COPPER MESH.
5 x 50 STAINLESS STEEL CHANNEL BOLTED TO STEEL ANGLE ON THE FLOOR AND CEILING LEVELS.
5 x 19 STEEL ANGLE FIXED ON FLOOR SLAB.
56% SOUND TRANSPARENCY.
15 x 15 STAINLESS STEEL CHANNEL BOLTED TO STEEL ANGLE ON FLOOR AND CEILING LEVELS.
1:2.
DETAIL -E-
BRASS PIN SCREWED TO TOP COVER AND ROTATES IN METAL PLATE.
5 x 20 METAL PLATE WITH HOLES Ø6.5 TO ACCOMODATE Ø6.35 BRASS PIN AT 600 CENTRES.
FOAM RUBBER TOP SEALER.
600 x 600 x 19 SOLITUDE CEILING TILES TEXTURED PLAIN LAID IN SUSPENSION SYSTEM.
DS 100 PRIMARY GRID MEMBER AT 1200 CENTRES.
DS 103 FIXING CLIP
DS 101 I BEAM AT 600 CENTRES.
5 THICK ALUMINIUM HEAD COVER.
SOUND ABSORBING SURFACE.
80 THICK ISOLATION BLANKET.
DETAIL -F-
SOUND REFLECTING ALUMINIUM SURFACE 5 THICK.
80 THICK ISOLATION BLANKET.
FOAM RUBBER BOTTOM SEALER.
BRASS PIN SCREWED ON BOTTOM COVER.
STEEL BEARING PLATE WITH CADMIUM PLATED SOCKET.
5 THICK ALUMINIUM BOTTOM COVER PLATE.
CARPET, HEAVY, ON 1.35 KG/M² FOAM RUBBER.
20 THICK CEMENT-SAND SCREED FLOOR.
METAL ANCHOR BOLT.
150 CONCRETE FLOOR SLAB.


Kaduna Music Industry:
Thesis artist
Idoiya C. Ali
ISOMETRY

6.3.4 Services

The recording studios are ventilated mechanically. A central air conditioning system is used for this purpose. All service ducts and ductworks are done within the space. between the suspended ceiling and roof. In the production hall, ductwork and conduits are to be passed between the webs of the steel joist.

6.3.5 Drainage

Roof gutters are incorporated in the design, The construction material is concrete and the outlet points are coordinated with the structural grid of the building. Their contents is then drained into the gutter on the ground which is running round.the buildings. Surface water will be drained into the stream on the western side of the site, while the effluent water and other wastes from the industry will be treated before disposal.

6.3.6 Acoustics

The accustical requirements of the rooms were taken into consideration in the design. The recording studios need the amount of acoustical Privacy. highest studios have variable sound absorbers on three of their four wall surfaces. The fourth wall have control window and a door on it, they are of sound insulating materials. The control room and recording studio are entered through a sound lock. The advantage of a sound lock construction is that it eliminates the use of expensive sound uinsulating doors. The walls here also are treated with acoustical materials.

The rehearsal studios have slit resonators with sound absorbing porous materials as the absorbers. The reverberation time designed for this room is 0.4 secs, which is the optimum acceptable for music over the frequency range of $63H_z$ to $8,000H_z$.

The control rooms have a reverberation time of 0.4 secs also, this is good for easy monitoring of the music.

B I B L I O G R A P H Y

1. Askill, J. (1979). Physics of Musical Sounds. D. Van Nostrand Company, Inc.

2. Doelle, L. L. (1965). Acoustics in Architectural Design Bibliography No. 29 of the Devision of Building Research Ottawa.

3. Doelle, L. L. (1972). Environmental Acoustics. McGraw-Hill Book Company.

4. Fansworth, P. R. (1969). The Social Psycology of Music The Iowa State University Press.

5. Gyan, (1985). Acoustics. Unpublished Part III lectures. Department of Architecture, Ahmadu Bello University, Zaria, Nigeria.

6. Josephs, J. J. (1967). The Physics of Musical Sounds. D. Van Nostrand Company, Inc.

7. Kinzey and Sharp. (1965). Technologies in Architecture Prentice-Hall, Inc. PP. 318-377.

8. Kyentu, D. D. (1979). Factory for Records and Tapes, Jos. Unpublished M.Sc. Thesis. Ahmadu Bello University, Zaroa Nigeria.

9. London, C. C. (1951) Royal Festival Hall. Max Parrish

10. Mohammed, A. (1984) State Radio Broadcasting house, Bauchi X (Architectural solutions to studio Acoustics problems). Unpublished M.Sc. Thesis. Ahmadu Bello University, Zaria, Nigeria.

11. Navarra, J. G. (1969). Our Noisy World. Doubleday and Company, Inc.

12. Neufert, E. (1980) Architectects Data. Granada Publishing. PP. 395 - 397.

13. Newman, R. B. (1974) Acoustics. In: Callender J. H,. Time Savers Standard for Architectural Design Data. PP. 689 - 726.

14. Sabine, W. C. (1964). Collected Papers on Acoustics Dover Publisations, Inc.

15. Sharland, I. (1972). Woods Practical Guide to Noise Control Woods Acoustics.

16. Walter, E. (1973). The Technique of the Film cutting Room Focal Press Limited. PP. 31-38.

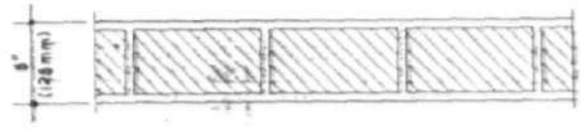
17. Winstanley, J. W. (1952). Textbook on Sound. Longmans, Green and Co.

18. Yarwood, M. (1953). Acoustics. Macmillan and Co., Limited

APPENDIX A

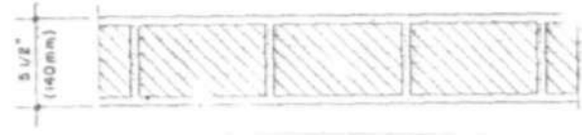
The following figures A1 to A9 are of typical wall constructions with their corresponding architectural - acoustical data. The sound transmission class (STC) given are average values derived from testing and research by leading authorities in the field of acoustical testing and research. It should be noted that the poor values may fall below the stated values due to poor workmanship and flanking transmission.

1. 4" (100mm) BRICK



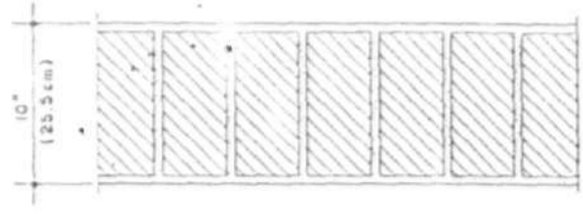
W = 43 (210)
STC = 40+

2. 4 1/2" (114mm) BRICK



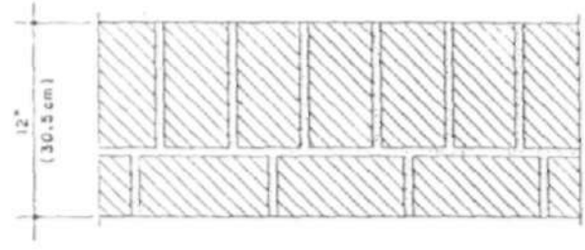
W = 55 (270)
STC = 42

3. 9" (23cm) BRICK



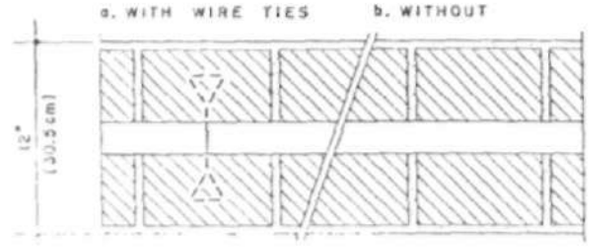
W = 100 (490)
STC = 52

4. 12" (30.5cm) BRICK



W = 121 (590)
STC = 54+

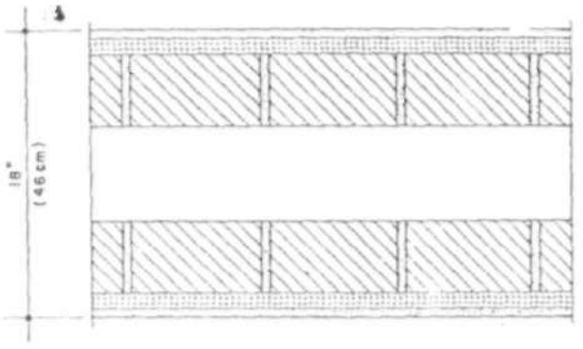
5. CAVITY BRICK



Wa = 100 (490)
STC$_a$ = 49
Wb = 100 (490)
STC$_b$ = 54

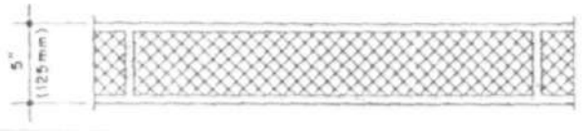
FIGURE A1. SOUND INSULATION VALUES OF MASONRY WALLS: W, WEIGHT IN lb/ft^2 (KG/M^2); STC IN DECIBELS.

6.



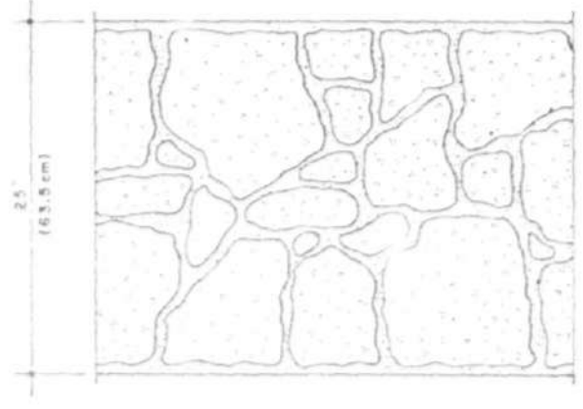
W = 120 (585)
STC = 62

7. 4" (100mm) HOLLOW GYPSUM BLOCK



W = 23.5 (115)
STC = 40+

8. 24" (61 cm) STONE



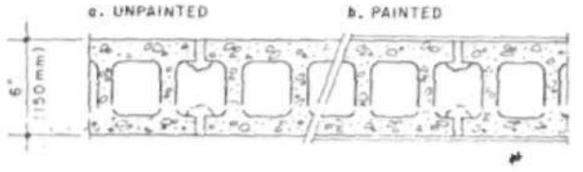
W = 280 (1370)
STC = 56

9. 6" (150mm) CONCRETE



W = 80 (390)
STC = 52+

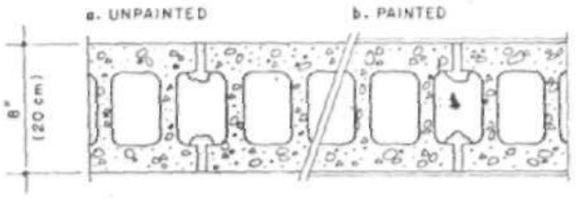
10. 6" (150mm) HOLLOW DENSE CONCRETE BLOCK



W_a = 30 to 40 (145 to 195)
STC_a = 43+
W_b = 30 to 40 (145 to 195)
STC_b = 45+

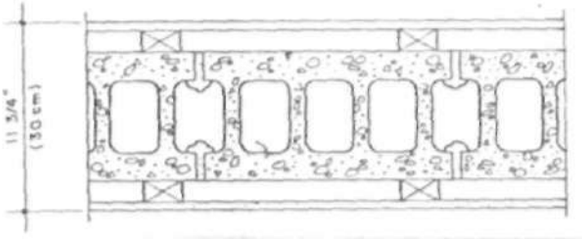
FIGURE A1. [CONTINUED] SOUND-INSULATION VALUES OF MASONRY WALLS: W, WEIGHT IN lb/ft² [kg/m²], STC IN DECIBELS.

11. 8"(20cm) HOLLOW DENSE CONCRETE BLOCK



W_a = 40 to 50 (195 to 245)
STC_a = 45+
W_b = 40 to 50 (195 to 245)
STC_b = 48+

12.



W = 45 to 55 (220 to 270)
STC = 50+

FIGURE A1 [CONTINUED] SOUND-INSULATION VALUES OF MASONRY WALLS: W, WEIGHT IN Lb/FT² [KG/M²], STC IN DECIBELS.

13. GYPSUM WALLBOARD



W_a = 1.6 (8) STC_a = 26
W_b = 2.1 (10) STC_b = 28
W_c = 2.7 (13) STC_c = 29

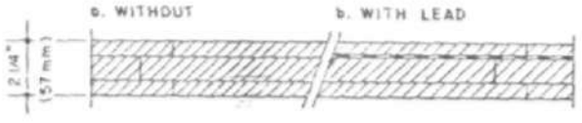
14. TWO LAYERS OF GYPSUM WALLBOARD



1/2" (13mm) GYPSUM BOARD
1/2" (13mm) GYPSUM BOARD

W = 4.6 (22)
STC = 31

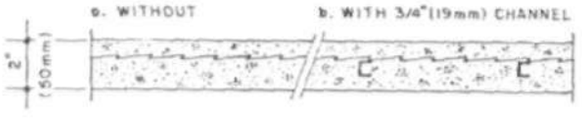
15. GYPSUM SANDWICH PANEL



1/2" (13mm) GYPSUM BOARD
1/8" (3mm) LEAD
1" (25mm) GYPSUM COREBOARD
5/8" (16mm) GYPSUM BOARD

W_a = 10 (49)
STC_a = 34+
W_b = 17 (83)
STC_b = 40+

16. SOLID PLASTER

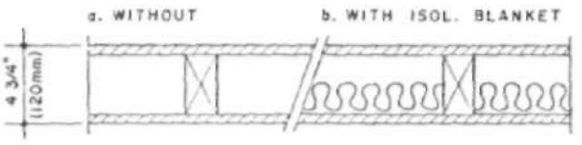


SANDED GYPSUM PLASTER
METAL LATH
3/4" (19mm) CHANNEL

W_a = 18.5 (90)
STC_a = 36
W_b = 18.5 (90)
STC_b = 36+

FIGURE A2. SOUND-INSULATION VALUES OF LIGHTWEIGHT WALLS WITH SINGLE LEAF ASSEMBLIES: W, WEIGHT IN Lb/ft² [KG/M²]; STC RATING IN DECIBELS.

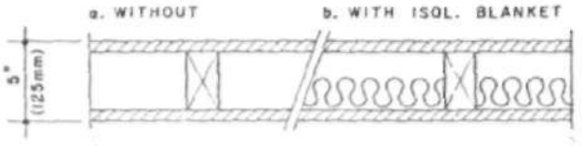
17.



1/2"(13mm) GYPSUM BOARD
2"x4"(50x100mm) WOOD STUD
2"(50mm) ISOLATION BLANKET
1/2"(13mm) GYPSUM BOARD

Wa = 4.2(21)
STCa = 33
Wb = 4.7(23)
STCb = 36

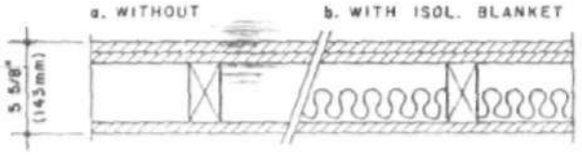
18.



5/8"(16mm) GYPSUM BOARD
2"x4"(50x100mm) WOOD STUD
2"(50mm) ISOLATION BLANKET
5/8"(16mm) GYPSUM BOARD

Wa = 5.4(26)
STCa = 34
Wb = 5.9(29)
STCb = 38

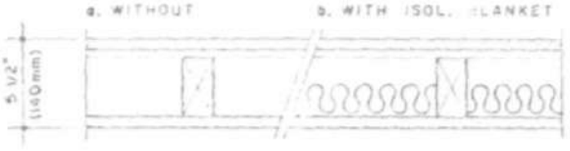
19.



5/8"(16mm) GYPSUM BOARD
5/8"(16mm) GYPSUM BOARD
2"x4"(50x100mm) WOOD STUD
2"(50mm) ISOLATION BLANKET
5/8"(16mm) GYPSUM BOARD

Wa = 8.5(42)
STCa = 36
Wb = 9(44)
STCb = 39

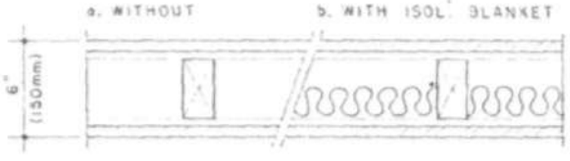
20.



5/8"(16mm) GYPSUM BOARD
HORIZONTAL RESILIENT BAR 24"(61cm) O.C.
2"x4"(50x100mm) WOOD STUD
2"(50mm) ISOLATION BLANKET
5/8"(16mm) GYPSUM BOARD

Wa = 5.4(26)
STCa = 38
Wb = 5.9(29)
STCb = 47

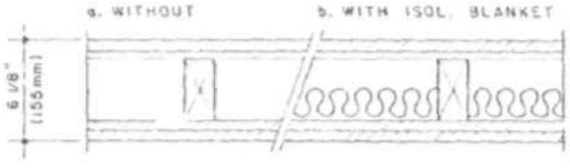
21.



5/8"(16mm) GYPSUM BOARD
HORIZONTAL RESILIENT BAR 24"(61cm) O.C.
2"x4"(50x100mm) WOOD STUD
2"(50mm) ISOLATION BLANKET
HORIZONTAL RESILIENT BAR 24"(61cm) O.C.
5/8"(16mm) GYPSUM BOARD

Wa = 5.4(26)
STCa = 39
Wb = 5.9(29)
STCb = 49

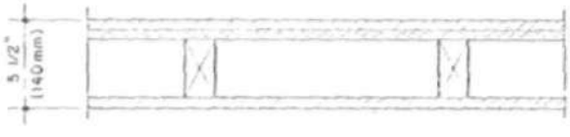
22.



5/8"(16mm) GYPSUM BOARD
HORIZONTAL RESILIENT BAR 24"(61cm) O.C.
2"x4"(50x100mm) WOOD STUD
2"(50mm) ISOLATION BLANKET
5/8"(16mm) GYPSUM BOARD
5/8"(16mm) GYPSUM BOARD

Wa = 8.5(42)
STCa = 43
Wb = 9(44)
STCb = 50

23.



5/8"(16mm) GYPSUM BOARD
1/2"(13mm) FIBERGLAS BOARD
2"x4"(50x100mm) WOOD STUD
5/8"(16mm) GYPSUM BOARD

W = 5.8(29)
STC = 36

24.

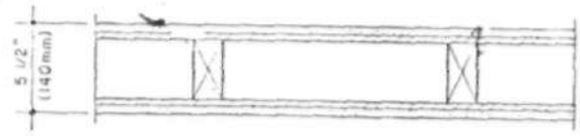


1/2"(13mm) GYPSUM BOARD
1/2"(13mm) WOOD FIBERBOARD
2"x4"(50x100mm) WOOD STUD
1/2"(13mm) WOOD FIBERBOARD

W = 6.6(32)
STC = 42

FIGURE A3. SOUND-INSULATION VALUES OF WOOD-STUD PARTITION WALLS WITH 16-INCHES (41CM) SPACINGS: W, WEIGHT IN LB/FT² (KG/M²); STC RATING IN DB (DECIBELS).

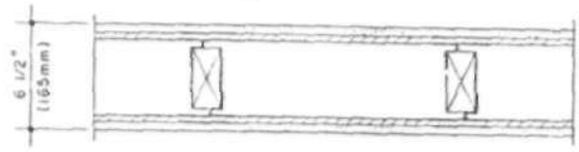
25.



W = 14 (68)

STC = 46

26.

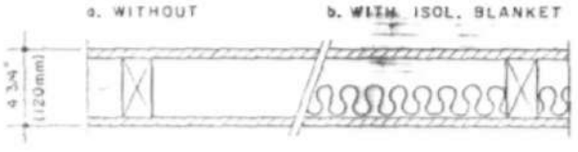


W = 13.1 (64)

STC = 50+

FIGURE A3 (CONTINUED) SOUND INSULATION VALUES OF WOOD-STUD PARTITION WALLS WITH 16in. (41CM) SPACINGS: W, WEIGHT IN Lb/FT^2 (KG/M^2); STC RATING IN DECIBELS.

27.



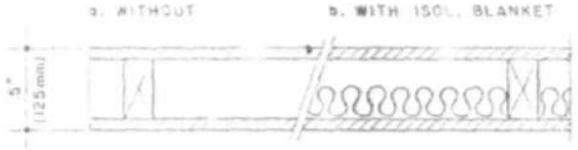
W_a = 4.2 (21)

STC_a = 35

W_b = 4.7 (23)

STC_b = 40

28.



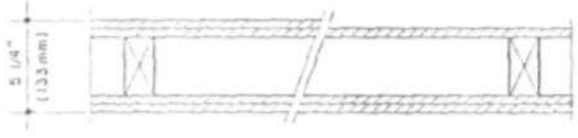
W_a = 5.4 (26)

STC_a = 36

W_b = 5.9 (29)

STC_b = 39

29.



W_a = 9.2 (45)

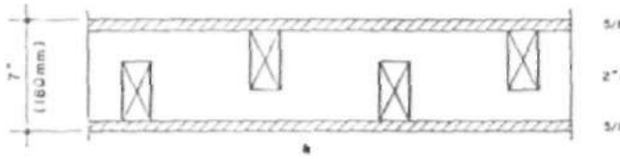
STC_a = 39

W_b = 6.7 (33)

STC_b = 41

FIGURE A4. SOUND-INSULATION VALUES OF WOOD STUD PARTITION WALLS WITH 24-in. (61CM) SPACINGS: W, WEIGHT IN Lb/FT^2 (KG/M^2); STC RATING IN DECIBELS.

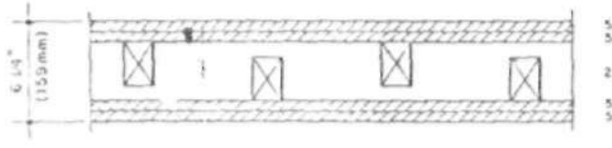
30.



W = 5.4 (26)

STC = 39

31.

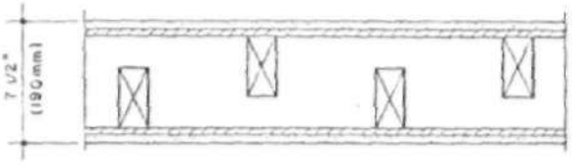


W = 13.4 (65)

STC = 44

FIGURE A5. SOUND-INSULATION VALUES OF WOOD-STUD PARTITION WALLS WITH 8-in. (20-CM) SPACINGS: W, WEIGHT IN Lb/FT^2 (KG/M^2) STC RATING IN DECIBELS.

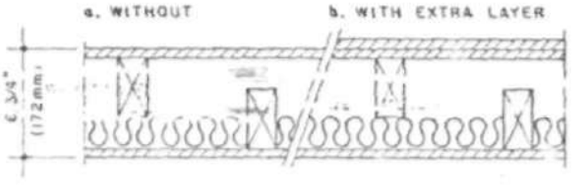
32.



W = 13.5 (66)

STC = 45+

33.



W_a = 4.7 (23)

STC_a = 46

W_b = 7.5 (37)

STC_b = 50+

FIGURE A5. SOUND-INSULATION VALUES OF WOOD-STUD PARTITION WALLS WITH 8-in. (20 CM) SPACINGS: W, WEIGHT IN Lb/FT² (KG/M²): STC RATING IN DECIBELS.

34.



W_a = 14 (68)

STC_a = 40+

W_b = 15 (73)

STC_b = 45+

35.



W = 12.3 (60)

STC = 47

36.

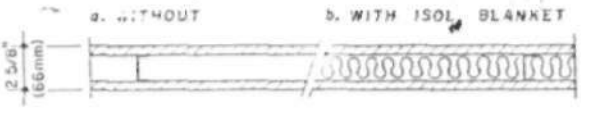


W = 7.5 (37)

STC = 48

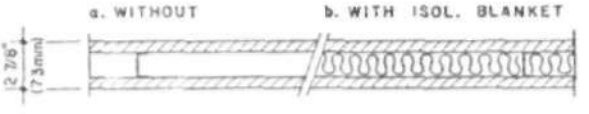
FIGURE A6. SOUND INSULATION VALUES OF METAL-STUD PARTITION WALLS WITH 16-in. (41 CM) SPACINGS: W, WEIGHT IN Lb/FT² (KG/M²) STC RATING IN DECIBELS.

37.



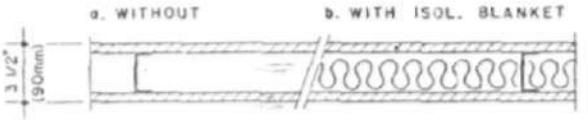
Wa = 5.1 (25)
STCa = 35
Wb = 5.3 (26)
STCb = 41

38.



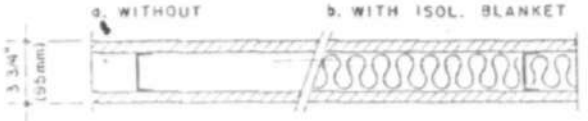
Wa = 6.1 (30)
STCa = 38
Wb = 6.3 (31)
STCb = 46

39.



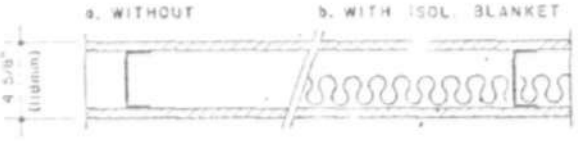
Wa = 4.2 (21)
STCa = 36
Wb = 4.7 (23)
STCb = 44

40.



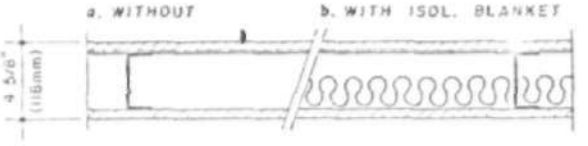
Wa = 5.4 (26)
STCa = 40
Wb = 6.3 (31)
STCb = 46+

41.



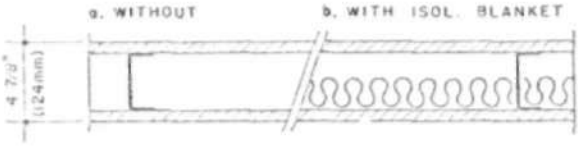
Wa = 4.2 (21)
STCa = 37
Wb = 4.7 (23)
STCb = 46

42.



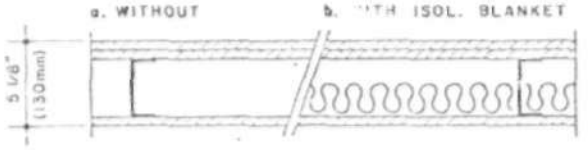
Wa = 5.2 (25)
STCa = 40
Wb = 5.7 (28)
STCb = 48

43.



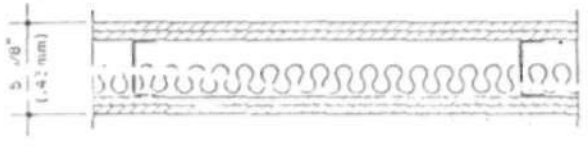
Wa = 5.4 (26)
STCa = 39
Wb = 5.9 (29)
STCb = 47

44.



Wa = 6.7 (33)
STCa = 42
Wb = 7.2 (35)
STCb = 48+

45.

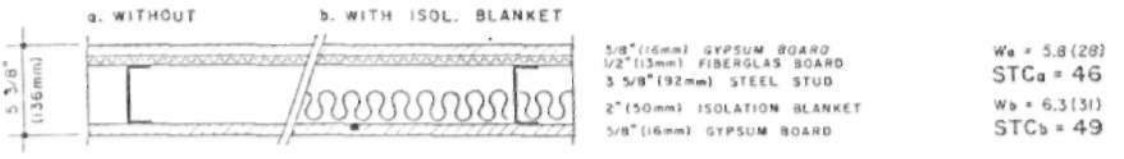


W = 9.2 (45)

STC = 51

FIGURE A7. SOUND INSULATION VALUES OF METAL-STUD PARTITION WALLS WITH 24 in (61 cm) SPACINGS: W, WEIGHT IN Lb/FT² (KG/M²): STC, RATING IN DECIBELS.

46.



47.

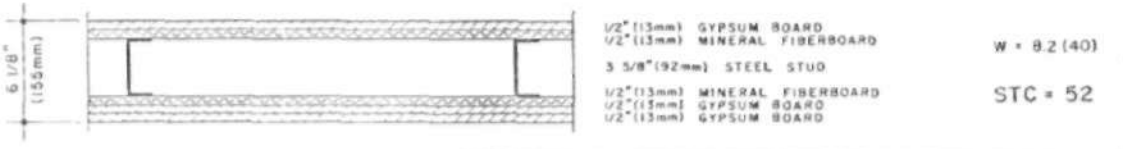
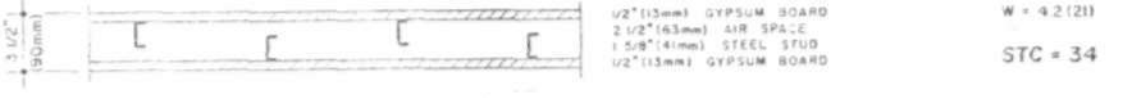


FIGURE A7. SOUND INSULATION VALUES OF METAL-STUD PARTITION WALLS WITH 24-in (61CM) SPACINGS: W, WEIGHT IN Lb/FT² (KG/M²): STC, RATING IN DECIBELS.

48.



49.



50.

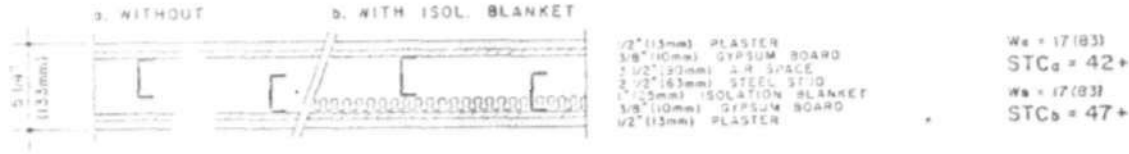
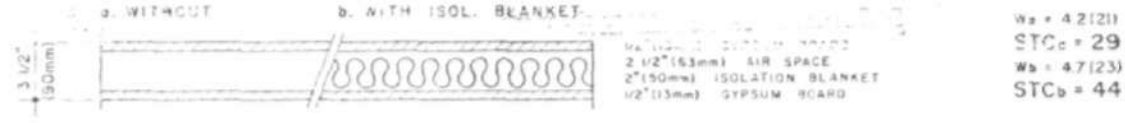
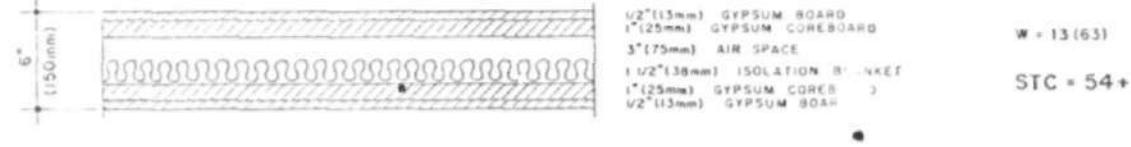


FIGURE A8. SOUND INSULATION VALUES OF STAGGERED METAL-STUD PARTITION WALLS WITH 8-in. (20CM) SPACINGS: W, WEIGHT IN Lb/FT² (KG/M²): STC, RATING IN DECIBELS.

51.



52.



53.

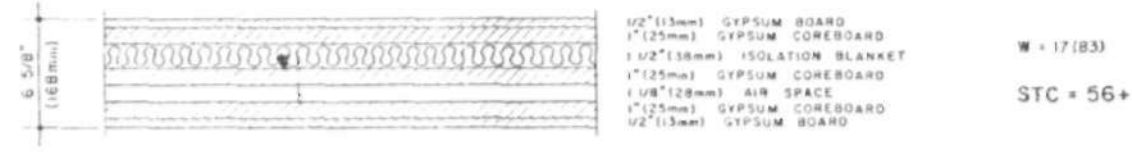
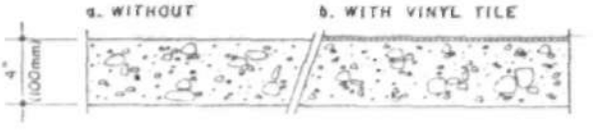


FIGURE A9. SOUND INSULATION VALUES OF STUDLESS PARTITION WALLS: W, WEIGHT IN Lb/FT² (KG/M²); STC, RATING IN DECIBELS.

APPENDIX B

The accompanying figures B1 to B4 are of typical floor constructions with their corresponding architectural-acoustical data. The sound transmission class (STC) given are average values derived from tests and research carried out by leading authorities in the field of Acoustical testing and Research. It should be noted that these values may fall below the stated value due to poor workmanship and flanking transmission

1. 4" (100mm) CONCRETE SLAB



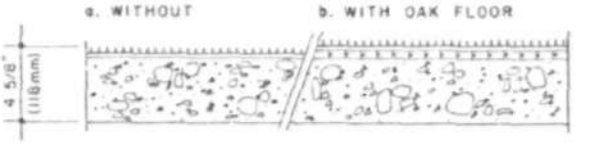
Wa = 53(260)
STCa = 44
IICa = 25
Wb = 54(265)
STCb = 44
IICb = 28

2.



Wa = 55(270)
STCa = 44
IICa = 45
Wb = 56(275)
STCb = 44
IICb = 45

3.



Wa = 54(265)
STCa = 44
IICa = 80
Wb = 56(275)
STCb = 44
IICb = 84

4. 5" (125mm) CONCRETE SLAB



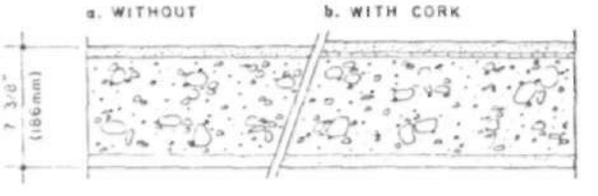
W = 70(340)
STC = 48+
IIC = 47

5.



W = 90(440)
STC = 51
IIC = 53

6. 6" (150mm) CONCRETE SLAB

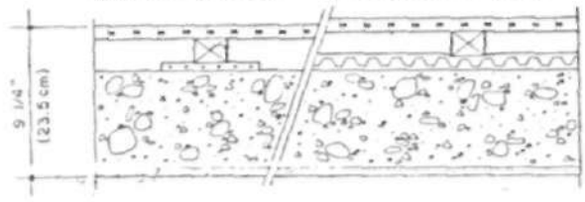


Wa = 85(415)
STCa = 47
IICa = 31
Wb = 85(415)
STCb = 47
IICb = 46

FIGURE B1. SOUND-INSULATION VALUES OF CAST-IN-PLACE CONCRETE FLOORS: W, WEIGHT IN Lb/FT² (KG/M²) STC RATING IN DECIBELS; IIC (IMPACT INSULATION CLASS RATING).

7.

a. WITH CORK PAD b. WITH GLASS WOOL

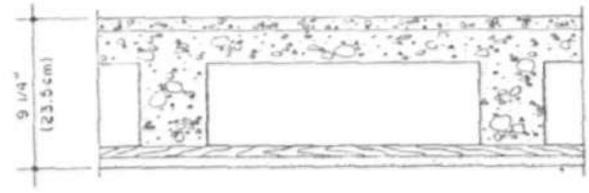


5/8"(19mm) T&G WOOD FLOOR
1 1/2" x 2" (38x50mm) SLEEPER
1/2"(13mm) CORK / 1"(25mm) GLASS-WOOL QUILT
6"(150mm) CONCRETE SLAB
1/2"(13mm) PLASTER

W_a = 75(365)
STC_a = 53+
IIC_a = 53

W_b = 83(405)
STC_b = 55
IIC_b = 57

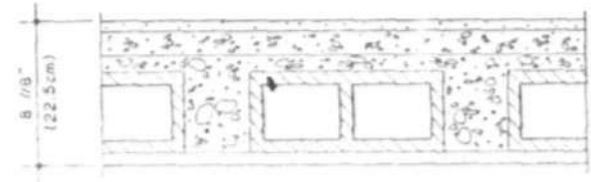
8. BEAM AND SLAB CONSTRUCTION



3/4"(19mm) CONCRETE TOPPING
2"(50mm) REINFORCED CONCRETE SLAB
5 1/4"(133mm) AIR SPACE
5/8"(16mm) WOOD LATH
5/8"(16mm) REEDS & PLASTER

W = 45(220)
STC = 46
IIC = 42

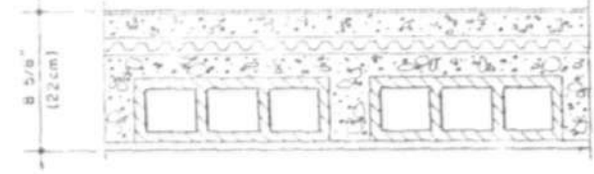
9. CONCRETE FLOOR WITH HOLLOW BLOCKS



5/8"(16mm) PITCH-MASTIC ON FELT
1 1/2"(38mm) CONCRETE TOPPING
REINFORCED CONCRETE FLOOR
5"x12"(12.5x30.5cm) HOLLOW BLOCK
3/4"(19mm) PLASTER

W = 70(340)
STC = 49
IIC = 30

10.

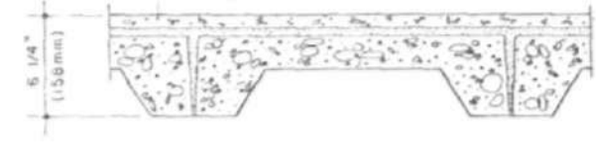


THERMOPLASTIC TILE
1 1/2"(38mm) CONCRETE TOPPING
1"(25mm) BITUMEN-BONDED GLASS WOOL
REINFORCED CONCRETE FLOOR
4"x12"(10x30.5cm) HOLLOW BLOCK
1/2"(13mm) PLASTER

W = 65(315)
STC = 52
IIC = 47

FIGURE B1. SOUND-INSULATION VALUES OF CAST-IN-PLACE CONCRETE FLOORS: W, WEIGHT IN Lb/FT² (KG/M²) STC RATING IN DECIBELS; IIC IMPACT INSULATION RATING).

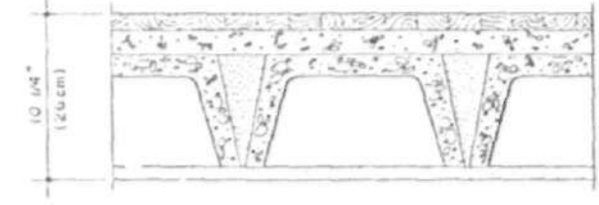
11.



3/4"(19mm) CONCRETE TOPPING MORTAR
5"(125mm) PRECAST CONCRETE ELEMENT

W = 28(136)
STC = 42
IIC = 32

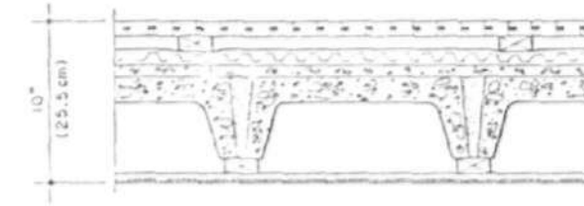
12.



1"(25mm) WOOD FLOOR
1 1/2"(38mm) CONCRETE TOPPING
7"(180mm) PRECAST CONCRETE ELEMENT
3/4"(19mm) PLASTER

W = 65(315)
STC = 47
IIC = 42

13.

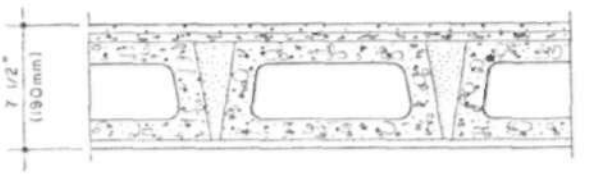


7/8"(22mm) T&G WOOD FLOOR
1"x2"(25x50mm) SLEEPER
1"(25mm) GLASS-WOOL QUILT
3/4"(19mm) CONCRETE TOPPING
5"(125mm) PRECAST CONCRETE ELEMENT
1"x2"(25x50mm) WOOD BATTEN
5/8"(10mm) GYPSUM BOARD
1/8"(3mm) PLASTER

W = 4[illegible](220)
STC = 50
IIC = 53

FIGURE B2. SOUND INSULATION VALUES OF PRECAST CONCRETE FLOORS: W, WEIGHT IN Lb/FT² (KG/M²) STC RATING IN DECIBELS; IIC (IMPACT INSULATION CLASS RATING).

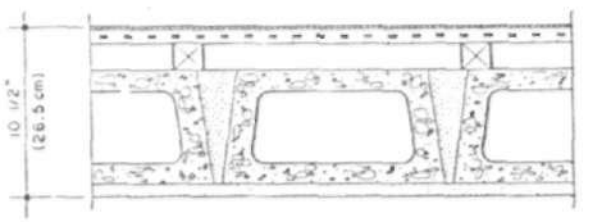
14.



1/2"(13mm) PITCH-MASTIC FLOOR
1/2"(13mm) CONCRETE TOPPING
6"(150mm) PRECAST CONCRETE ELEMENT
1/2"(13mm) PLASTER

W = 55(270)
STC = 45
IIC = 31

15.

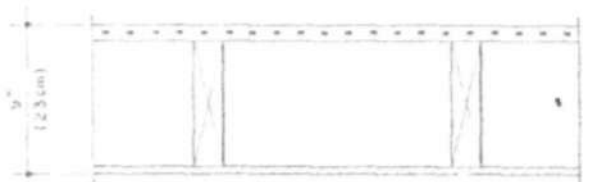


LINOLEUM
7/8"(22mm) T&G WOOD FLOOR
2"x2"(50x50mm) WOOD BATTEN
7"(180mm) PRECAST CONCRETE ELEMENT
3/4"(19mm) PLASTER

W = 45(220)
STC = 44
IIC = 48

FIGURE B2 (CONTINUED)

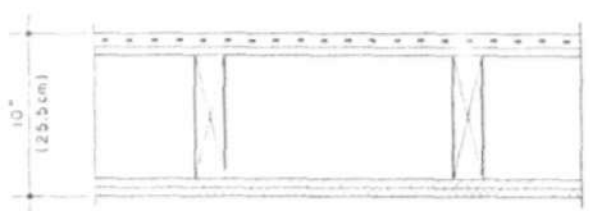
16.



7/8"(22mm) T&G WOOD FLOOR
2"x8"(5x20cm) WOOD JOIST
3/8"(10mm) GYPSUM BOARD

W = 7(34)
STC = 34
IIC = 32

17.

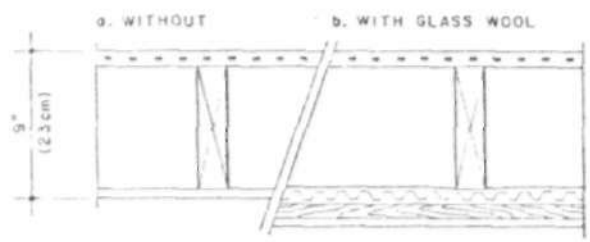


25/32"(20mm) HARDWOOD FLOOR
1/2"(13mm) PLYWOOD
2"x8"(5x20cm) WOOD JOIST
1/2"(13mm) GYPSUM BOARD
CEILING TILE

W = 9.9(48)
STC = 39
IIC = 37

18.

a. WITHOUT b. WITH GLASS WOOL

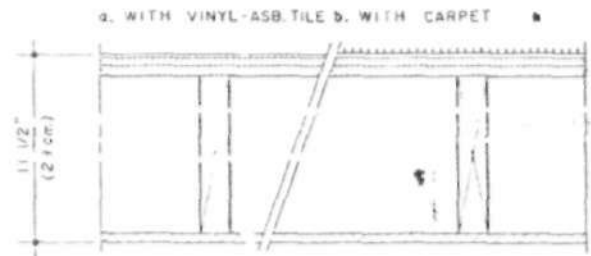


7/8"(22mm) T&G WOOD FLOOR
2"x8"(5x20cm) WOOD JOIST
1"(25mm) GLASS-WOOL QUILT
1"x2"(25x50mm) WOOD BATTEN
1/2"(13mm) PLASTER ON METAL LATH // 1/2"(13mm) PLASTER ON WOOD LATH

Wa = 13(63)
STCa = 41
IICa = 36
Wb = 12(59)
STCb = 43
IICb = 43

19.

a. WITH VINYL-ASB. TILE b. WITH CARPET

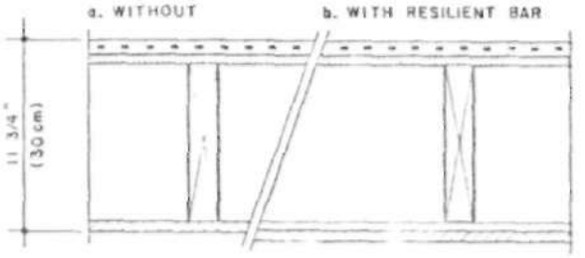


1/8"(3mm) VINYL-ASB. TILE // 3/8"(10mm) NYLON CARPET 1/4"(6mm) FOAM-RUBBER PAD
1/2"(13mm) PLYWOOD
5/8"(16mm) PLYWOOD
2"x10"(5x25.5cm) WOOD JOIST
1/2"(13mm) GYPSUM BOARD

Wa = 9(44)
STCa = 37
IICa = 33
Wb = 9(44)
STCb = 37
IICb = 53

FIGURE B3. SOUND INSULATION VALUES OF WOOD-JOIST FLOORS WITH 16 in (41CM) SPACINGS: W, WEIGH IN Lb/FT^2 (KG/M^2); STC RATING IN DECIBELS; IMPACT INSULATION CLASS RATING (IIC).

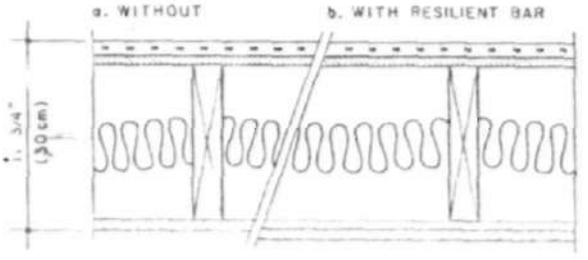
20.



Wa = 9.5 (46)
STCa = 37
IICa = 32

Wb = 9.6 (47)
STCb = 47
IICb = 39

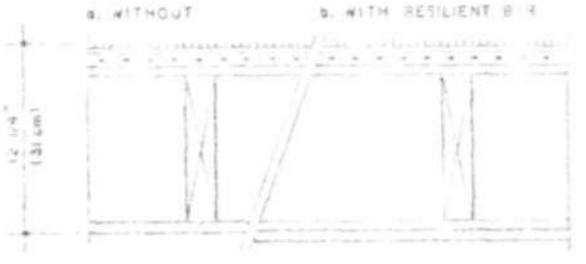
21.



Wa = 10 (49)
STCa = 40
IICa = 32

Wb = 10.1 (49)
STCb = 49
IICb = 46

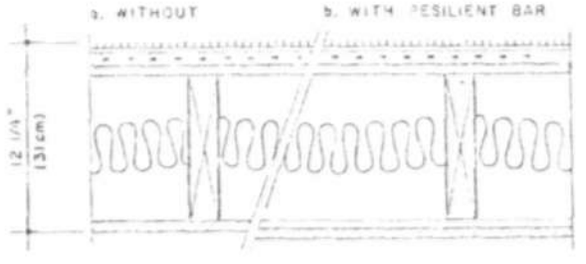
22.



Wa = 10 (49)
STCa = 38
IICa = 56

Wb = 10.1 (49)
STCb = 47
IICb = 56

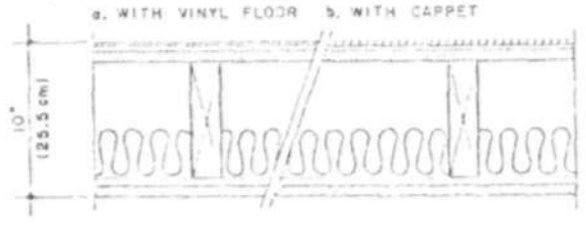
23.



Wa = 10.5 (51)
STCa = 39
IICa = 58

Wb = 10.6 (51)
STCb = 50
IICb = 70

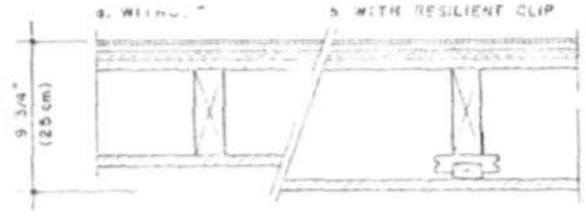
24.



Wa = 8.9 (43)
STCa = 45
IICa = 44

Wb = 8.6 (42)
STCb = 47
IICb = 69

25.

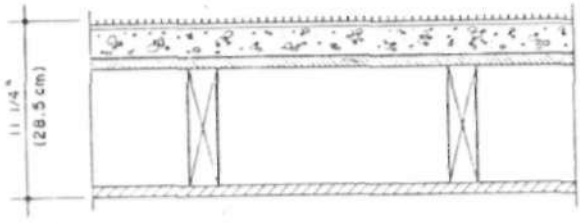


Wa = 9.5 (46)
STCa = 38
IICa = 34

Wb = 9.3 (45)
STCb = 50
IICb = 47

FIGURE B3 (CONTINUED). AS ABOVE.

26.



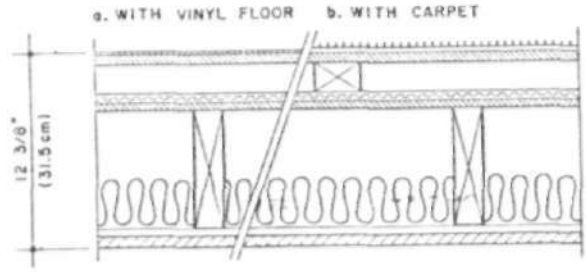
44 oz/yd² (1.5 kg/m²) CARPET
40 oz/yd² (1.35 kg/m²) HAIR PAD
1 5/8" (41mm) LIGHT-WEIGHT CONCRETE
POLYETHYLENE FILM
5/8" (16mm) PLYWOOD

2"x8" (5x20cm) WOOD JOIST

5/8" (16mm) GYPSUM BOARD

W = 18.4 (90)
STC = 47
IIC = 66

27.



5/64" (2mm) VINYL // 44 oz/yd² (1.5 kg/m²) CARPET
FLOOR // 40 oz/yd² (1.35 kg/m²) HAIR PAD
5/8" (16mm) PLYWOOD SUBFLOOR
2"x3" (50x75mm) SLEEPER
1/2" (13mm) CANE FIBERBOARD
1/2" (13mm) PLYWOOD

2"x8" (5x20cm) WOOD JOIST

3" (75mm) ISOLATION BLANKET

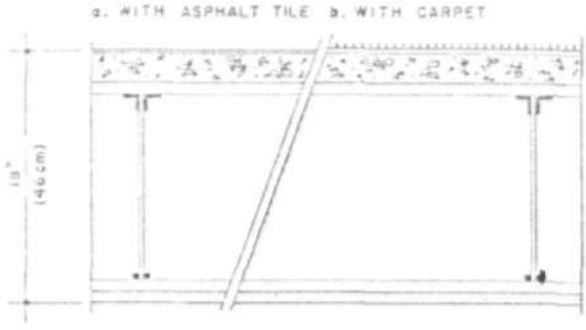
RESILIENT BAR 24" (61cm) O.C.
5/8" (16mm) GYPSUM BOARD

Wa = 10.9 (53)
STCa = 52
IICa = 49

Wb = 11.7 (57)
STCb = 51
IICb = 78

FIGURE B3 (CONTINUED). AS ABOVE.

28.



1/8" (3mm) ASPHALT TILE // 3/8" (10mm) CARPET
1/4" (6mm) FELT PAD
2 1/2" (63mm) CONCRETE
CORRUGATED STEEL

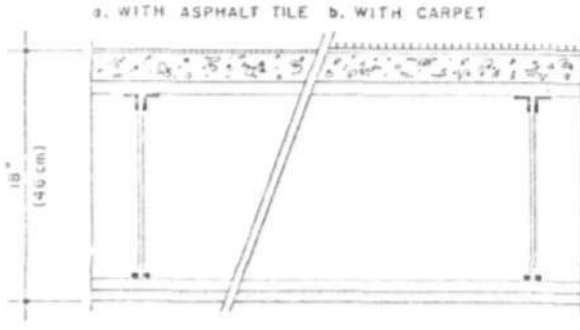
14" (35.5 cm) STEEL-BAR JOIST

3/4" (19mm) FURRING CHANNEL
5/8" (16mm) PERLITE-GYPSUM PLASTER

Wa = 41 (200)
STCa = 49
IICa = 35

Wb = 41 (200)
STCb = 49
IICb = 64

29.



1/8" (3mm) ASPHALT TILE // 3/8" (10mm) CARPET
1/4" (6mm) FELT PAD
2 1/2" (63mm) LIGHT-WEIGHT CONCRETE
CORRUGATED STEEL

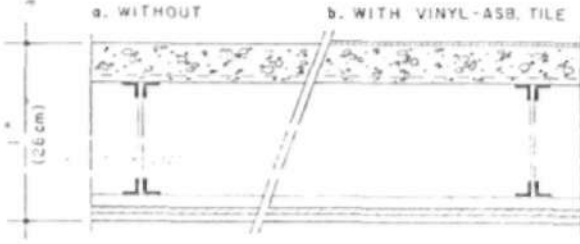
14" (35.5 cm) STEEL-BAR JOIST

3/4" (19mm) FURRING CHANNEL
5/8" (16mm) PLASTER ON METAL LATH

Wa = 23.2 (113)
STCa = 47
IICa = 37

Wb = 23.2 (113)
STCb = 47
IICb = 59

30.



1/8" (3mm) VINYL-ASB. TILE
2" (50mm) CONCRETE
3/8" (10mm) METAL RIB LATH

7" (180mm) STEEL-BAR JOIST 27" (68.6 cm) O.C.

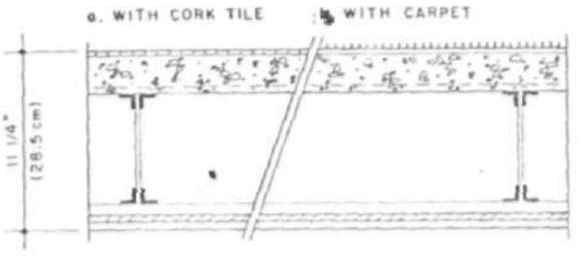
3/4" (19mm) FURRING CHANNEL
3/8" (10mm) GYPSUM BOARD
1/2" (13mm) PLASTER

Wa = 38.2 (187)
STCa = 48
IICa = 33

Wb = 38.3 (188)
STCb = 48
IICb = 38

FIGURE B4. SOUND-INSULATION VALUES OF STEEL-JOIST FLOORS: W, WEIGHT IN LB/FT² (KG/M²); STC RATING IN DECIBELS; IIC (IMPACT INSULATION CLASS RATING).

31.



32.

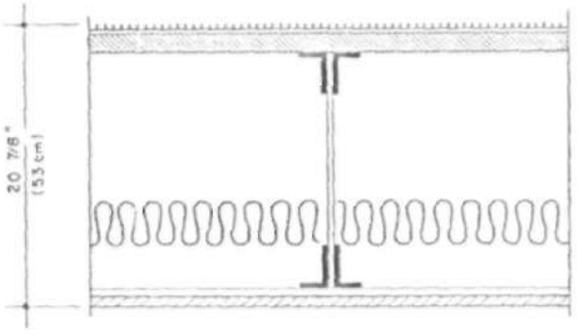


FIGURE A4 (CONTINUED). AS ABOVE.