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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

SOUND TRANSMISSION IN BUILDINGS

PRACTICAL NOTES FOR ARCHITECTS AND BUILDERS

BY

R. FITZMAURICE, B.Sc., Assoc.M.Inst.C.E.

and

WILLIAM ALLEN, B.Arch., A.R.I.B.A.

4/-

LONDON · HIS MAJESTY'S STATIONERY OFFICE · 1939

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PREFATORY NOTE

IN the last few years special attention has been given in the joint work on architectural acoustics of the National Physical Laboratory and the Building Research Station to the question of noise transmission in buildings. The subject is well recognized to be important. If emphasis on its importance were needed, it was provided by the work of the Committee of the Ministry of Health on the Construction of Flats for the Working Classes. The inquiries made by that Committee served to bring out, with new force, the necessity for an attack on the problem of noise in buildings, and gave an impetus to the investigations.

The investigations began with a study of noise transmission through the different elements of the fabric of a building, i.e. through walls and floors. Much was learnt on the effectiveness of different forms of floor and wall construction, on the value of different types of floor covering, of " floating " floors, of suspended and independent ceilings, and so forth. This work was fundamental and necessary, but it fairly soon became clear that investigations on the separate elements of the building structure taken independently were not enough. The interaction of walls, floors, and ceilings was of no less importance than the effect of the individual components. It was decided, therefore, to supplement the studies of these by investigations in a structure in which the effect of walls, floors, ceilings, and their interconnections were taken together. A steel frame became available at the Building Research Station which lent itself very well to experiments of this kind, for with it modifications of construction could be readily made for investigations on a full scale. The various stages of this work have been briefly described in the Annual Reports of the Building Research Board, and a full account of it is now being prepared by the National Physical Laboratory. In general, it may be said that a technique of construction offering an insulation of a high order has now been developed.

At the same time advantage was taken of opportunities provided by outside authorities, mainly Government Departments, for tests in actual buildings of different types. As this work proceeded, it became clear that with normal forms of construction only a limited degree of insulation against sound can be provided, and it has finally been determined that so long as a building structure is rigidly continuous in all its parts, as most buildings are, the overall insulation obtainable against air-borne sound is unlikely to be better than that which one would expect from 9-in. brick wall or a hollow concrete block floor. Such an insulation value is inadequate for many present-day conditions.

When this point had been definitely determined, the problem of applying the new technique, in terms of practicable constructions, became of increased importance, and every effort was made to resolve it. The work has taken some time, but it is believed that a certain degree of success has now been achieved, sufficient at least to warrant suggestions which, if followed, will bring real improvement not at present attainable by normal methods of construction. It would be difficult, however, to present the full effect of the investigations by only giving the values, in units of sound reduction, of various forms of floor or wall construction, of their interconnections or lack of connection. In this publication, therefore, an attempt has been made to give the results in the form in which they can be most readily appreciated by the architect and builder—namely in the form of suggested practical constructions.

In effect, therefore, the volume may be taken as showing, in terms of practical constructions, how the subject presents itself to-day. Undoubtedly modifications in detail will suggest themselves as the investigations proceed further, for the subject is by no means exhausted, but it is believed that the broad outlines will remain, and the conclusions of the authors are therefore presented with confidence that they are worthy of trial by architects and builders. The constructions now advocated must necessarily involve extra labour in detailing on the part of the architect, as well as more care in certain directions on the part of the building craftsman, but it can be said that very considerable improvement in sound insulation may be secured by using the technique, and that in this volume there is at least presented a solution for this important problem.

The report is based on team work in which members of the Sound Transmission Sub-Committee of the Architectural Acoustics Committee, officers of the National Physical Laboratory and of officers of the Building Research Station including others than the immediate authors have taken part. It is believed that as a result of their joint efforts a real contribution has been made to the problem of the reduction of noise in buildings which is expressed not only in this volume but in other publications giving more directly an account of the experimental work.

The authors wish specially to acknowledge the valuable help they have received from their Assistant, Mr. K. W. Barns, in resolving the problems of architectural detailing which are presented by the types of construction described in the report.

R. E. STRADLING
Director of Building Research

BUILDING RESEARCH STATION,
Garston, Herts.
November, 1939

CONTENTS

LIST OF FIGURES

SOUND TRANSMISSION IN BUILDINGS

INTRODUCTION

IT cannot be too strongly emphasized that the approach to the problem of sound insulation in buildings begins at the earliest stage of design. It will be shown in these notes that good sound insulation is not always easily attained, and the first step is to ensure that the need for insulation is reduced to a minimum. In planning it is essential that sources of noise should be grouped together and separated as far as possible from those rooms where quiet is desired. It is very much open to question whether it would be possible to contrive structural insulation adequate to compensate for serious deficiencies in planning ; and, in any event, considerable additional cost would be entailed.

The first step, then, is to ensure that unnecessary noises are reduced to the minimum. Equipment should be chosen with a view to silence in operation. Electric machinery ought to have quiet rotating parts, properly balanced, and free from brush-scream. Quiet electric lighting switches are now on the market. Sanitary equipment can be either quiet or noisy ; silent flushing of W.Cs. and filling of tanks is most desirable, and can be obtained. All pipes ought to be streamlined. It is true that at the present day items of this kind usually mean some extra cost, but if there was a greater demand for quiet equipment and if technical engineers would concentrate upon the problems involved, cost might be reduced later.

When, by the aid of planning and the careful choice of equipment the need for sound insulation has been reduced to a minimum, it is necessary to identify the paths by which unwanted sound will travel and to ensure that the construction adopted is adequate for the particular conditions.

In the following pages, the subject is dealt with in three sections. First there is a discussion of the way in which sound is transmitted from one part of a structure to another together with examples. The second section deals with the amount of noise associated with various types of occupancy, the degree of quiet required in different circumstances, and includes nomograms by which it is possible quite quickly to show whether a structure is adequately sound resistant or not. The third section deals with the methods of introducing discontinuities into structures to achieve insulation of a higher order than is possible in rigidly continuous structures. This work is so far largely based on laboratory experiments, and practical experience with many of the suggested constructions is yet to be obtained. However, it is considered that the principles are so well-founded as to afford a broad justification of the suggestions made.

The suggestions for detail cover most of the current structural types where insulation of a high order is in demand, but there will also be many individual problems, not directly represented in the selection, which require similar treatment. Many such have, in fact, been met in the day-to-day inquiries at the Building Research Station, and it is interesting to note that in none of these has any difficulty been found in applying what are apparently the fundamental principles of the subject, although in each case it was necessary to devise novel structural details.

I. THE NATURE AND TRANSMISSION OF SOUND

Nature of sound—Origin of sound—Mode of vibration of structures—Transmission of air-borne sound—Analysis of transmission paths—How impact sounds are transmitted—Summary.

For a long time past it has been customary for the designers of buildings to think of sound insulation between two rooms in a building only in terms of the sound insulation of the intervening element, whether a wall or a floor. We know now that this is not sufficient ; sound may and very often does travel by circuitous paths in buildings, and there are many common structural combinations where the more devious path is the one by which most of the sound is transmitted. The first step, therefore, is to make a rapid analysis of any proposed design, in order to ascertain which are the paths by which sound will be most readily transmitted ; in other words, to identify the component offering the least insulation. The object of this chapter is to show how this may be done, and it is desirable as a preliminary to describe the nature of sound and the way in which it travels in structures.

NATURE OF SOUND

Sound takes the form of vibrations which travel outwards in all directions, from some source of disturbance, through the surrounding media.

A vibration has two important characteristics—*frequency*, which is usually defined as the number of vibrations per second, and *amplitude*, which is the maximum distance through which any point in a vibrating material is displaced from its position of rest. The range of frequencies of vibrations which constitute sound (i.e. which can be heard by the human ear) is usually taken to be from about 20 cycles per second to 20,000 cycles per second, the actual range depending on the sensitiveness of the listener's ears. If the frequency of the vibrations is increased, the pitch of the sound will be raised. If the amplitude of the vibrations is increased, the sound will be louder. The frequency, or pitch, of sound is of practical importance, *because the insulation afforded by building structures varies according to frequency, and the sensitiveness of human hearing also varies at different frequencies.* These are complications of which account must be taken in refined acoustic design, though for the purpose of this volume, average and simplified values have been taken from which approximations may be made. Exceptions to the simplified rules which should be considered in everyday practice are indicated.

ORIGIN OF SOUND

Sounds usually originate in one of two ways :

(*a*) As a disturbance in air, such as the human voice or music from an instrument—usually called an " air-borne " sound.

(*b*) As a blow or impact applied directly to some part of the building structure, in which case it is termed " impact " or " contact " sound. Examples are footsteps on a floor or vibration from a machine fixed direct to a floor.

The practical importance of this distinction lies in the fact that *rather different methods have to be adopted to insulate the two kinds of noise in buildings, although the fundamental principles of sound transmission are the same.*

MODE OF VIBRATION OF STRUCTURES

A structure, whether wall or floor, may be set in vibration by an impact or when a sound wave in air reaches it. The vibrations will be transmitted to the opposite side of the structure in two ways :

(1) By vibration of the structure as a whole, which bends in the manner of a flexible plate or diaphragm.

(2) By a sound wave of compression and rarefaction which actually travels through the material of the structure as light travels through glass, without causing it to vibrate as a whole.

Of these two modes of vibration it is the first which is important in the transmission of sound in buildings.

Since light structures are more easily set in vibration than heavy ones, it is obvious that there must be a weight relationship of some kind in operation. Experimental work has long since confirmed that for simple homogeneous structures a relationship does exist for air-borne sound, at least. It is such, however, that doubling the weight only produces a slight improvement in conditions, and unfortunately a point is quickly reached in this manner where, to secure adequate insulation to deal with loud noises, an extravagant weight of material is necessary.

The frequency of the vibration of structures must be mentioned at this stage. Any building element, be it a wall or floor, when subjected to some disturbance, such as a sound wave in air or a blow, tends to vibrate more readily at certain frequencies than at others. The lowest frequency of such vibration is termed the natural frequency of the structure, and the range of higher frequencies corresponds to a series of vibrations which are frequently multiples of the natural frequency. When the frequency of the sound wave in air impinging on the structure corresponds to the natural frequency of the structure, a state of " resonance " is said to exist ; and less sound energy is required to build up a large amplitude of vibration in the structure. Consequently, sound is transmitted more readily. The natural frequency of floors and walls in buildings tends to be low, *and therefore it is more difficult to insulate noises of low pitch.* A hum or boom will tend to be very persistent in a building.

The natural frequency of vibration of a structure depends upon the physical properties of the materials of which it is made and, to an important extent, upon the dimensions of the structure. Thus the study of sound transmission is complicated, for different values will be obtained for any single type of structure, depending upon the frequency of the sounds to be insulated. There will also be differences in the sound transmission with differences in the overall dimensions of the structure.

The data presented in this book are based on average values of sound transmission, through common types of structure over a range of frequencies. Only in this way is it possible to simplify the treatment of the subject. For special cases, where it is desired to take due account of different frequencies of sound to be insulated, the tables given in Building Research Special Report No. 26 should be consulted.

THE TRANSMISSION OF AIR-BORNE SOUND

If we consider the case of a room in a building which contains a source of sound, such as, say, a wireless loudspeaker, then the air in the room is set in vibration and the sound will travel outwards from the source by any continuous air paths. Open doors or windows constitute such paths and even the narrow crack round a poorly fitting door or temporary partition may allow the passage of a large amount of noise.

The vibrations in the air of the room will set all the bounding structures in vibration, walls and floors alike. If the walls and floors are all of much the same order of weight, they will all vibrate with very much the same amplitude. If, now, we consider the conditions in an adjacent room, then not only will the dividing walls between the two rooms be vibrating but also the side walls and floors which are common to the two rooms. This is shown diagrammatically in Figure 1. Thus, in dealing with the insulation of air-borne noise between different parts of a building, *it is never sufficient to think in terms of the dividing structure only.* This applies equally to walls and floors.

DIAGRAMMATIC INDICATION OF HOW AIR-BORNE SOUND TRAVELS IN A CONTINUOUS BUILDING STRUCTURE

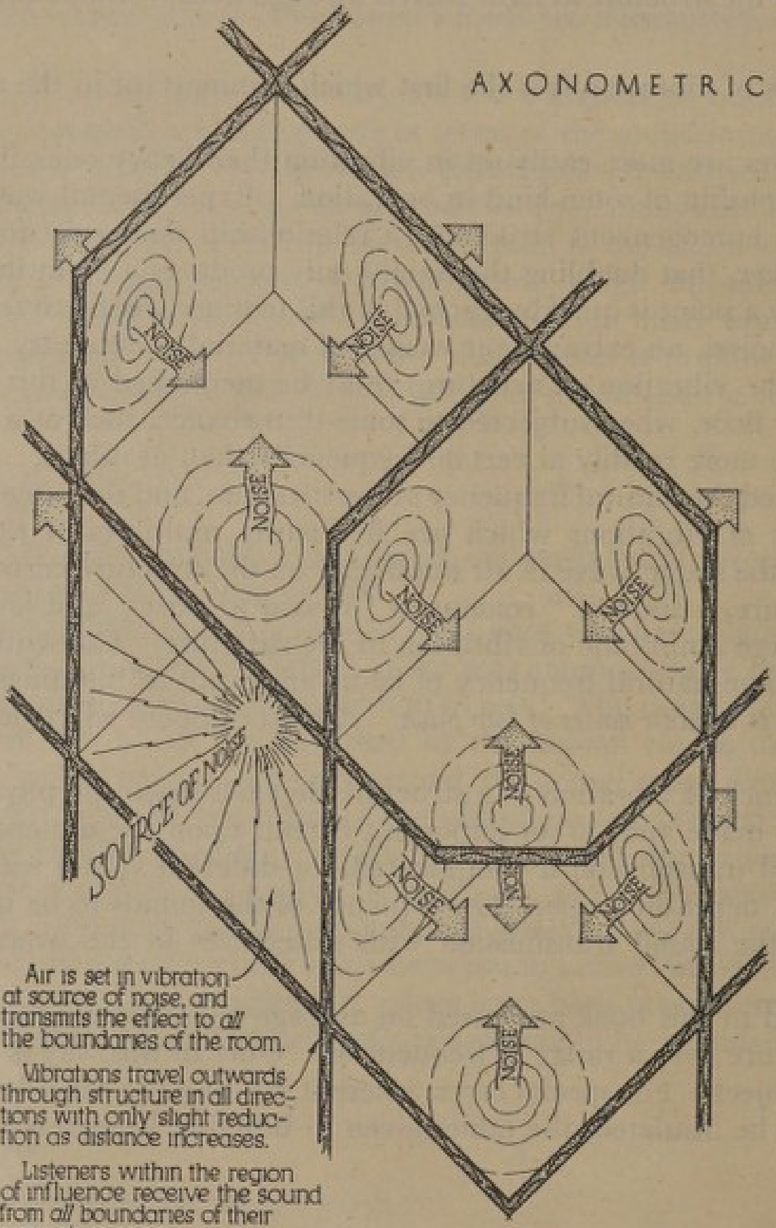


FIGURE 1.

In a problem of sound transmission it is the path offering least resistance in the insulation which will determine the amount of noise which will be heard, and it will often be unprofitable to incur additional expense in making, say, a highly insulating dividing wall between two rooms when the common side walls provide a ready path for transmission of noise.

The problem of the transmission of sound by indirect paths is still under investigation, and there is not yet sufficient information based on scientific measurements to lay down hard-and-fast rules.

From elementary principles, however, it is possible to formulate some simple ideas on the subject and, in particular, to enable the architect *to decide which is the path offering least resistance to the sound in any given case, for this is the problem which will most often arise in practice.*

Some examples are shown in Figure 2.

ANALYSIS OF TRANSMISSION PATHS

CASE 1.—*A flat or office building with massive external walls, reinforced concrete or hollow tile floors. The dividing wall between rooms A and B is a solid structural wall, 9 in. thick, and a relatively light clinker concrete slab wall is provided against the corridor. It is required to determine what will be the factor governing the sound transmission from Room A to Room B.*

The external wall, being the most massive, will be the least readily set in vibration.

The 9-in. dividing wall and the floor system, being of much the same order of weight, will be very similar in the extent to which they are set in vibration.

The 2½-in. clinker concrete slab partition is obviously weak. It is bonded, however, into a fairly massive 9-in. wall and its transmission into Room B will be reduced thereby, so that the overall transmission of the system would approximate that of the 9-in. dividing wall.

CASE 2.—*As Case 1, but with a light clinker concrete slab dividing wall.*

In this case it seems likely that the sound transmission should be approximately equally shared between the dividing wall and the corridor wall, though the latter may be slightly improved by its connection to the relatively heavier floor and ceiling. The overall transmission would be greater than Case 1.

CASE 3.—*As Case 2, but it is proposed to improve the insulation between rooms A and B by erecting a special double partition with edge isolation.*

With this arrangement the weak point will probably be the light corridor wall, which will not be stiffened by the partition owing to the edge isolation of the latter. Consequently this arrangement is unlikely to show any appreciable advantage over the conditions in Case 2, and there is no definite justification for the expense of the special construction of the partition.

CASE 4.—*A double partition between rooms A and B, but without edge isolation: the continuity of the corridor partition is broken where it meets the double partition.*

By doing this the transmission along the corridor partition is overcome, except in so far as it is carried across the gap by the floor or ceiling, and the overall insulation between room A and room B will probably be that of the floors or outer wall. In this case the floors are less massive than the outer wall and will be the factor deciding the transmission comparable with Case 1.

CASE 5.—*Case 5 shows the method of approach to the problem of vertical transmission of air-borne sound. Solid structural walls not less than 9 in. in thickness carrying board and joist timber floors with lath and plaster ceilings.*

The timber floors are supported by, but not rigidly connected to, the walls, and the transmission horizontally between room A and room B will be largely determined by the wall system, since the floors are discontinuous.

Considering room A as the source of noise, what will be the condition in room C immediately below? The floor is far less massive and rigid than the walls, and consequently the sound transmission will be determined by the floor. The floor could be improved by pugging or by inserting a false ceiling, but it would not be possible by any treatment of the floor to obtain insulation greater than that offered by the walls.

Still considering room A as the source of noise, it will be seen that the conditions in rooms B and D (diagonally below A) will be very similar, but slightly better than in room C.

Case 6.—*Solid structural walls, with continuous reinforced concrete or hollow tile floors and light clinker concrete partitions between rooms.*

Considering the transmission of sound between room A and room C, it is evident that the lower partition is unlikely to vibrate to any greater extent than the floor, and the insulation therefore will be determined by that of the floor system. The conditions in rooms C and D will be very similar, with a source of sound in room A.

THE EFFECTS OF RELATIVE BOUNDARY AREAS

In rooms of average shape, the total of the areas of boundaries constituting indirect paths for sound transmission is usually greater than the single area which is the direct path. This contributes in a measure to the importance of the indirect paths, for the amount of noise heard by a listener in a room is influenced by the area of radiating surface. The effect is to reduce slightly the insulation which one might expect from studying laboratory results. Should the rooms be long and narrow, with the *long* side as the direct path, the indirect paths will be of less importance, but in this book it is the practice in this, as in other instances, to assume average conditions.

The case of the composite building element, where different parts offer different degrees of sound insulation, will often arise. Borrowed lights and recesses in solid walls and partitions are typical of such cases. Methods of calculating the sound transmission of such structures are given fully in Building Research Special Report No. 26, and it will suffice here to note that where the less insulating component of the structure constitutes not less than one-third of the total area there will be no serious error in assuming that the overall insulation is that of the weaker component.

HOW IMPACT SOUNDS ARE TRANSMITTED

An important difference between the problem prescribed by the insulation of air-borne noise and that of impact noise in structures is the vastly greater amount of energy which is imparted to the structure by the impact. For this reason impact noises tend to be very persistent and they travel long distances in buildings. The slamming of a door, or the hiss of water from a noisy valve are sounds which are often met with in everyday practice and they can be heard all over a building.

Owing to the very large amount of energy available in impact noises it is impracticable to obtain the necessary insulation in structures by increasing weight and rigidity. There is little to choose between any of the normal structural floors of such types as reinforced concrete or hollow tile and reinforced concrete in resistance to transmission of footstep noises. Considerable differences in weight and thickness of such floors do not seem to affect materially the amount of noise heard beneath them. It is necessary, therefore, to obtain the required insulation by structural discontinuity.

Since a complete structural break is impossible in floors, it is necessary to interpose some form of resilient between rigid members. Obviously it will be a matter of common sense to place the resilient as near the source of sound as possible in order to reduce to a minimum the amount of sound admitted into the structure. Thus with a floor, if the noise of footsteps cannot be reduced by thick carpet and underfelt it is desirable to interpose a resilient immediately below the wearing surface, in order to prevent impact noises from passing into the structural floor and so to all other parts of the building which are rigidly connected to the floors.

SUMMARY

The following is a brief summary of the more important factors to be taken into account in dealing with the transmission of noise from one part of a building to another:

(1) Sounds may originate as " air-borne " or " impacts " on the structure.

EXAMPLE CASES OF THE TRANSMISSION OF AIR-BORNE SOUND BY INDIRECT PATHS

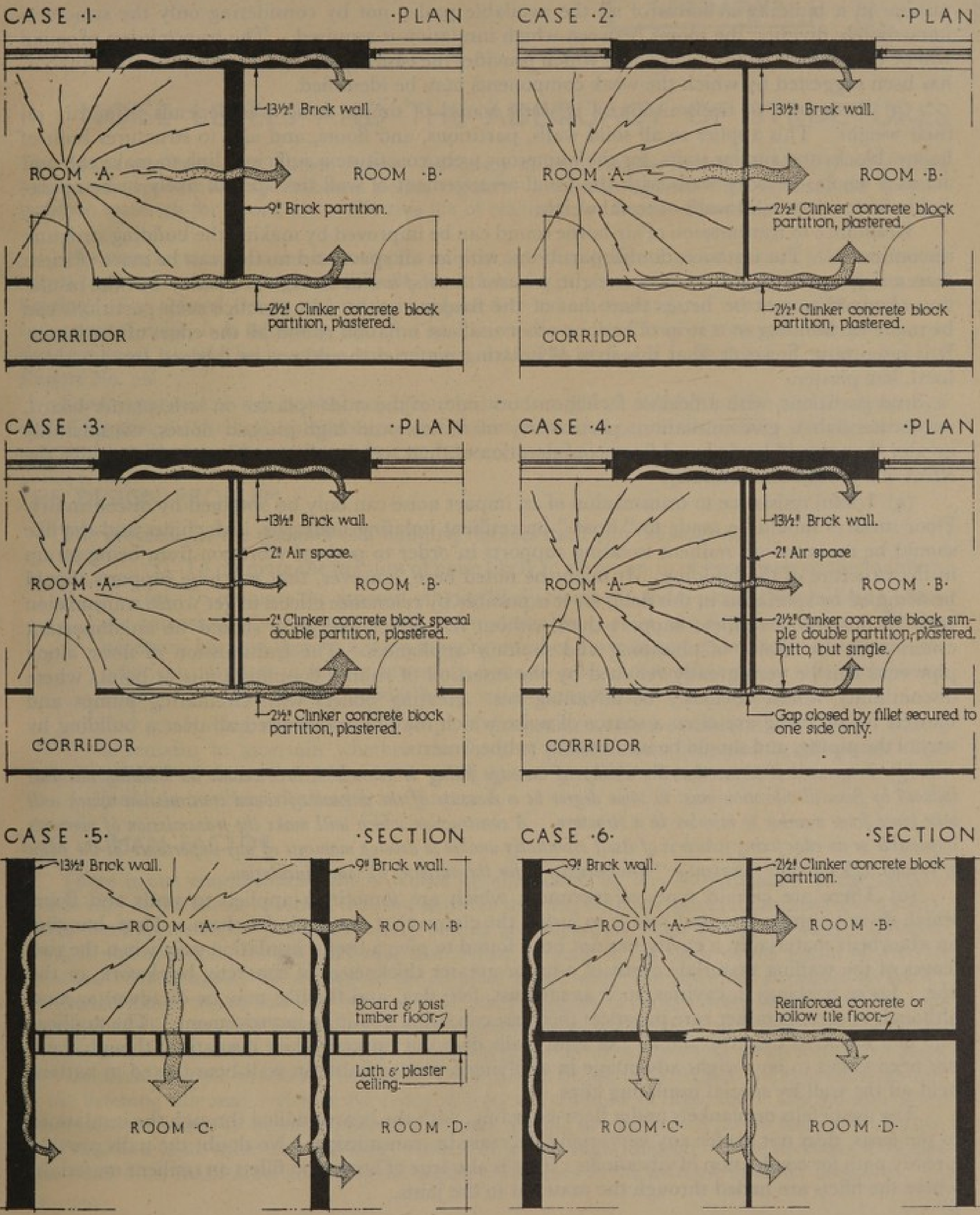


FIGURE 2. NOTE: Arrows indicate paths of sound, in roughly relative amounts. The broadest arrow in each case shows the path offering least resistance to the transmission of sound.

(2) Sound travels by devious paths and it is necessary to consider a problem of sound transmission in a building in terms of all the available paths, not by considering only the structures immediately dividing the rooms between which insulation is required. The transmission of sound will be determined by the component which provides the easiest path. A simple method of analysis has been suggested by which the weak components may be identified.

(3) Resistance to transmission of *air-borne* sound of simple structures depends primarily on their weight. This applies to all solid walls, partitions, and floors, and also to structures built of hollow blocks and similar units, for the numerous webs constitute a sufficient link to make the unit act as a whole. Cavity walls with the usual arrangement of wall ties are not likely to be appreciably better than solid walls of equal weight.

Resistance to transmission of air-borne sound can be improved by making the building structure discontinuous. For instance, double partitions, with an air space and no ties, can be more efficient than a single partition of the same weight, *provided the solid link at the edges is broken* ; but the insulation obtained cannot be better than that of the flanking paths. In practice such partitions can be made by building in a strip of cork or other resilient isolation round all the edges of the leaves. It is important, however, that this strip of isolating material should not be bridged by something hard, like plaster.

Stud partitions, with a flexible facing on both sides of the studs (plaster on lath, plaster-board, or fibrous slabs), give insulation, particularly of middle and high-pitched noises, considerably greater than would be deduced from consideration of their weight alone. They do in fact give the effect of a partial discontinuity.

(4) Useful resistance to transmission of an impact noise can only be obtained by discontinuity. Floor surfaces should be made to " float " on resilient isolating materials. Machines and the like should be mounted on resilient isolating supports in order to prevent vibration from being set up in the structure of the building. It might be noted here, however, that machine supports should be designed by specialists in this field, for it is possible by resonance effects to get worse transmission with an unsuitable resilient support than without it. Quiet operation should be an important criterion in the choice of plumbing and sanitary appliances. The transmission of noise along pipe runs can be very greatly reduced by the insertion of rubber coupling units at points where discontinuity would obviously be advantageous. Heating boilers with circulating pumps and blowers for oil firing are often a source of noise which may be transmitted all over a building by way of the piping, and should be insulated by rubber inserts.

(5) *In general it seems that the ability of an edge fixing or connection to transmit the bending moments induced by flexural vibration must to some degree be a measure of the amount of sound transmission which will take place from member to member in a structure. A construction which will make the transmission of moments impossible or an edge fixing which is of itself essentially unable to develop moments of any importance at the point of contact will therefore represent a " discontinuity " for the purposes of sound insulation.*

(6) There are certain types of treatment which are sometimes applied to walls and floors which do not appear from test results to justify the claims that are made for them. Thus, hanging an absorbent material in a cavity has not been found to give a useful insulation gain when the two leaves of the walling material consist of 2-in. or greater thicknesses of concrete, brickwork, or the like. Loose packings in cavities, such as sawdust, felt, slag, and the like may be disadvantageous, although in certain rather rare instances their use can bring about an improvement. The application of absorbents direct to the face of solid walls does not improve their insulation, though there has been found to be a slight advantage in applying a plaster finish on wall-board fixed to battens held off the wall by special insulating clips.

The use of felts or blankets under floor-boarding, with the boards nailed through the insulations to the joists, does not confer any very useful decrease in transmission. No doubt the nails provide a ready path for conduction of vibrations. This is also true of boards on fillets on resilient materials, where the fillets are nailed through the material to the joists.

II. NOISE LEVELS AND THE ADEQUACY OF STRUCTURES

The design problem—The human factor—Adequacy of construction solved graphically—Insulating outdoor noises—Insulating air-borne noises indoors—Insulation against impact noises on floors—Isolation materials for floors, etc.—Effective life of resilients for floors—Summary

The measurement of noise is a complex subject and the application of the result of the measurements to the practical problem is difficult, for it introduces, among other things, the mechanism of hearing. For refined design, where it is required to take advantage of every possible means of reduction of noise, it is advisable that the insulation of various forms of structure, whether partitions or floors, should be known; the relevant data will be found in Building Research Special Report No. 26.

For the purpose of this book the subject has been simplified, and both noise and the insulation of various structural members against noise have been plotted on suitable scales in order that the practical implications of any given case can be seen at a glance.

THE DESIGN PROBLEM

The problem for the designer of a building resolves itself into the following:

(1) To estimate the amount of noise likely to be set up in certain parts of the building.

(2) To estimate the amount of noise likely to exist in those parts of the building where the intrusion of other noises will be undesirable (i.e. in the listening room). This is necessary because there is always a background of noise in any room and it is sufficient for practical purposes to reduce intruding noise to a level somewhat below the background noise. Complete silence, besides being usually unattainable, is unnecessary.

(3) Having decided on the scope of the problems from considerations 1 and 2 above, it remains to ascertain whether the form of construction proposed is adequate. The method of determining the weak point in the insulation between different parts of the building has been dealt with in Chapter I.

THE HUMAN FACTOR

There is one complication which cannot be eliminated by any simplification of the subject. People vary in the extent to which they are sensitive to noise, both as regards its amount and quality. There are hypersensitive people to whom almost any intruding noise of human origin, however small, is objectionable, though they may not dislike the song of the birds or the sound of wind in the trees. Then, again, the enthusiast for classical music will often have the strongest dislike for syncopated dance tunes, and vice versa. It is rarely possible to reduce noise in buildings to complete inaudibility, and the most that can be hoped for is to reduce it to an unobjectionable level. In these notes the aim has been to set the reduction levels of various forms of construction to a point where ordinary people would not complain, but it has to be appreciated that hypersensitive people on the listening side may consider the reduced level still a source of objection. On the side of the source of noise it has to be remembered that some people are inherently more noisy than others. They talk in a loud voice and run their wireless at a very high intensity. The architect who uses these notes must make some allowance for a client who goes to the extreme in either direction.

ADEQUACY OF CONSTRUCTION SOLVED GRAPHICALLY

A method of solving the problem of the adequacy of a proposed method of construction to reduce the loudness of noises of various kinds to an unobjectionable level is given diagrammatically in Figures 3, 4, and 5.

Figure 3 shows how outdoor noises can be dealt with, and, naturally, is mainly in terms of window construction.

Figure 4 deals with indoor noises originating mainly as air-borne sounds.

Figures 3 and 4 are based on the experimental data which are given more fully in Building Research Report No. 26 and represent working approximations.

Figure 5, which deals with impact noises on floors, is based on experimental data, but the scale of noisiness has been fitted to the scale of insulation arbitrarily. In the present state of knowledge it is not possible to do more than that.

The diagrams are self-explanatory.

Any problem of sound insulation involves consideration of the following factors :

(1) The amount of noise likely to exist under various conditions. Thus it might be necessary to know what will be the intensity of sound in the living-room of a house with the wireless playing at normal loudness. The appropriate noise levels for various conditions in and out of doors will be found on the left-hand scales of Figures 3 and 4. In Figure 5, dealing with impacts, a noise source equivalent to heavy footsteps has been assumed.

(2) The amount of noise which can be tolerated in rooms in various kinds of occupancy. The noise existing in a room masks intruding noises so that the latter need not be reduced to inaudibility. These tolerable noise levels, which must not be exceeded by intruding noises, are given on the right-hand scale of Figures 3 and 4, and the left-hand scale of Figure 5.

(3) The adequacy of a given method of construction to provide the sound insulation required in a given case is shown on the centre scale of Figures 3 and 4. The conditions of any particular case as regards noise emission and silence required are identified on the left- and right-han dscales respectively and the intersection on the centre scale of a line joining these two points shows the type of structure required to give the necessary insulation.

In Figure 5 the adequacy of the various constructions is shown on the right-hand column, and the diagram can be read directly.

In this way it has been possible to dispense with any reference in this book to the units of loudness and reduction of noise.

For information regarding actual values of sound reduction of various forms of construction reference should be made to the data given in Building Research Special Report No. 26.

INSULATING OUTDOOR NOISES

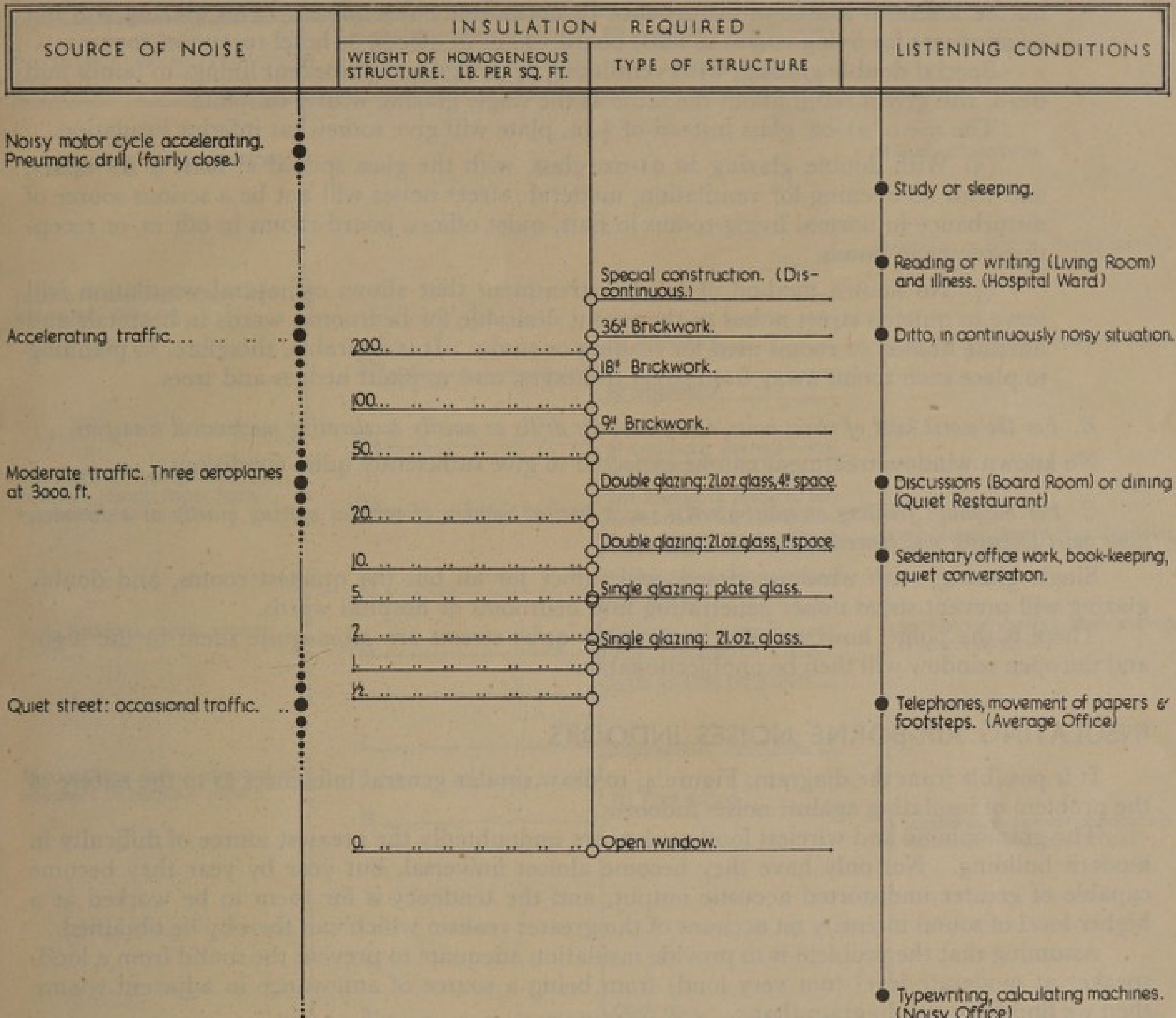
From a broad consideration of the diagrams certain important facts can be deduced. Taking Figure 3, outdoor noises, it can be seen :

A. For Buildings Fronting on Busy City Streets

(1) With open windows the street noise can be a disturbing element in any building, however occupied, even in rooms such as typing offices where there may be a high noise level in the room.

If comfortably quiet conditions are required in rooms fronting on a busy city street it is necessary to provide a ventilation system independent of the windows and to use special types of double window.

DIAGRAM TO DETERMINE APPROXIMATELY THE ADEQUACY OF BUILDING STRUCTURES TO INSULATE OUTDOOR AIR-BORNE NOISES



HOW TO USE DIAGRAM.

(1) Decide maximum amount of noise likely to be made in the situation which is considered as source of noise and find the appropriate point on the scale in the left hand column.

(2) Decide minimum conditions likely to exist in listening room and find appropriate point on the scale in the right hand column.

(3) Join the points so determined in the two outside columns by a straight line. The intersection of this line with the centre scale shows approximately the adequacy of various structures which may be common to source of noise and listening room to give a satisfactory degree of quiet in the listening room. Any structure falling above this point of intersection should be adequate, any falling below it, inadequate.

(4) A structure not listed in the centre column can be roughly placed by determining its weight per sq. ft. of superficial area or by consulting BUILDING RESEARCH Special Report Nº 26.

NOTE: The insulation of the various forms of glazing is based upon the assumption that the area of glazing is more than one third of the total external wall area, for in that case it is the glazing which determines the amount of sound transmission. Where the area of glazing is less than one third of the total external wall area the diagram may give a slight under-estimate of the overall insulation for any given constructions of wall & window. (see BUILDING RESEARCH Special Report Nº 26.)

The noise sources are as for day-time conditions. An allowance must be made where night-time occupancy is concerned. The diagram is based upon average sound reduction values for average listeners in rooms near the street level. Insulation against low notes will be less than the average reduction value indicated. Allowance may also have to be made for extra sensitivity on the part of the listener.

Rooms much above the street level suffer less from traffic than those lower down.

FIGURE 3.

(2) With single glazing in ¼-in. plate and tightly closed windows, street noises will not be a serious source of disturbance in normal or noisy offices. This glazing will not be adequate for living-rooms in flats, board-rooms in offices, or hotel reception-rooms.

Special double glazing, with ventilating openings and absorbent linings to jambs and head, will give a result about the same as the single glazing with ¼-in. plate.

The use of 21-oz. glass instead of ¼-in. plate will give somewhat inferior insulation.

(3) With double glazing in 21-oz. glass, with the glass spaced at least 4 in. apart, and with no opening for ventilation, moderate street noises will not be a serious source of disturbance in normal living-rooms in flats, quiet offices, board-rooms in offices, or reception-rooms in hotels.

(4) No known method of window treatment that allows of natural ventilation will serve to quieten street noises to the extent desirable for bedrooms, wards in hospitals and nursing homes, or rooms used for reading or study. It is desirable, therefore, in planning to place such rooms away from street frontages, and to plant hedges and trees.

B. For the worst kind of street noise, i.e. pneumatic drills or noisily accelerating mechanical transport.

No known window treatment can be expected to give sufficiently quiet conditions.

C. For buildings fronting on quiet streets, i.e. a limited number of vehicles moving quietly at a distance, some quiet footsteps, and conversation.

Single glazing, with windows closed, will suffice for all but the quietest rooms, and double glazing will prevent street noises penetrating into bedrooms or hospital wards.

There is the point, however, that reasonably quiet streets are often quite silent in the night and the open window will then be unobjectionable.

INSULATING AIR-BORNE NOISES INDOORS

It is possible from the diagram, Figure 4, to draw similar general inferences as to the nature of the problem of insulating against noises indoors.

The gramophone and wireless loudspeaker are undoubtedly the greatest source of difficulty in modern building. Not only have they become almost universal, but year by year they become capable of greater undistorted acoustic output, and the tendency is for them to be worked at a higher level of sound intensity on account of the greater realism which can thereby be obtained.

Assuming that the problem is to provide insulation adequate to prevent the sound from a loudspeaker at moderate level (not very loud) from being a source of annoyance in adjacent rooms, then we find from the diagram that :

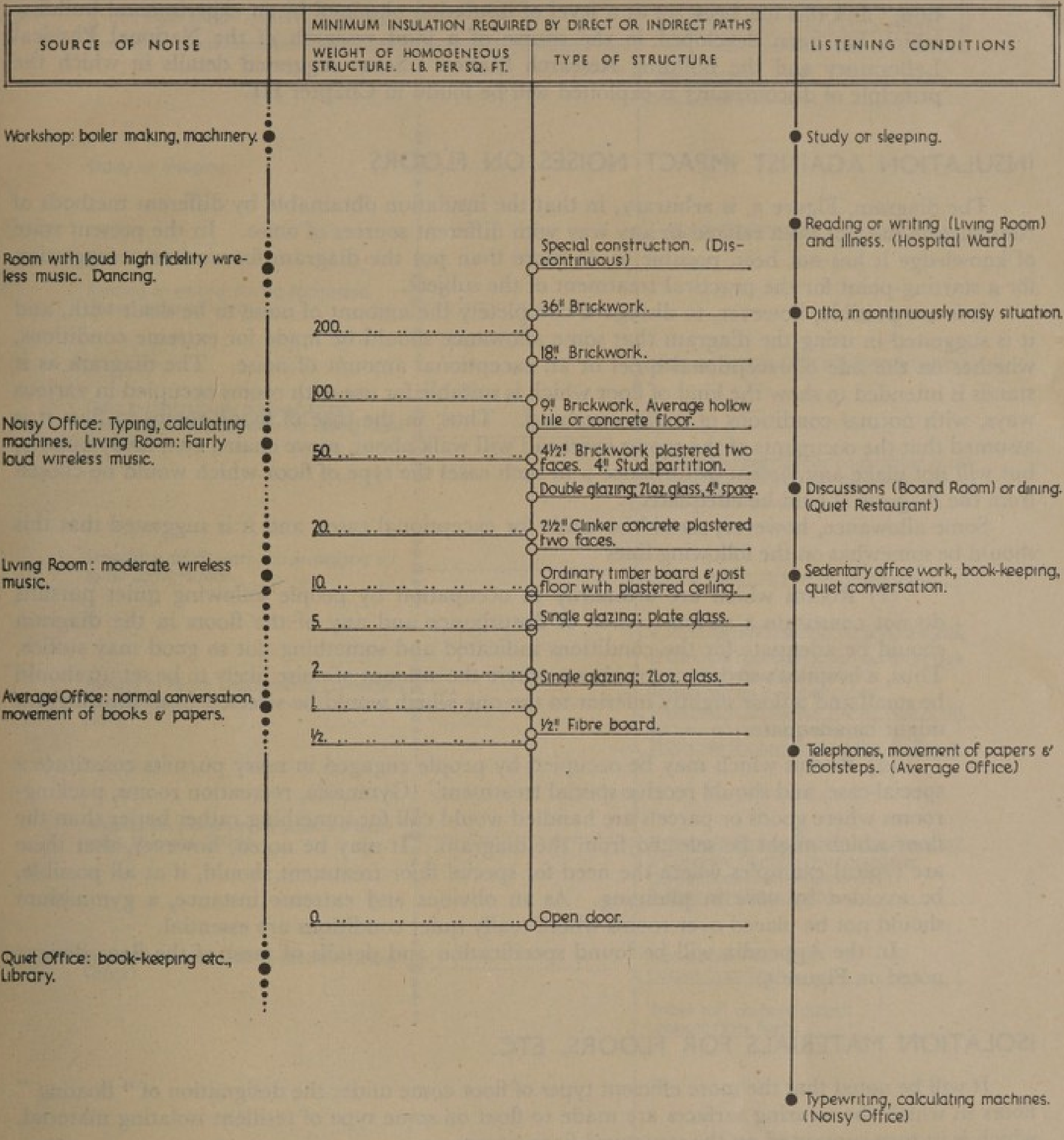
(1) Ordinary construction (equivalent to 9-in. brickwork or concrete or hollow tile floors weighing not less than about 50 lb. per sq. ft. finished) is adequate to reduce the sound intruding into all rooms except those where very quiet conditions are required.

(2) The wooden board and joist floor, however, falls far short of the requirements and where a useful sound reduction is required it is necessary to increase the weight of the floor by pugging or to provide an independent ceiling.

(3) It can be seen at a glance that ordinary construction (equivalent to 9-in. brickwork or concrete floors) fails to provide sufficient insulation against average noise where really quiet conditions are required—as, for instance, for sleeping or study—and similarly it also fails to provide sufficient insulation against very loud noise where only moderately quiet conditions are demanded.

(4) It is evident, therefore, that there is ample scope for the development of forms of construction which will afford markedly greater insulation than the normal methods of

DIAGRAM TO DETERMINE APPROXIMATELY THE ADEQUACY OF BUILDING STRUCTURES TO INSULATE INDOOR AIR-BORNE NOISES



HOW TO USE DIAGRAM ·

1. Decide maximum amount of noise likely to be made in room which is considered as source of noise and find the appropriate point on the scale in the left hand column.
2. Decide minimum conditions likely to exist in listening room and find the appropriate point on the scale in the right hand column.
3. Join the points so determined in the two outside columns by a straight line. The intersection of this line with the centre scale shows approximately the adequacy of various structures which may be common to both rooms to give a satisfactory degree of quiet in the listening room. Any structure falling above this point of intersection should be adequate, any falling below it, inadequate.
4. A structure not listed in the centre column can be roughly placed by determining its weight per sq. ft. of superficial area or by consulting BUILDING RESEARCH Special Report Nº 26.

NOTE: This diagram is based upon average sound reduction values for the average listener. If the noise source contains dominant low frequencies, transmission will be slightly greater than anticipated. Allowance should be made for this and for the listener's sensitivity to noise.

FIGURE 4.

construction. On the diagram will be found a note of "special discontinuous construction," and this has been set at a level of insulation obtained in an experimental building which has been developed in the course of a joint research of the National Physical Laboratory and the Building Research Station. Some suggested details in which the principle of discontinuity is exploited will be found in Chapter III.

INSULATION AGAINST IMPACT NOISES ON FLOORS

The diagram, Figure 5, is arbitrary, in that the insulation obtainable by different methods of construction has not been related in any way with different sources of noise. In the present state of knowledge it has not been possible to do more than put the diagram forward as a suggestion for a starting-point for the practical treatment of the subject.

It is not possible, however, to disregard completely the amount of noise to be dealt with, and it is suggested in using the diagram that some allowance should be made for extreme conditions, whether on the side of exceptional quiet or an exceptional amount of noise. The diagram as it stands is intended to show the kind of floor which is suitable for use with rooms occupied in various ways, with normal conditions of traffic overhead. Thus, in the case of living-rooms in flats it is assumed that the occupants of the rooms overhead will walk about, move chairs, etc., fairly quietly, but will not make any violent disturbance ; in such cases the type of floor which would be chosen from the diagram should be adequate.

Some allowance, however, should be made for exceptional cases, and it is suggested that this should be somewhat on the following lines :

(1) Rooms which are ordinarily in occupation by people following quiet pursuits do not constitute a serious source of disturbance and any of the floors in the diagram should be adequate for the conditions indicated and something not so good may suffice. Thus, a hospital ward is a typical case where the amount of noise likely to be set up should be small and a floor slightly inferior to the one which would be selected from the diagram might be adequate.

(2) Rooms which may be occupied by people engaged in noisy pursuits constitute a special case, and should receive special treatment. Gymnasia, recreation rooms, packing-rooms where goods or parcels are handled would call for something rather better than the floor which might be selected from the diagram. It may be noted, however, that these are typical examples where the need for special floor treatment should, if at all possible, be avoided by care in planning. As an obvious and extreme instance, a gymnasium should not be placed over rooms where really quiet conditions are essential.

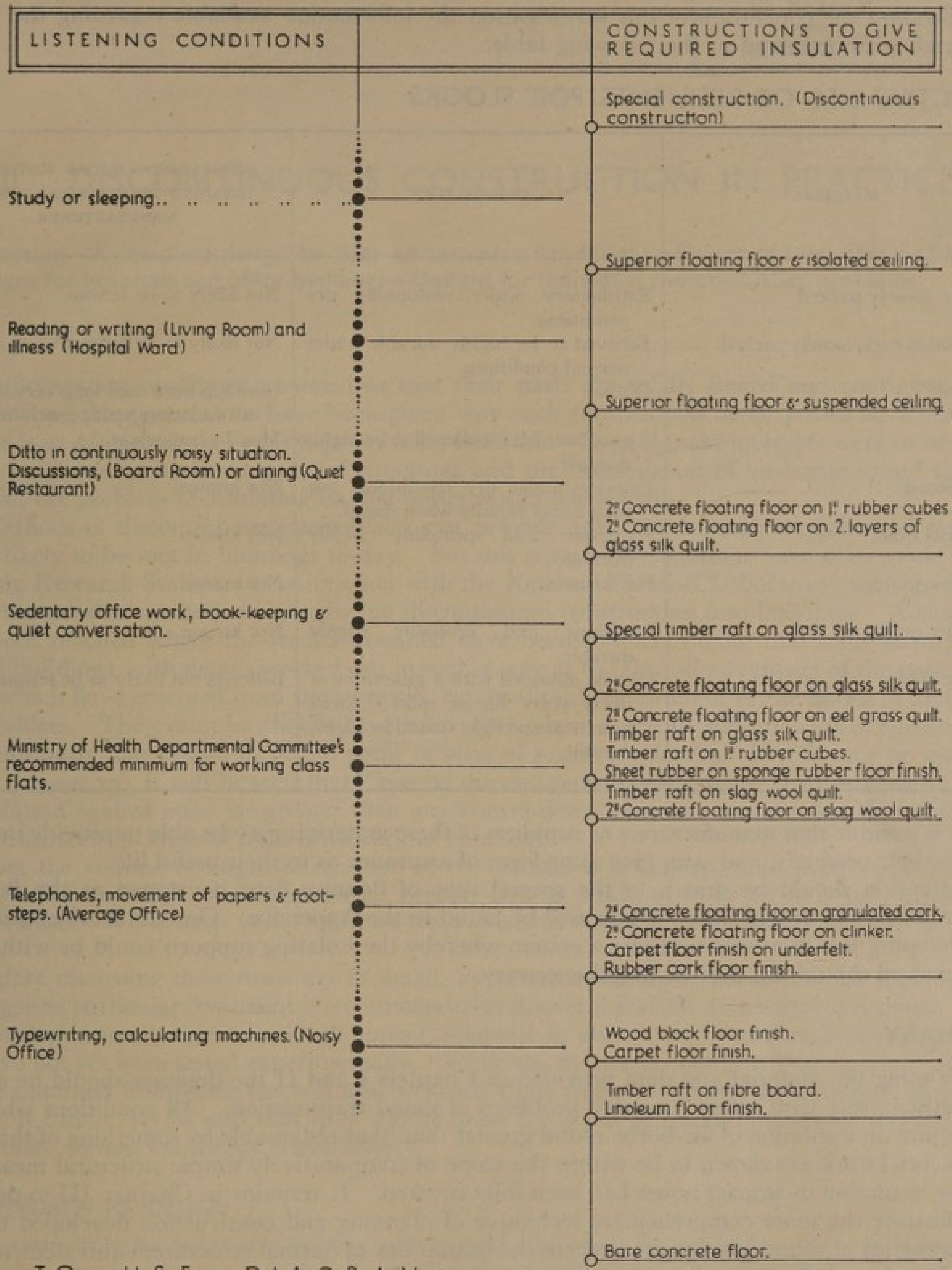
In the Appendix will be found specification and details of most of the floor designs noted on Figure 5.

ISOLATION MATERIALS FOR FLOORS, ETC.

It will be noted that the more efficient types of floor come under the designation of "floating" floors in which the wearing surfaces are made to float on some type of resilient isolating material, which is in turn supported on the structural floor system.

It is important in using a floor of this type that the isolation shall have satisfactory durability, and, in particular, that it shall retain its property of resilience in service. It can readily be imagined that certain materials might tend to take up some degree of permanent compression under loads sustained over a long period. Tests are in progress to determine the extent to which various materials lose their resilient property under long-period loading, but results are not yet available.

DIAGRAM TO DETERMINE APPROXIMATELY THE ADEQUACY OF BUILDING STRUCTURES TO INSULATE IMPACT NOISES



HOW TO USE DIAGRAM·

(1) Decide minimum conditions likely to exist in listening room and find the appropriate point on the scale in the left hand column.

(2) A horizontal line from the point so determined intersecting with the scale in the right hand column shows approximately the adequacy of various structures which may be common to source of noise and listening room to give a satisfactory degree of quiet in the listening room. Any structure falling above the point of intersection should be adequate, any falling below it, inadequate.

A further list of structures is given in BUILDING RESEARCH Special Report No 26.

NOTE: The relative insulations given are approximately additive and assume a concrete, or hollow tile structural floor, (or floor of similar weight.)

The diagram is based upon average sound reduction values for the average listener and for impacts of the order of heavy footsteps. Allowance will have to be made for any special conditions which may arise.

FIGURE 5.

Pending the conclusion of this investigation the information available regarding the various materials is summarized in the following table.

EFFECTIVE LIFE OF RESILIENTS FOR FLOORS

MATERIAL	DURABILITY	COMPRESSION UNDER SUSTAINED LOADING AS RECOMMENDED BY MANUFACTURER
Clinker, loosely packed	Satisfactory under reasonably dry conditions.	Not likely to be serious.
Granulated cork, loosely packed	Believed to be highly durable under normal conditions.	Not likely to be serious.
Slab cork	Ditto.	Cork has been used for a very long time as insulation under machines.
Felt	A good hair felt is believed to be highly durable.	May be important.
Fibre-board	Durable under dry conditions, but may decay rapidly when damp.	Not known.
Slag-wool quilt	Inorganic and probably highly durable.	Not known.
Eel-grass quilt	Not known.	Not known.
Glass-silk quilt	Inorganic and probably highly durable.	Not known.
Rubber cubes	Can be obtained with a guarantee of thirty years' life or more. Away from heat and light should be highly durable.	Believed not likely to be serious.

It is possible that manufacturers or suppliers of these materials may be able to provide information on their products, and even give some form of assurance as to their useful life.

Attention should be drawn to the special type of floating floor developed at the Building Research Station, and of which details will be found in the Appendix. One of the objects in view in developing this floor was to devise a system whereby the isolating supports could be withdrawn and renewed should this ever be found necessary.

SUMMARY

By using the material and data provided in Chapters I and II the designer should be able to deal satisfactorily with many everyday problems of sound transmission. All conditions which do not require an insulation of air-borne sound greater than that obtainable by something of the order of 9-in. brickwork are shown to be within the scope of comparatively simple structural measures; and the insulation of impact noises has been fully covered. It remains in Chapter III to describe and illustrate the more comprehensive technique of planning and construction developed to deal with problems of sound transmission where the limitations of normal structure, equivalent to 9 in. of brickwork or hollow tile floors, are recognized as failing to give the conditions of quiet which the case requires.

III. DISCONTINUOUS CONSTRUCTION IN PRACTICE

Introduction—A complete design for flats—Alternative flat designs—Design of semi-detached houses—Designs for hospitals and office buildings—Designs for individual rooms—Other problems.

INTRODUCTION

Buildings are usually constructed so that their parts are solidly linked and continuous. In the previous chapters reasons have been given why such construction *cannot prevent the transmission of sound to an adequate degree for contemporary living conditions*. Even if great increases were to be made in the weights of component parts of structures and the transmission of air-borne sound thereby reduced, the problem of insulating impact noises would still remain.

Methods of discontinuous construction can provide adequate insulation against all types of sound likely to be met in buildings to-day. For this reason investigations have been made at the Building Research Station, in conjunction with the National Physical Laboratory, with the object of finding suitable methods of introducing discontinuous construction into buildings. A stage has now been reached where the results obtained have been so encouraging that some examples of typical buildings, with details worked out in such a way as to take full advantage of the basic principles which have emerged from the research, can profitably be brought to the notice of architects and builders. The examples chosen have been some where conventional methods of construction are notoriously inadequate from the point of view of sound insulation. If reference be made to Figure 4 (page 13), it will be seen that " special discontinuous construction " can provide a degree of insulation against noise far greater than any conventional construction and roughly equivalent to some six feet thickness of solid brickwork or concrete.

From the volume of inquiries received at the Station it is believed that flats, semi-detached houses, office buildings, and hospitals all present serious problems, and hence details have been prepared for such buildings to demonstrate ways in which discontinuous construction can be introduced.

Before discussing these drawings in detail, however, it should be noted that for each type of building one particular treatment is recommended and several possible alternatives are given. The latter include some treatments which appear adequate in theory, and incidentally less expensive, but have not yet been tested experimentally. While the Station is confident that the results which will be obtained from their use will much exceed those from continuous construction of normal weight, it cannot yet be said that they will be quite the equal of the recommended treatment, of which more certain knowledge is available.

THE APPROACH TO DESIGN

In approaching the design of a building when a novel principle as far reaching as this is to be employed, it is obvious that consideration must be given to it at the earliest stages. To adapt it properly, easily, and most economically, it must almost certainly in fact be a function of the design ; no doubt architects will be able to view it in this manner.

Having passed the design stage the successful exploitation of the principle of discontinuity calls for a special technique in detail and supervision, not in itself difficult, but a technique which must be followed right through all stages in the progress of the building.

Adequate insulation can be obtained by discontinuous construction but it is nevertheless wise to ease that problem as far as possible by placing noisy rooms away from quiet rooms and by planning the entire building, where possible, in such a way as to group " noise " and " quiet " as distinct sections. (See Building Research Special Report No. 26.)

A COMPLETE DESIGN FOR FLATS

GENERAL

Flats constitute the most severe residential noise problem. The noise sources are :

(*a*) From flat to flat.

The wireless or radio-gramophone, which, to operate at its optimum efficiency of reproduction, must be quite loud.

Impacts : footsteps, door slamming, and even light switches.

(*b*) From building structure to flat.

Services : water supply, stairs, lift.

The possibility of a high noise level in one flat coupled with a reasonable desire for quiet in the next constitutes the problem, and from Figures 4 and 5, Chapter II, it is apparent that ordinary continuous construction is inadequate to meet the case.

Assume then, for example, a large block of flats in the heart of a large city. Site problems are not discussed here, though orientation will enter to some degree in planning. Lifts and stairs must be provided, also central heat and water.

THE APPROACH TO THE PROBLEM

The application to this problem of a technique of discontinuous construction has been experimentally studied and the most reasonable solution which has presented itself is one where *each flat is considered and constructed as an individual box* entirely separate, as far as rigid links are concerned, from the structure. The remainder of the building is continuous and solid, providing access and service distribution, and acting as shelving for the boxes, which themselves are resiliently supported from the structure.

Figure 6 shows in section and plan a diagrammatic layout of a building conceived in this way, and might be said to present a mental picture which the designer should have at this stage of his design. An isometric detail and section of a possible construction of the idea are also provided, but will be referred to later.

It is perhaps debatable whether service areas such as kitchens and bathrooms should be included within the box or allowed to remain part of the continuous structure. It is probably true, however, that sound insulation of a high order is not necessary between rooms of this type, and, as they are commonly the source of some noise, it was finally decided that they should remain part of the continuous structure in this example. They are so shown in Fig. 6.

THE CONSTRUCTION PRINCIPLES

The elements of a box are the floors, the walls, and the ceiling. Each must be continuous with other elements, to prevent direct air paths for sound, but none can rigidly touch the frame, or a condition of short circuit will be established.

The floor will be a floating floor. From Figure 5 it can be seen that there are several types which are efficient. The merits of each of these for this purpose will be discussed later.

The walls are erected on the floors and are perfectly normal in every way. Weather protection is provided by a structural wall continuous with the frame of the building and being outside the box need not be considered.

DISCONTINUOUS CONSTRUCTION
DIAGRAMMATIC LAYOUT & BASIC CONSTRUCTION FOR EXAMPLE FLATS

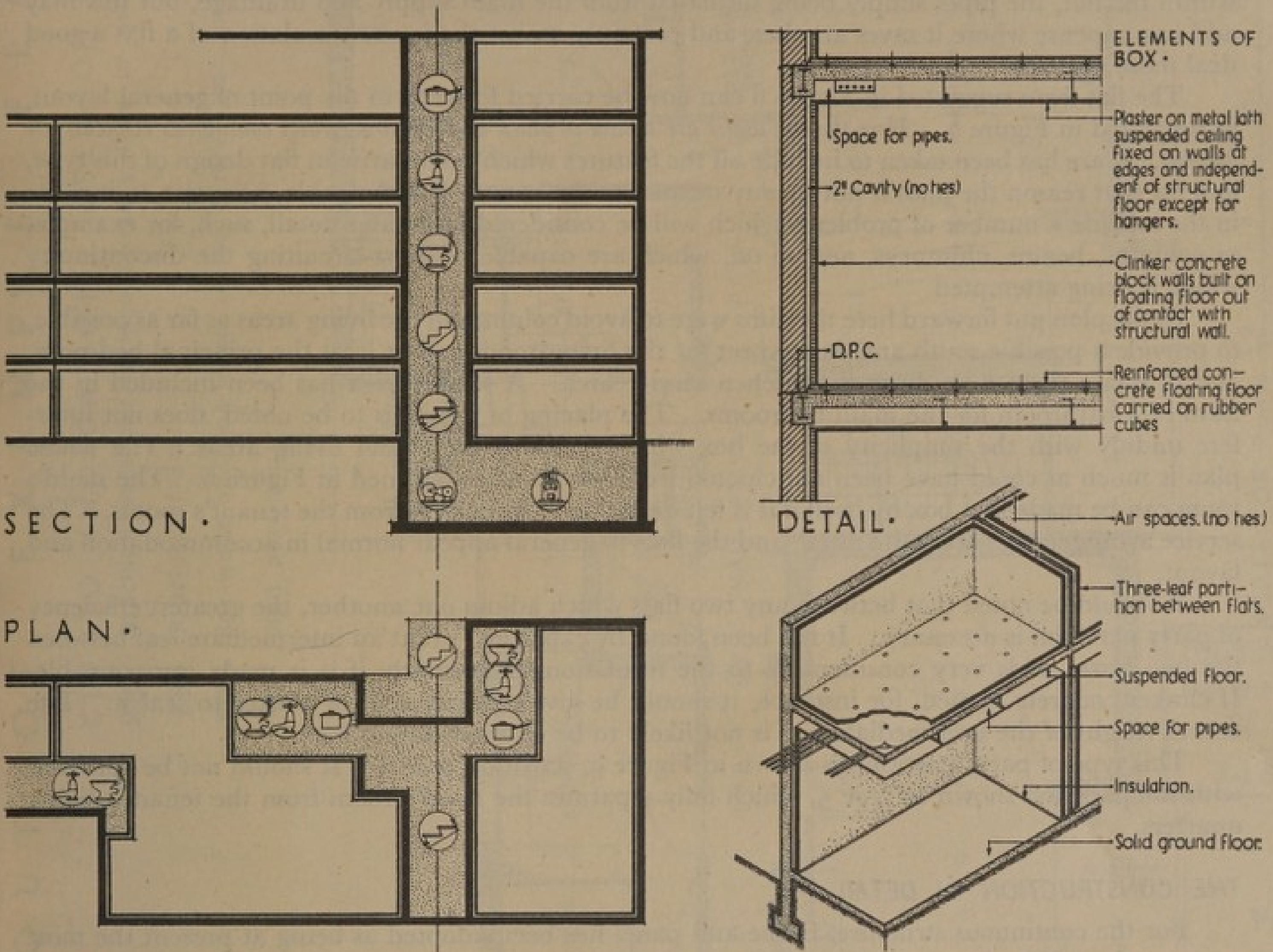


FIGURE 6.

Theory would indicate that the ceiling should be carried solely by the walls. If this was essential in practice it would hamper planning and cause considerable loss of height. It is fortunate, therefore, that a sufficiently close approximation is found in a suspended ceiling, which transmits very little energy to the structure by means of the hangers. Thus the battens or ribs of the ceiling can be keyed into the box walls and partitions, but are suspended from the structural floor.

A box so constructed is shown in section and in isometric in Figure 6, the floor in this case being carried on rubber cubes, the walls formed of clinker concrete slabs and the suspended ceiling of plaster on metal lath on a metal frame. Service pipes formerly laid in the floor can now be fitted in the ceiling space, including heating pipes.

Such, then, is an adequate box for the purpose in mind.

THE PLAN IN DETAIL

Care will have to be taken at this stage to ensure that the service areas are properly centralized and conveniently related to the box containing the living quarters so that the plan is adequate from the point of view of workability, orientation, and the various other considerations. It is possible, of course, that all flat services, the bathrooms, kitchens, and so on, could be included within the flat, the pipes simply being insulated from the main supply and drainage, but this may add one expense where it saves another, and certainly makes the *internal* insulation of a flat a good deal more difficult.

The flat form suggested in Figure 6 can now be carried forward to the point of general layout, as suggested in Figure 7. *Here the box walls are shown in black and the structurally continuous elements are hatched.* Care has been taken to include all the features which might arise in flat design of this type, and for that reason the plan is not by any means an ideal one. It is desirable, however, to include in the scheme a number of problems which will be considered in greater detail, such, for example, as columns, beams, chimneys, and so on, which are capable of short-circuiting the discontinuity which is being attempted.

In the plan put forward here the aims were to avoid columns in the living areas as far as possible, to provide a possible south and east aspect for the living-room and at least the principal bedroom, and to relate these suitably to the kitchen service area. A service area has been included in the form of a bathroom for the main bedrooms. The placing of this, it is to be noted, does not interfere unduly with the simplicity of the box which contains the actual living areas. The whole plan is much as could have been anticipated from the sketches outlined in Figure 6. The maid's room can be made as a box by itself if it is felt desirable to insulate it from the tenant's rooms. The service arrangements are quite usual, and the flats in general appear normal in accommodation and layout.

It should be noted that between any two flats which adjoin one another, the greatest efficiency of party partition is necessary. It has been found by experiment that an intermediate leaf between the two boxes adds very considerably to the insulation, particularly if it is made impermeable. If clinker concrete is used, for instance, it should be given a skim coat of plaster to seal it. The actual weight of the intermediate leaf is not likely to be of great importance.

This type of party partition is shown in Figure 9, partition type 6. It should not be confused with the partition shown as type 5, which only separates the maid's room from the tenant's living quarters.

THE CONSTRUCTION IN DETAIL

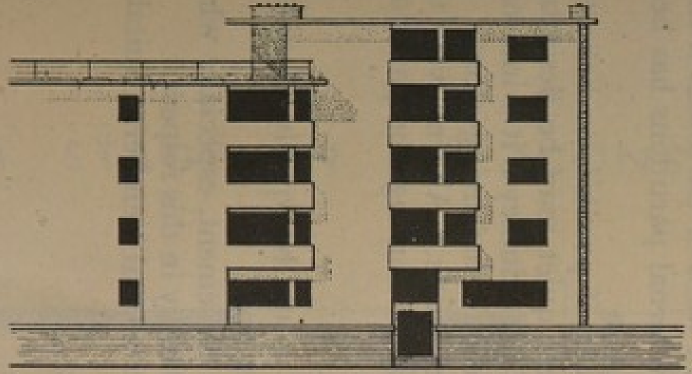
For the continuous structure, frame and panel has been adopted as being at present the most common form of basic construction for flats. This does not preclude the use of other constructions, which might, indeed, easily prove to be more suitable and amenable. Structural floors are provided and where a service area has an external wall this is of cavity construction to provide protection against damp penetration. Where a box adjoins an external wall the structural wall is of 9-in. brickwork. The fact that the wall of the box does not have a rigid contact with this exterior wall *ipso facto* provides protection against damp and excellent thermal insulation as well.

When the building has reached the stage where most of the services are in place and possibly the walls of service rooms, such as bathrooms and kitchens, the floating floors have to be considered.

These may be to any one of several alternative designs. One that has proved successful is that developed at the Building Research Station with this special purpose in view. It consists of a 2-in. concrete slab, lightly reinforced in mid-section, cast upon the structural floor and incorporating small sockets at regular intervals such that when the slab has set it may be raised bodily an inch or so out of rigid contact with the structural floor to rest finally upon rubber cubes. There is no apparent limit to the extent over which such a floor may be laid, and it may be adjusted to correct for levels. A final screed is given to receive the wearing finish.

The process of casting these floating slabs in large areas is as follows. Against all the extreme boundaries to which the floor is to be laid is placed a piece of timber to act as a shuttering. Placing of the paper, reinforcement, and sockets proceeds as described in detail in the Appendix. The

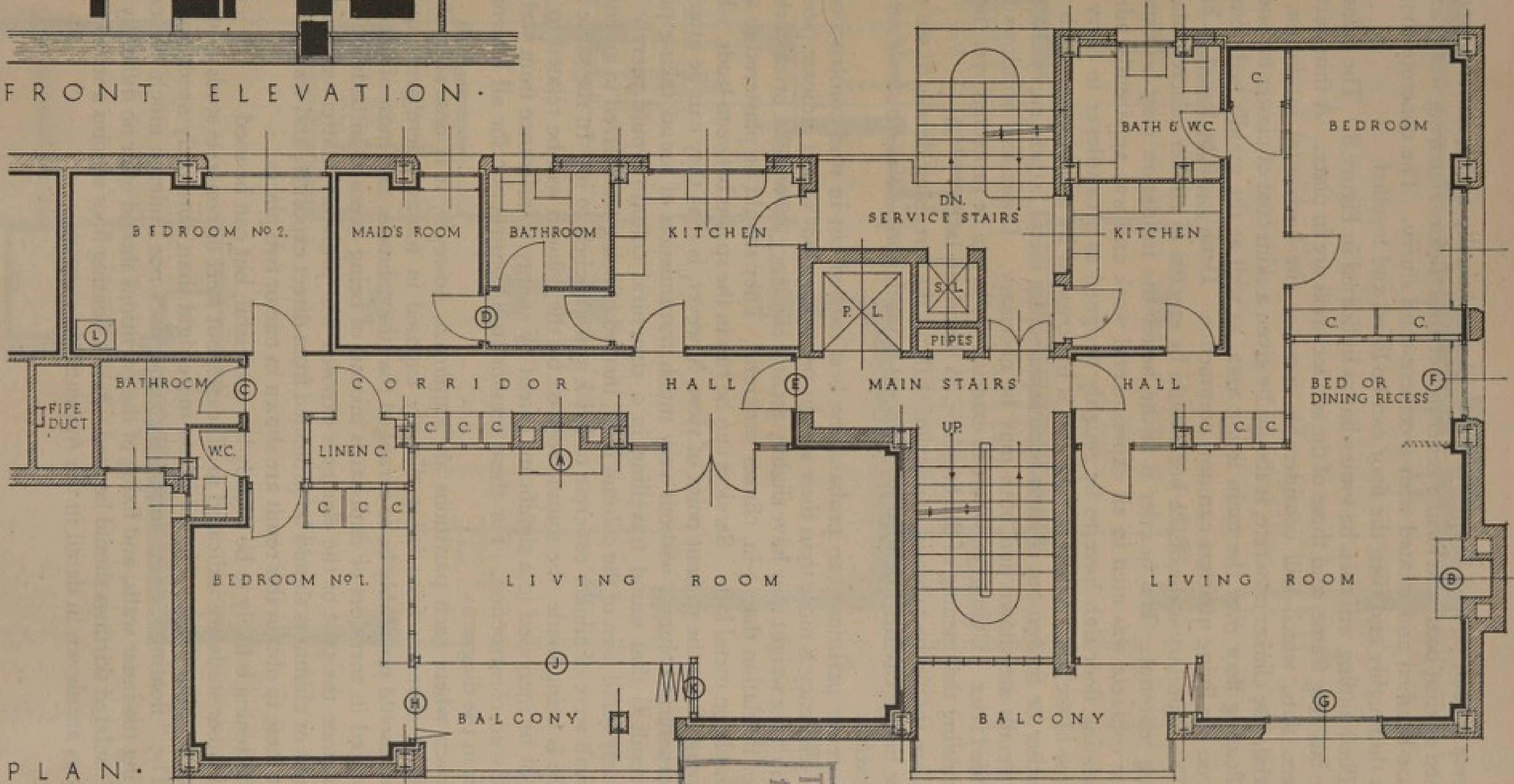
GENERAL LAYOUT OF EXAMPLE FLATS



FRONT ELEVATION·

KEY TO INDICATIONS USED ON PLAN

- Structural walls and partitions rigidly fixed to structure.
- Structural frame.
- Box walls and box leaves of two & three-leaf partitions.
- Stud partitions.



PLAN·

FIGURE 7.

SCALE FOR PLAN. 1 0 5 10 15 20 FT.

concrete is then poured to the chosen thickness (usually 2 in.), work stopped for the night being finished against boards to form a generous rebate. Before renewing work next day the joint should be wire-brushed and treated with a cement-sand slurry. The concrete should finally be allowed to set thoroughly and then the floor can be lifted and levelled.

The building will then be somewhat as indicated in Figure 8. The columns, the exterior walls of the building frame, and those of the service areas are in place. A thin partition has been erected between flats, which will considerably increase the horizontal insulation. If this is of porous material, like clinker concrete, it should be given a skim coat of plaster on one side to seal the pores. The floating floor over the main living area, as well as the maid's bedroom, has been lifted, and work on the living quarters can now commence. Details will be found in Figure 19.

The boundary walls of the box should be erected in clinker concrete slabs, brick, or any solid walling material. The heavier it is the better the insulation may be expected to be, although clinker concrete was used in all experimental work and was apparently adequate. The edges of the floating floor slab have to be roughly designed as a cantilever to carry the walls beyond the last row of sockets. Where a wall run is interrupted by a projection, such as a column, the wall can either be broken out around it or replaced by metal lath to carry the interior plaster across. Both details are shown and both may be necessary. Doors and windows should be designed as described later. Chimneys, where in external walls, can be protected over the area not immediately surrounding the opening of the fireplace, as described later.

Care should be taken in connexion with all the foregoing details to see that mortar droppings do not bridge cavities intended for purposes of insulation. *Wall ties should not be used between box wall and structure.*

Interior partitions can probably be best carried out in stud construction, for several reasons. Their efficiency is more than their weight per square foot would indicate (see Figure 4). At about one-third the weight they have slightly greater efficiency than $4\frac{1}{2}$-in. brickwork and very appreciably greater insulation than 3-in. clinker concrete. They should be plastered to at least $\frac{1}{2}$ in. thickness, preferably on metal lath. Services can be run in the spaces between studs. Probably their greatest advantage from the present point of view, however, is that they can be attached to solid members like structural columns without very much transmission of sound taking place to or from them. The result is that sound travelling in a structural column would merely be radiated from the relatively small area of the column itself, instead of being transferred to an entire wall, as it would if that wall were of clinker concrete or brick and attached to it. In the same way, in a room where a noise is being made, the sound received by the column will be related to the exposed area, but will not be increased to a significant extent by energy transference from walls or partitions if they are of stud construction. For these reasons stud construction for all internal partitions has been shown in the diagrams.

Even where such partitions are employed, however, it is desirable, if possible, to keep the structural elements from being directly exposed in rooms where great quiet may be desirable. Rooms should preferably be so arranged that the columns, and most of the chimney if it is internal, are placed in corridors or cupboards instead of being exposed in bedrooms and living-rooms. If this is done the part of the elements exposed will probably matter very little. Alternatively the columns or chimneys should be protected from direct exposure, and ways of working stud partitions about these to obtain this result are shown in one or two places.

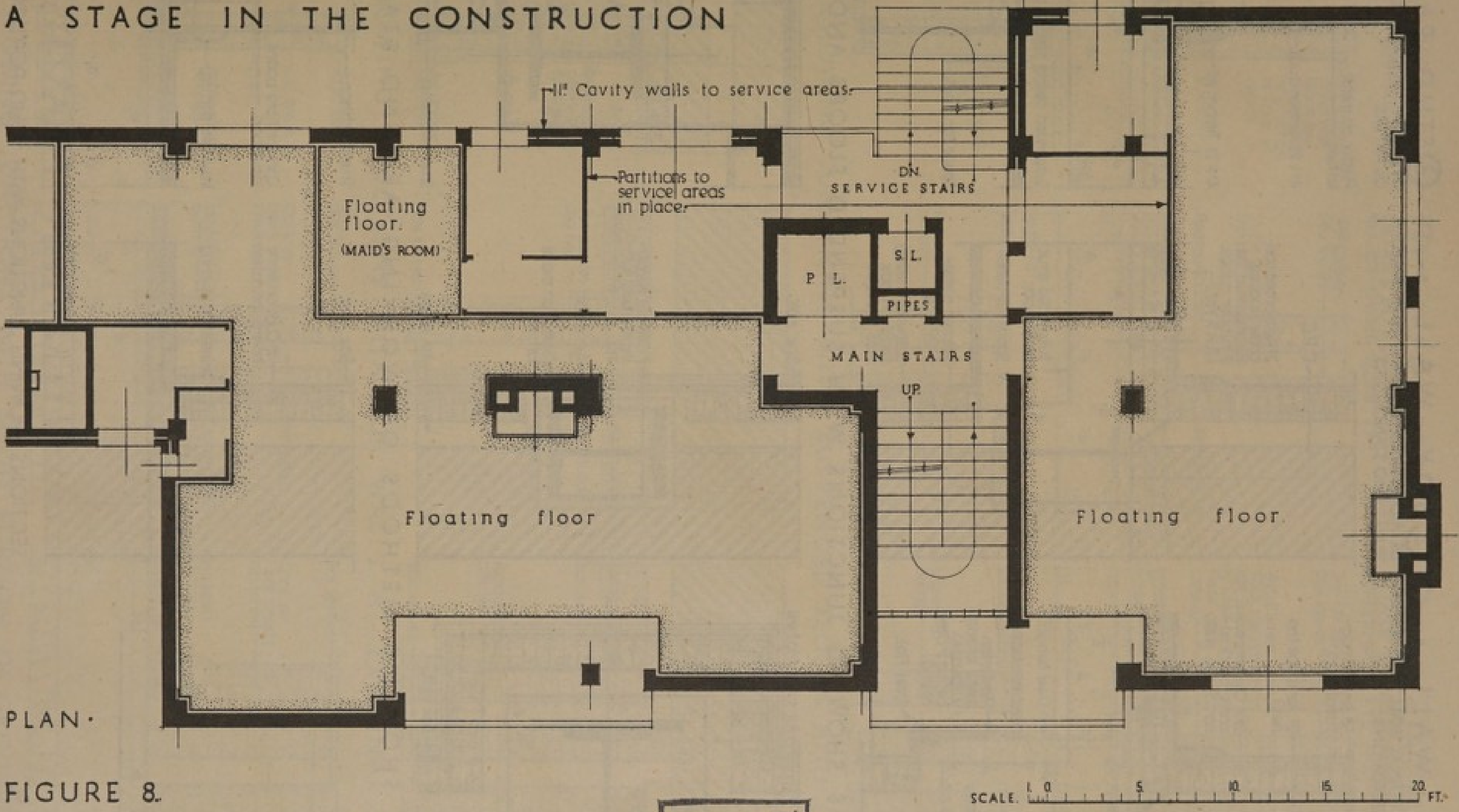
Battening is likely to be slightly less successful, but can be used.

Timber studs are indicated in all cases, but steel or concrete studs would be equally adequate. Fixing to columns, etc., should be no more rigid than absolutely necessary.

The "floating" floor, despite its name, does not undergo much movement, especially when carrying the inner walls, and fixing of the partitions should offer no difficulty in this respect.

Insulated skirtings should be used where a floating floor adjoins a structural member. Suitable skirtings are shown in detail in the Appendix.

A STAGE IN THE CONSTRUCTION



PLAN·

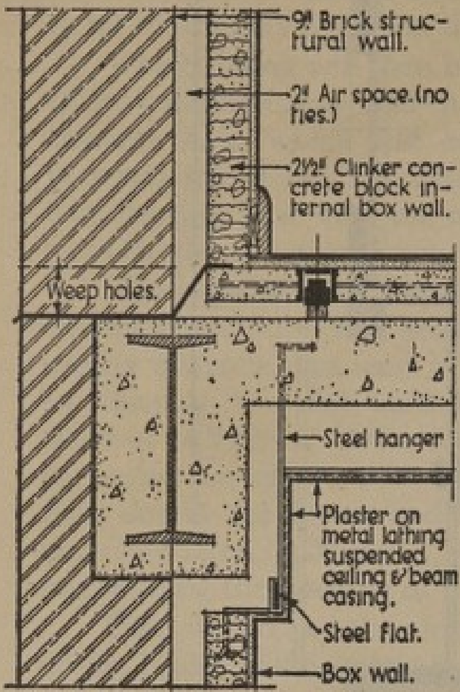
FIGURE 8.

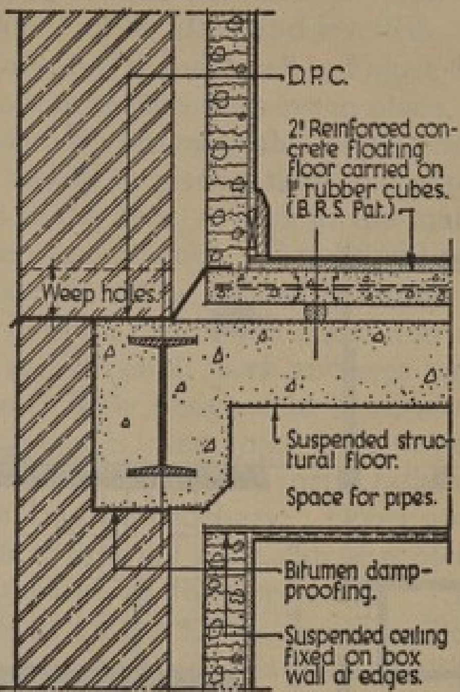
DETAILS OF WALLS AND PARTITIONS . . . .

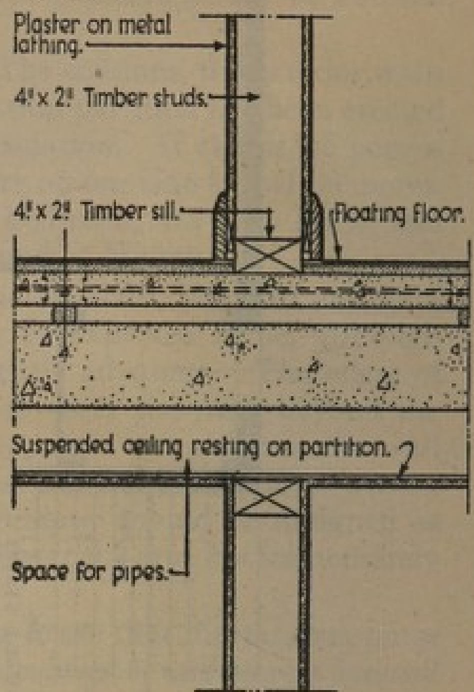
① BOX WALL ·
DETAILS AT EXTERNAL WALL WITH LARGE BEAMS AND STANCHIONS

② BOX WALL ·
DETAILS AT EXTERNAL WALL WITH SMALL BEAMS AND STANCHIONS

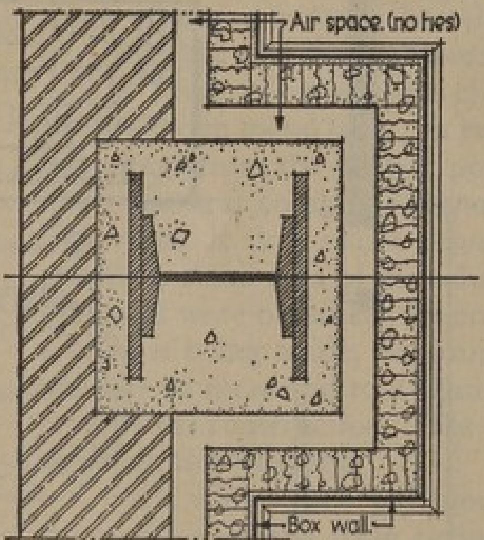
③ STUD PARTITION
DETAILS AT DIVISION WITHIN SAME LIVING QUARTERS

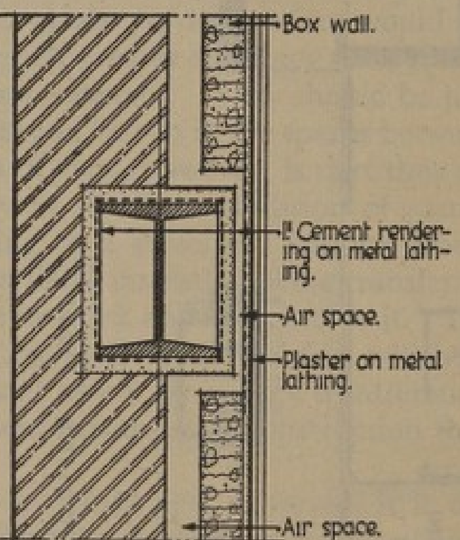


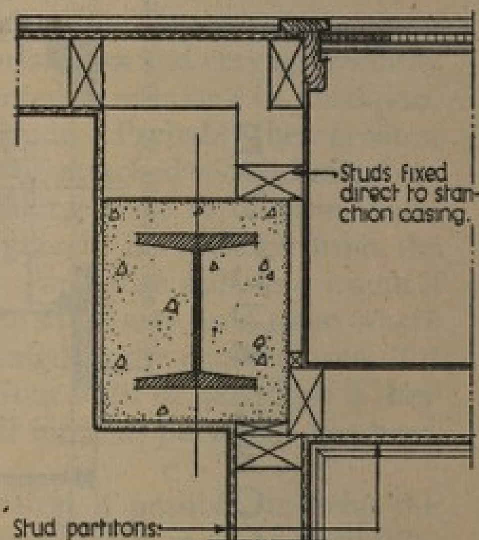




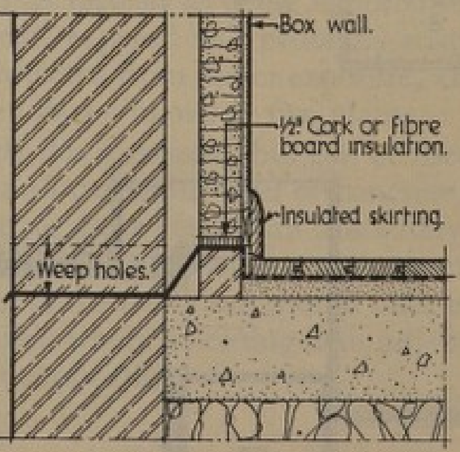
SECTIONS SHOWING JUNCTIONS WITH SUSPENDED FLOORS AND CEILINGS

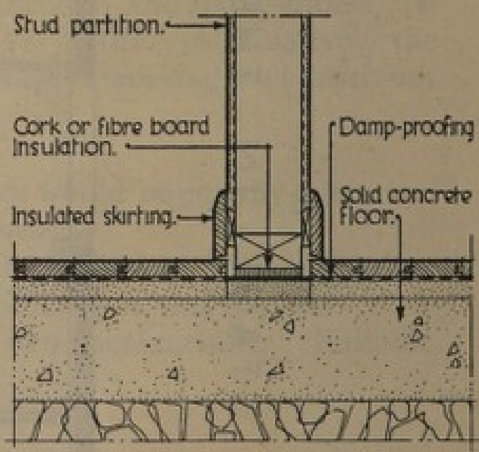






PLANS SHOWING METHODS OF WORKING AROUND STANCHIONS





SCALE.

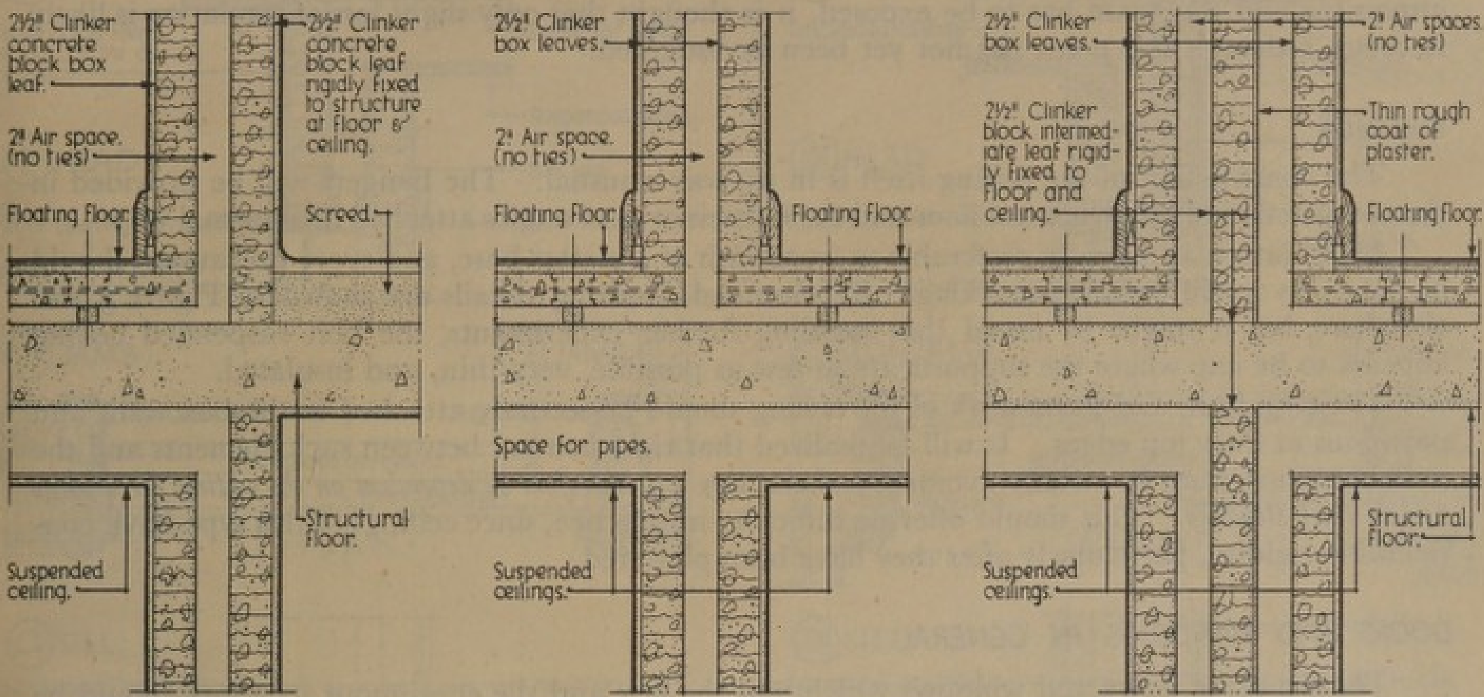
FIGURE 9.

SECTIONS SHOWING JUNCTIONS WITH SOLID PORTION OF GRD. FLR.

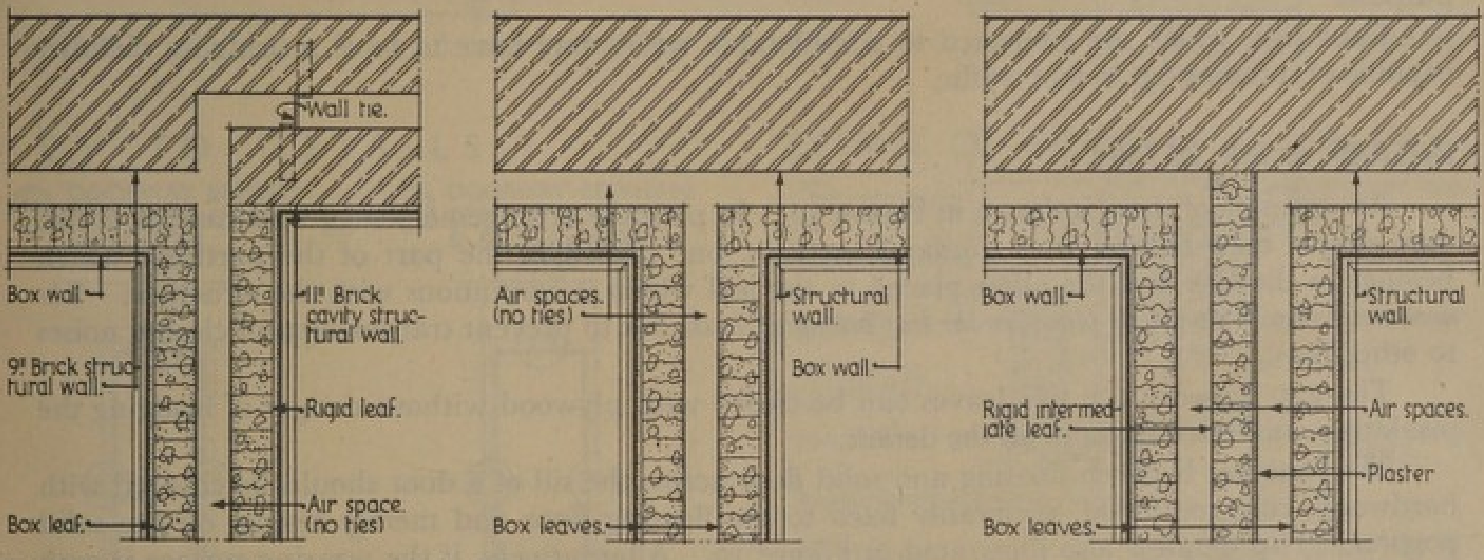
(4) TWO-LEAF PARTITION
DETAILS BETWEEN LIVING AND SERVICE QUARTERS

(5) TWO-LEAF PARTITION
DETAILS BETWEEN TENANT'S AND MAID'S LIVING QUARTERS

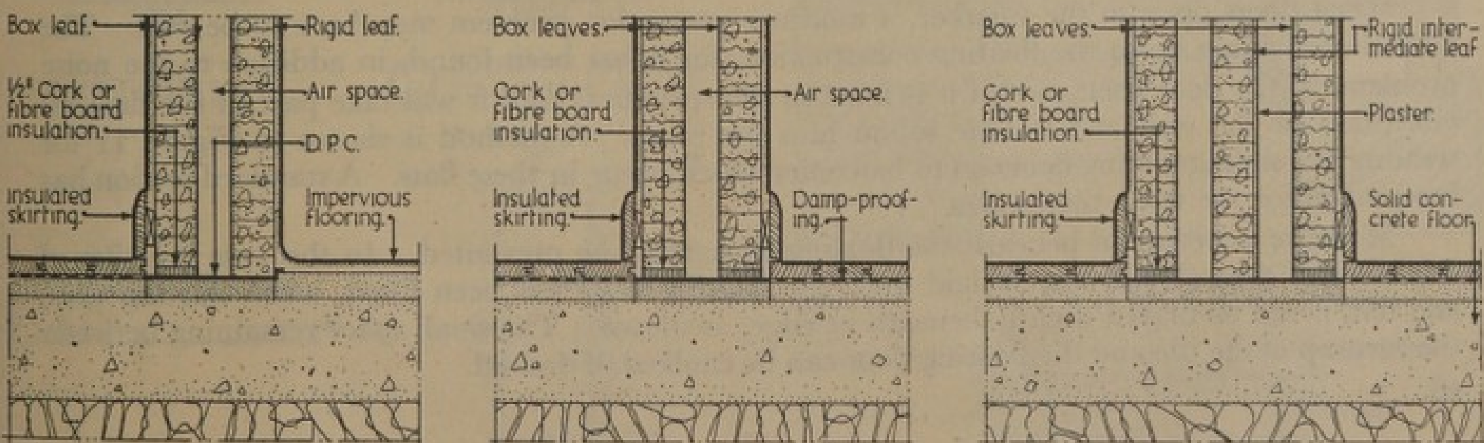
(6) THREE-LEAF PARTITION
DETAILS BETWEEN LIVING QUARTERS OF DIFFERENT FLATS (PARTY PARTITION)



SECTIONS SHOWING JUNCTIONS WITH SUSPENDED FLOORS AND CEILINGS



PLANS SHOWING JUNCTIONS WITH BOX WALLS AT EXTERNAL WALLS



SECTIONS SHOWING JUNCTIONS WITH SOLID PORTION OF GROUND FLOOR

Beams should be kept shallow and in any case should be exposed as little as possible below the structural floor. Where the projection is so great that it will interrupt the normal run of the suspended ceiling, the latter should be carried beneath, out of contact. Where even the latter is impossible and the beam has to be exposed, it is thought that only slight loss of insulation is likely to occur, although this point has not yet been investigated.

CEILINGS

The construction of the ceiling itself is in no way unusual. The hangers will be provided in the construction of the structural floor and the battens or steel angles attached in a normal way.

Metal lath is apparently preferable to wood lath as a plaster base, and every precaution should be taken to avoid possible cracking. Recommended ceiling details are shown in Figure 9 and elsewhere, but it might be noted that pending further experiments, the best suspended ceiling appears to be one where the supports are as few as possible, very thin, and insulated.

The ribs, lath, and framework of the ceiling should be securely attached to the box walls and partitions at their top edges. It will be realized that rigid contact between such elements and the main structure must be strictly avoided, *and that they will therefore be dependent on the ceiling for a large part of their stability*. This should offer no difficulty in practice, since ceilings of this type have considerable rigidity, particularly after they have been plastered.

DOORS AND WINDOWS IN GENERAL

The details of doors and windows which join the box and the continuous structure should be carefully considered. In general, the use of thin plywood and sheet metal is suggested for this purpose.

Door sills, which are subjected to considerable wear, may have to have a bridging member capable of standing up to foot traffic.

INTERIOR DOOR DETAILS

An example of these is shown in Figure 10. In plan the arrangement suggested consists of two very simple door frames, very similar in section, one placed in the part of the partition which belongs to the box and the other placed in the leaf which is continuous with the structure. *The door itself should always be placed in the leaf belonging to the box* to prevent transmission of closing noises to other flats.

The gap between the two leaves can be closed with plywood without danger of bridging the insulation, and is so shown in all the details.

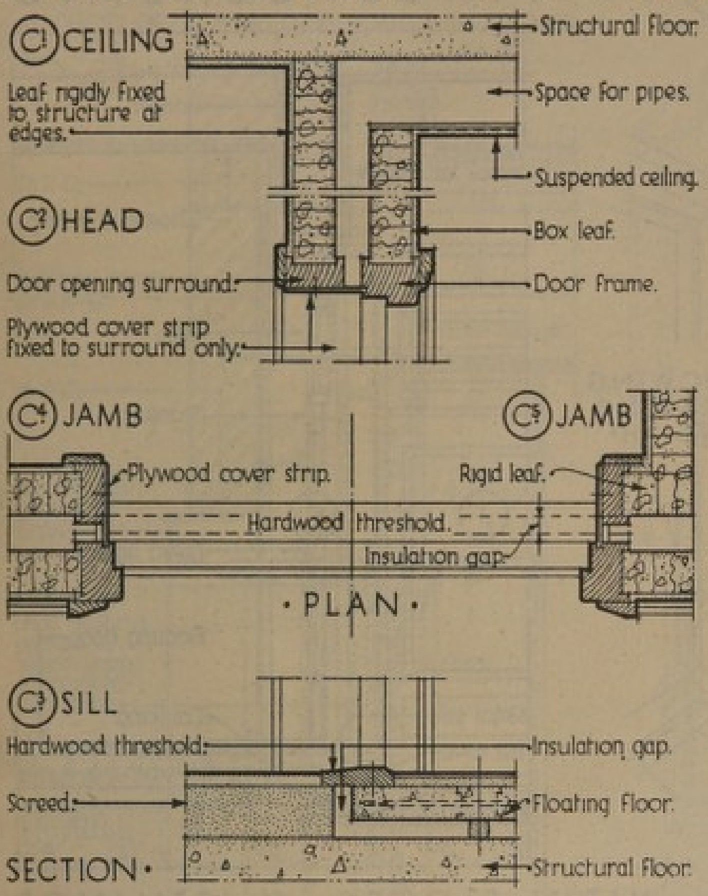
The junction between floating and solid floor across the sill of a door should be covered with hardwood, cork, or metal, preferably fixed to the floating floor and merely resting on the solid portion. This detail is also illustrated in Figure 10. Alternatively, if the wearing surface is cork or lino, this could be continuous if the gap is made sufficiently narrow.

When doors open to the weather, a moisture protection problem may have to be met. The door should again be in the floating construction, for it has been found, in addition to the noise problems of the door itself, that if it is fixed in the structural wall it will take part in the flexural vibrations of the wall and radiate sound into the room. A method is shown in Figure 11 for treating the sliding folding doors on to balconies which occur in these flats. A standard section has been taken for the doors themselves.

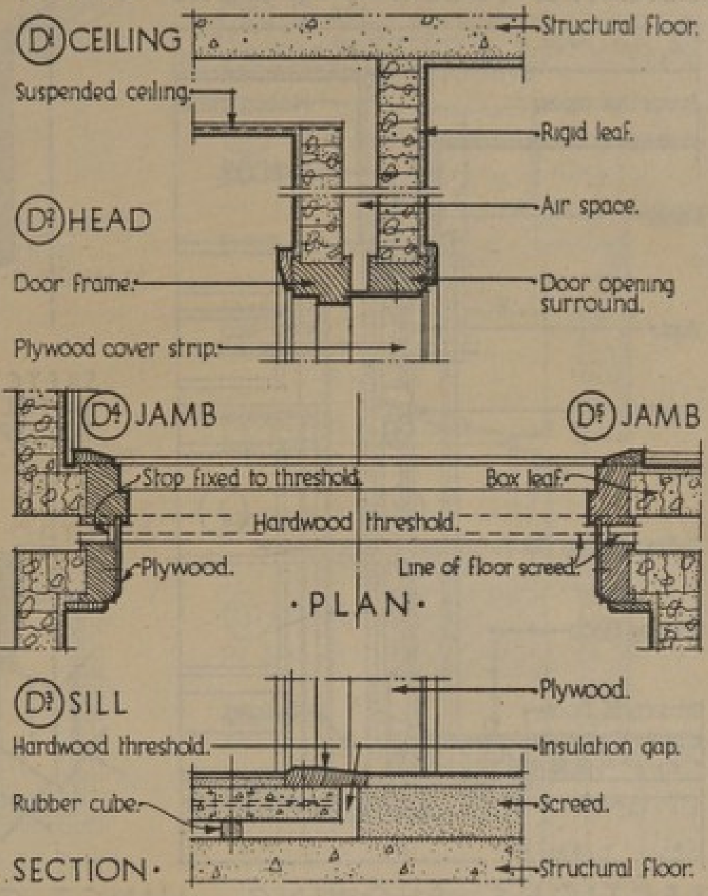
Moisture penetration beneath the floating floor must be prevented. In this case the tiles of the balcony area should not be laid until the floating floor has been lifted, when skirting tiles, laid flat, could be placed slightly beneath its edge, as shown. The small space remaining between the turn-up of the tile and the floating floor can be caulked, if desired.

DETAILS OF INTERNAL DOORWAYS

DETAILS OF DOORWAY ·C· ON PLAN

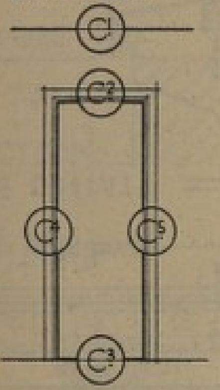


DETAILS OF DOORWAY ·D· ON PLAN

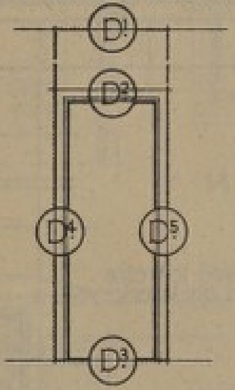


KEY TO DETAILS ·

(C) DOORWAY BETWEEN CORRIDOR & MAIN BATHROOM



(D) DOORWAY BETWEEN SERVICE CORRIDOR & MAID'S ROOM



ELEVATIONS ·

(E) DOORWAY BETWEEN STAIRCASE & HALL

SCALE FOR DETAILS ·

6 3 0 1 FT.

DETAILS OF DOORWAY ·E· ON PLAN

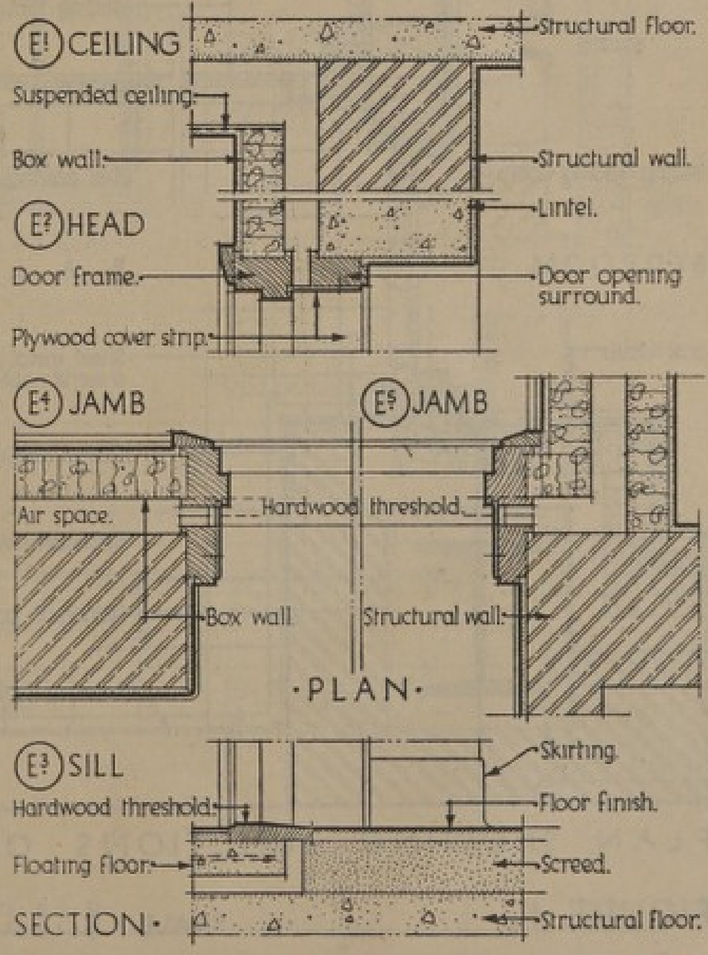
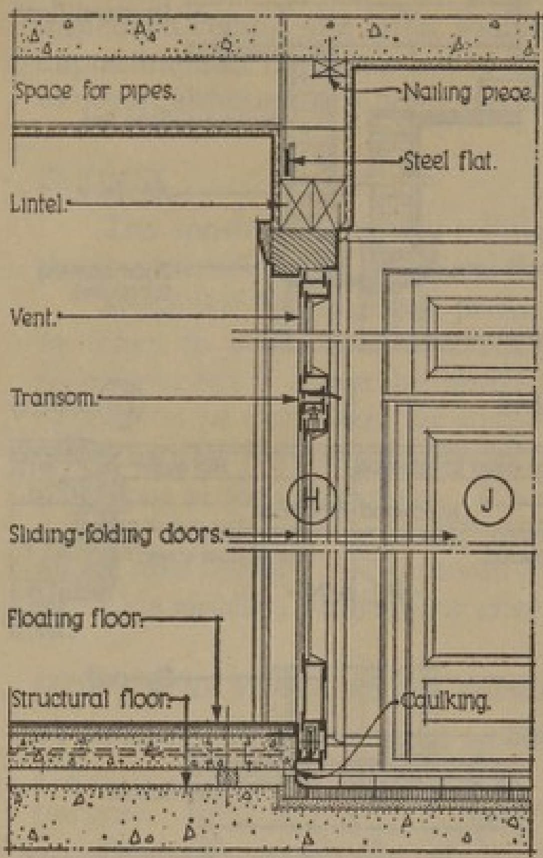
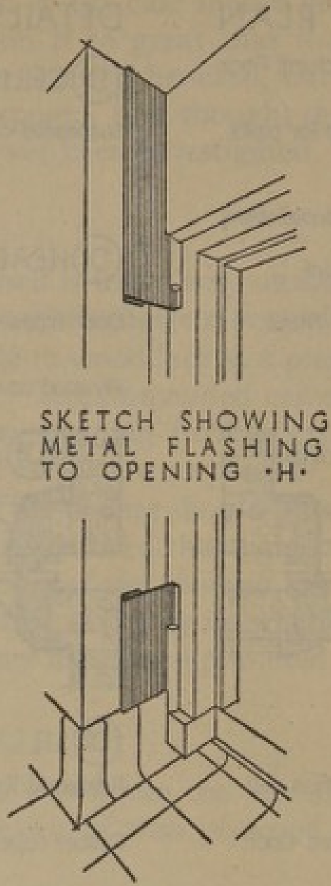


FIGURE 10.

DETAILS OF OPENINGS TO BALCONY

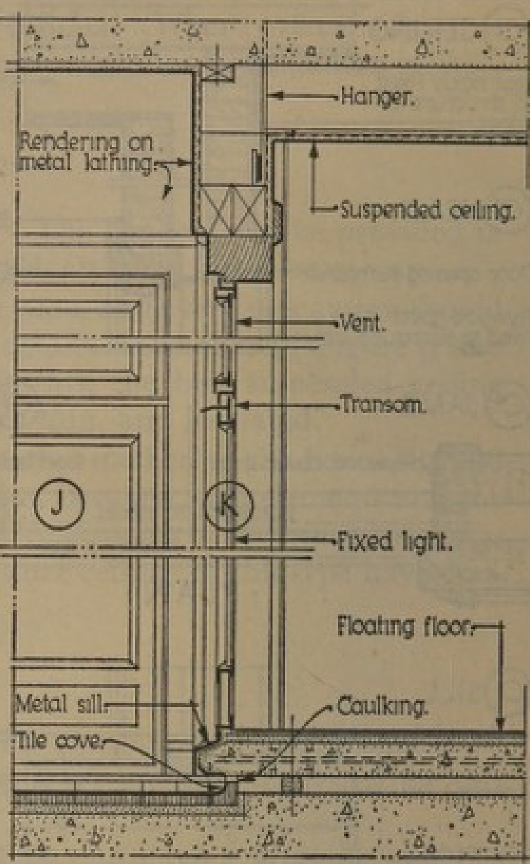
SLIDING-FOLDING DOORS



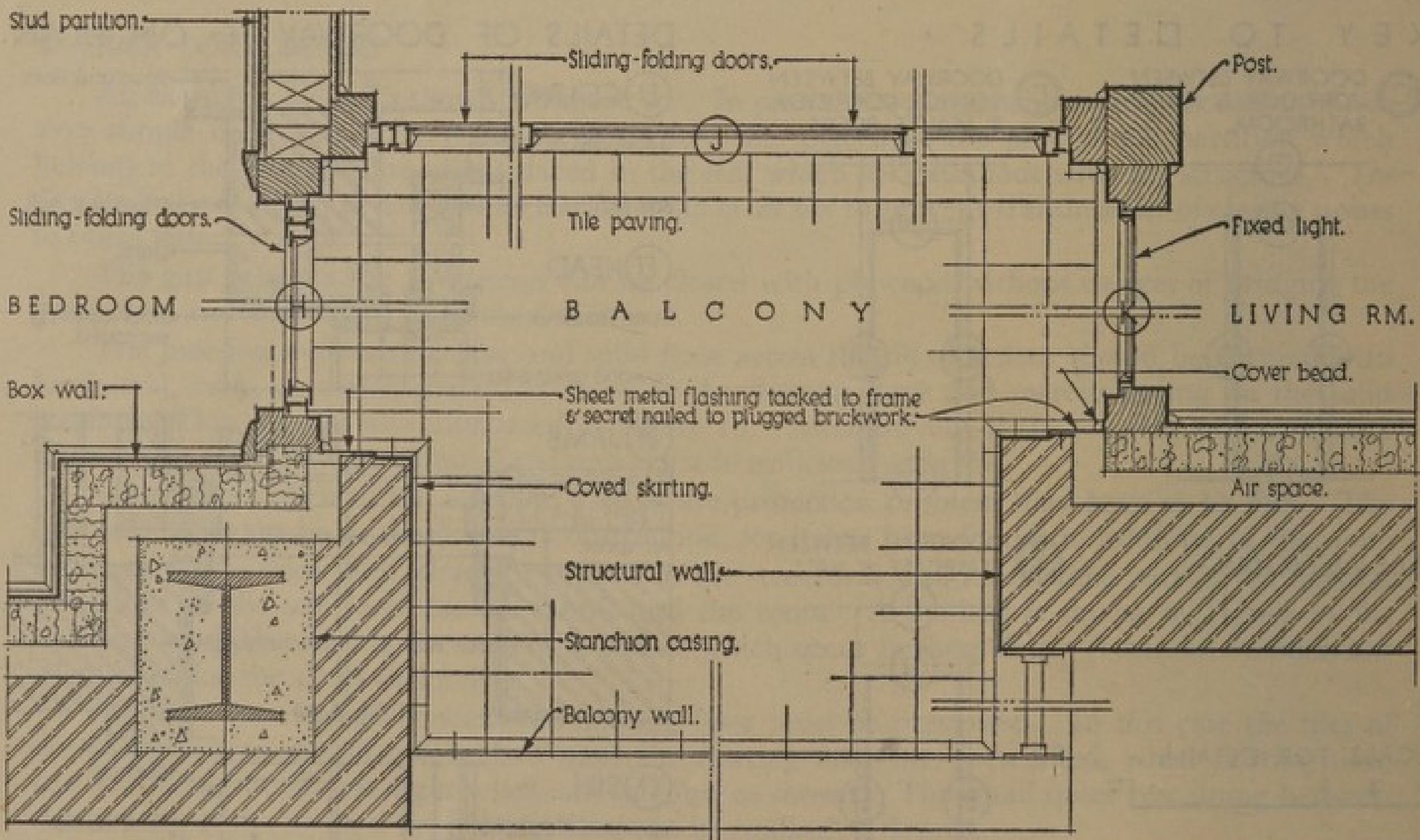


SKETCH SHOWING METAL FLASHING TO OPENING ·H·

FIXED GLAZING



SECTIONS SHOWING JUNCTIONS WITH FLOORS & CEILINGS



PLAN SHOWING JUNCTIONS OF JAMBS WITH BOX WALLS ETC.

FIGURE II.

SCALE. 12 9 6 3 0 1. 2. 3 FT.

DETAILS OF WINDOWS

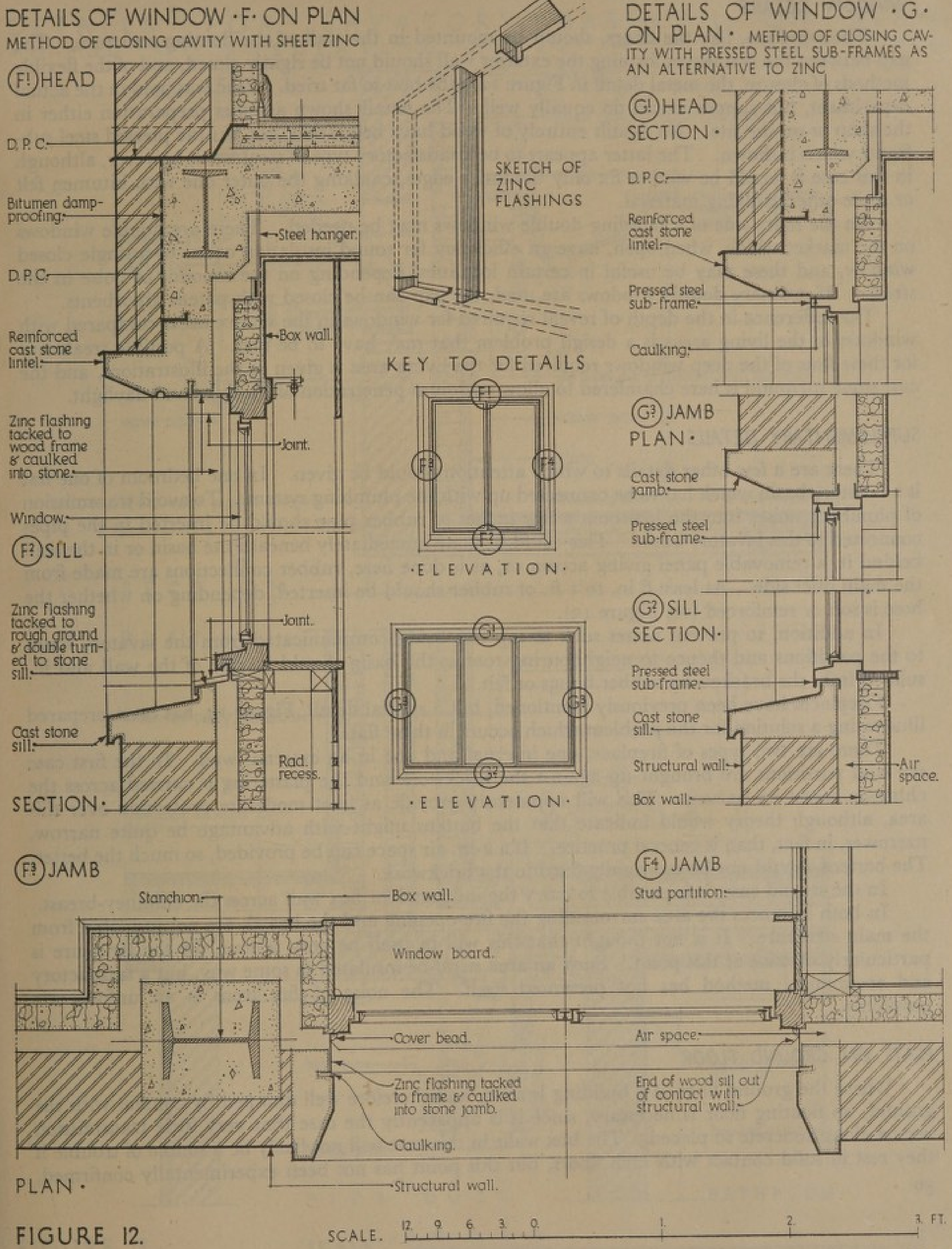


FIGURE 12.

WINDOW DETAILS

The windows, like the doors, should be mounted in the wall of the floating structure. The gap between the two leaves forming the exterior wall should not be rigidly closed, and of the flexible methods of closure, the metal detail in Figure 12 is the best so far tried. Zinc was used in the actual experiment, but copper would do equally well. The detail shown assumes preparation either in the shop or on the site. No details entirely of wood have been tried, nor has the pressed steel sub-frame which is shown. The latter appears to be a satisfactory type of treatment, however, although in this case it would be wise to fix only the inner edges, caulking the outer one with bitumen felt or some other caulking material.

On the noisy side of a building double windows may be needed. There are double windows on the market which, when open, have an efficiency for sound insulation equal to a single closed window, and these may be useful in certain localities, depending on the amount of noise in the streets. If ordinary double windows are used, the gap can be closed with patent absorbents.

The difference in the depth of reveal required for windows in the service areas compared with windows in the living areas is a design problem that may have to be met. A possible treatment for these flats of the deep windows required for the living area is given in the illustrations, and the cast stone surround is here chamfered to allow optimum penetration of sunshine and daylight.

SUPPLEMENTARY DETAILS

There are a few other details to which attention should be given. In one bedroom of one flat is a lavatory basin which has to be connected up with the plumbing system. To avoid transmission of plumbing noises into the bedroom a few inches of rubber pipe should be inserted in the pipes connected to this lavatory basin. This could be done immediately beneath the basin or in the wall behind it, a removable panel giving access, or, as is done here, rubber connections are made from the main duct side. At least 6 in. to 1 ft. of rubber should be inserted, depending on whether the hose is soft or reinforced (see Figure 13).

In addition, to prevent noises such as tap hiss being communicated from the lavatory basin to the partitions and thence to neighbouring rooms, the basin should be free of the wall and insulated from the brackets by rubber bungs or felt.

Fireplaces have been previously mentioned, but a special detail, Figure 14, has been prepared illustrating a solution for the problem which occurs in these flats.

There are two types of fireplace, one internal and one in an external wall. In the first case the stud partitions are brought up against the brickwork and the plastering is carried across the chimney-breast on battens. This will apparently provide at least moderate protection over this area, although theory would indicate that the battens might with advantage be quite narrow, narrower, in fact, than is general practice. If a 2-in. air space can be provided, so much the better. The battens should not be too rigidly fixed to the brickwork.

In the second case, it is possible to carry the independent box wall across the chimney-breast.

In both instances the area surrounding the fire-opening and the hearth are not insulated from the main structure. It is not thought that this will in itself be very serious, for the structure is particularly massive at this point. Such an area *might* be insulated in some way, but a satisfactory and economical method has not presented itself. The noise of fire irons is an unfortunate possibility.

FLATS ON GROUND FLOOR

Where the ground floor of a building is solid, and therefore well damped by contact with the ground, no floating floor is necessary, since it is apparently the case that very little transmission occurs along concrete so placed. The box walls in this case will not likely be a source of trouble if they rest in solid contact with such floors, but this point has not been experimentally confirmed,

DETAILS OF PLUMBING

DETAILS FOR LAVATORY BASIN ·L· ON PLAN

METHOD OF INSULATING PIPES WITH RUBBER HOSE

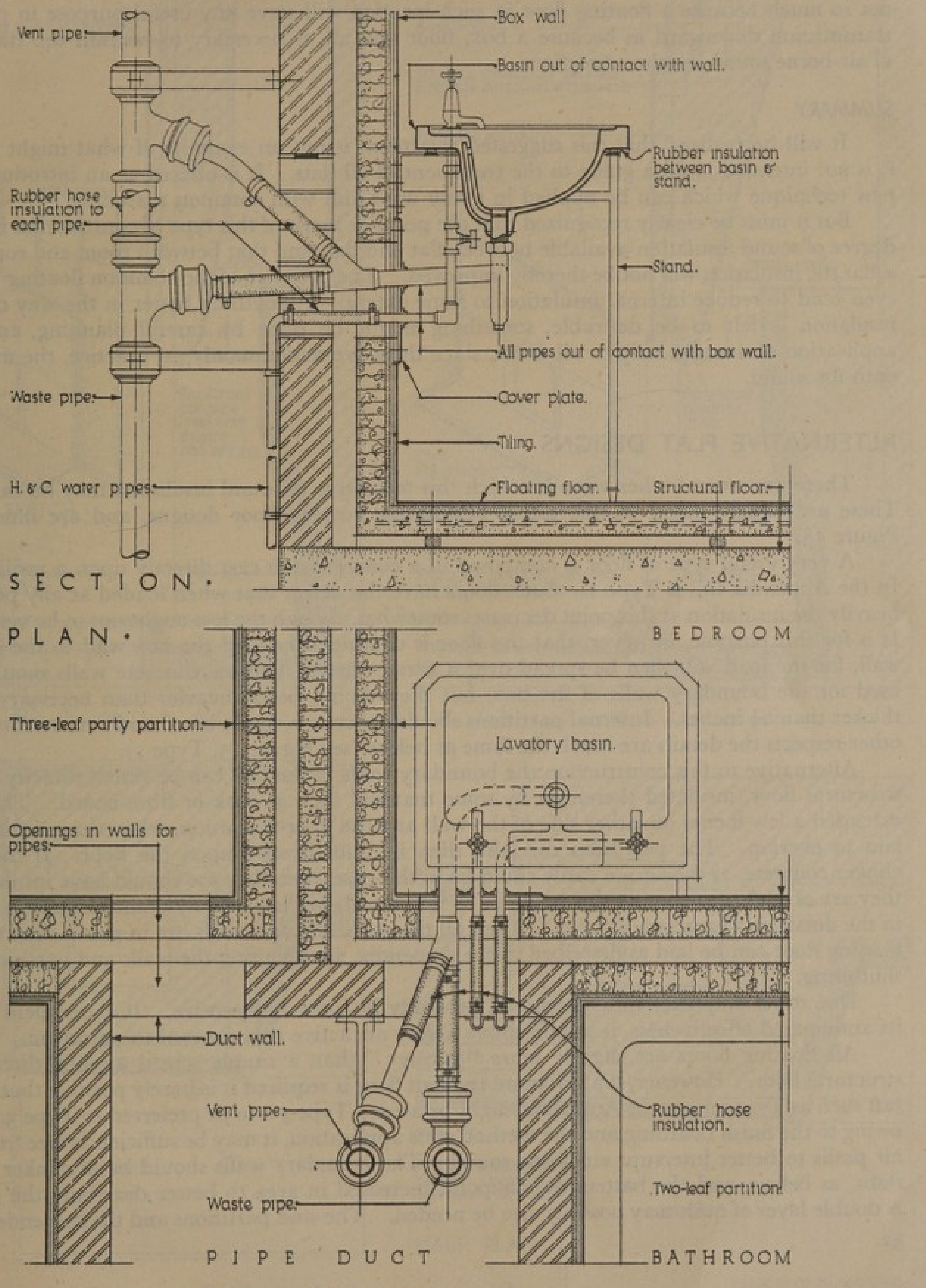


FIGURE 13.

SCALE 12 9 6 3 0 1 2 3 FT.

and those who wish to make certain of the insulation value for which they are aiming could use such details as are shown in Figure 9.

Flats on the ground floor with basement beneath should not differ from flats on other floors, not so much because a floating floor in such location will serve any useful purpose in preventing transmission downward as because a box, floor and all, is necessary to restrain the transmission of air-borne sound in other directions.

SUMMARY

It will be realized that this suggested treatment is but an example of what might be done; it is not intended to be a guide to the treatment of all flats. It is offered as an introduction to a new technique which can be applied in many ways and with common materials.

But it must be clearly recognized that the peculiar merit of this type of construction is the high degree of sound insulation available between flat and flat, and that between room and room within a flat the insulation will not be thereby improved. The presence of the common floating floor may even tend to reduce internal insulation to some extent. If anything better in the way of internal insulation is felt to be desirable, something might be done by careful planning, and by the application of draught strip to all doors, since these are so commonly, in practice, the most ready path for sound.

ALTERNATIVE FLAT DESIGNS

There are several other ways in which this technique of sound insulation may be carried out. These are largely based on the use of alternative floating floor designs, and are illustrated in Figure 15.

A very useful type of floor is composed of a concrete slab cast directly upon a resilient quilt. In the Appendix this is Type 1. Such floors have the defect that when loaded at any point fairly heavily the insulation at this point decreases somewhat, though the loss ought not to be very serious. It is for this purpose, however, that the floor is continued beyond the box wall to the structural wall, for the load will then be spread over a greater area. Clinker concrete walls should still be used for the boundary walls of the box, but they should be no heavier than necessary, say not thicker than $2\frac{1}{2}$ inches. Internal partitions should, of course, again be of stud construction, and in other respects the details are much the same as before (see Figure 15, Type 1).

Alternative to this construction the boundary walls of the box can be rested directly upon the structural floor, insulated therefrom by some material such as cork or fibre-board. This can be extended a few inches on either side of the wall and the floor insulation, whatever quilt it may be, laid to overlap. The partitions can also then be laid directly upon the floor. If they are of clinker concrete, as they quite easily could be in this case, then they too should have insulation. If they are of stud construction this may not be important, but is probably desirable, and is so shown in the details in Figure 15, Type 2. When all the partitions and walls are in place, then the entire floating floor can be laid as described in the Appendix, simply using the walls and partitions as the shuttering.

Due to its simplicity this system will probably be quite inexpensive. If experiment confirms its anticipated effectiveness, it should prove a very attractive treatment of the problem.

All floating floors are slightly more "springy" than a simple screed applied direct to the structural floor. However, if a still more resilient floor is required it is barely possible that a timber raft such as Type 4 from the Appendix might be used. Type 4 is to be preferred to Type 3, because, owing to the finish boarding and the method of its application, it may be sufficiently free from direct air paths to better interrupt air-borne sound. The boundary walls should be of clinker concrete slabs, as before, and the battens at this point increased in area to better distribute the pressure. A double layer of quilt may possibly also be needed. The stud partitions and the suspended ceiling

DETAILS OF FIREPLACES

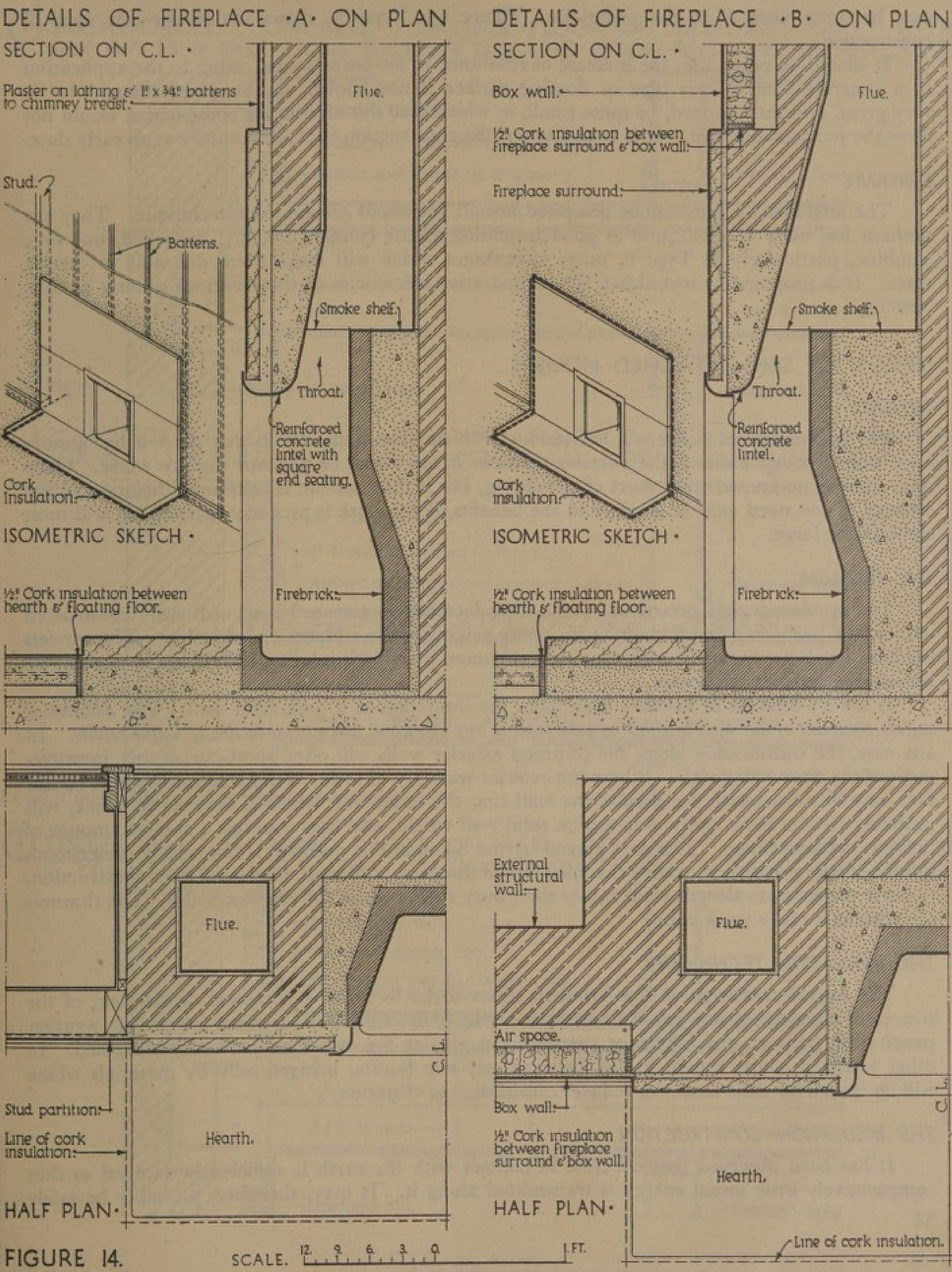


FIGURE 14.

can be quite normal to the technique. Figure 15, Type 3, shows details for this type of construction.

It should be noted that the increase of resistance to air-borne sound owing to the application to a concrete floor of this type of floating surface is not known, but it is not thought to be very great, and may, indeed, be quite small, in which case this alternative construction would not serve the purpose intended. It is hoped to test the construction in the laboratory at an early date.

SUMMARY

The alternative constructions described are all variations on the same technique. They are perhaps less likely to give quite as good insulation as the construction first described, but may combine, particularly in Type 2, other advantages which will make them desirable in certain cases. It is proposed to investigate the comparative efficiencies of these various systems as time permits.

DESIGN OF SEMI-DETACHED HOUSES

GENERAL

The semi-detached house is a less serious problem than flats only in that there is less annoyance from footstep noises ; the wireless problem is the same, or perhaps slightly worse. Once built there is no known cure, short of rebuilding, but if the problem is considered beforehand the element of cost need only be small, and the benefits, if the work is properly carried out, will most certainly be large.

THE PROBLEM

The problem is that presented by the semi-detached or terrace house, ordinarily constructed with a 9-in. party wall and 9-in. or 11-in. cavity exterior walls. Floors are of timber. The wireless loudness levels are common such that the maximum possible insulation economically obtainable is desirable between the houses.

It is very difficult to enhance materially the insulation of a 9-in. solid wall. *The addition of surface treatment of any kind to either or both faces is very expensive, and not productive of useful results.* In any case, the transmission along the common exterior walls will often short-circuit any improvement of the intervening wall. Where the exterior walls are of 11-in. cavity construction, the condition may be even worse, for despite the wall ties, the inner leaf, which is only 4½ in. thick, will probably vibrate more easily than a 9-in. solid wall would, and thus transmit a greater amount of noise to the next house. The part played by the floors in this problem is not clearly understood, but it is a wise precaution to keep the joists free of the party wall, and, in ground floor construction, to carry the joists on sleeper walls rather than bury their ends in the exterior walls. The thinness of firebacks is also a weak point.

THE INSULATION TECHNIQUE

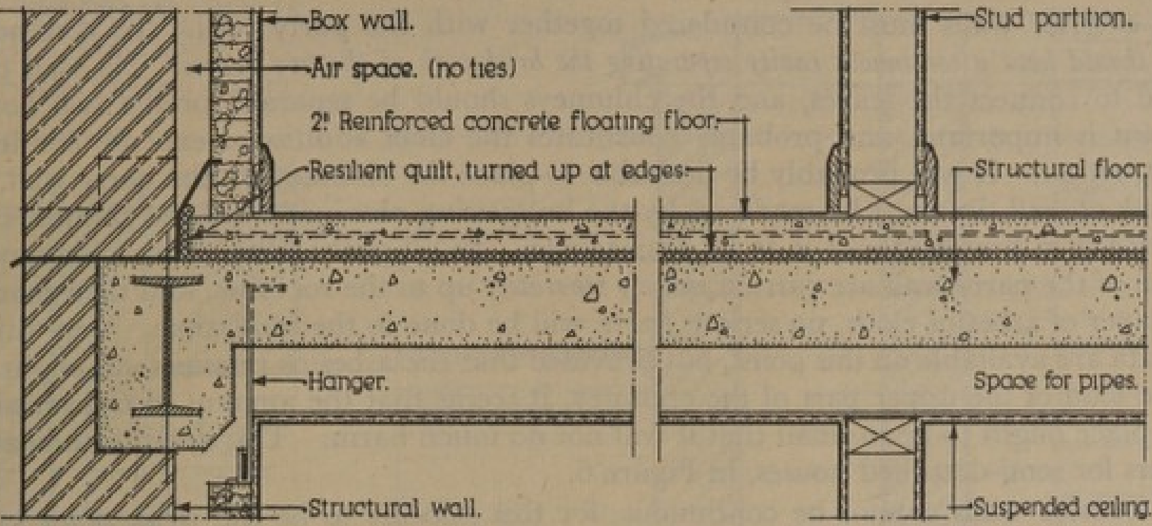
The logical treatment of this problem seems to be to make a complete detachment of the structural elements of one house from those of the house next to it, without permitting weather penetration between the houses or permitting a greater fire risk than previously obtained. In other words, a cavity should be left between any two houses, bridged only by materials which will be chosen for their ability to reduce transmission of vibration.

THE INSULATION CONSTRUCTION

It has been observed that concrete in contact with the earth is sufficiently damped so that comparatively little sound energy is transmitted along it. It may, therefore, probably be safely

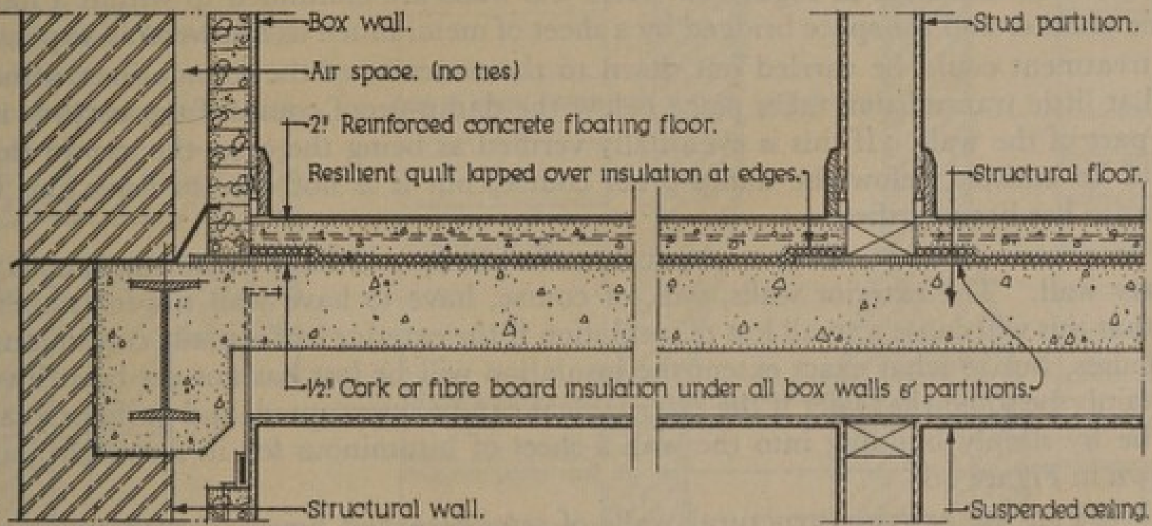
DETAILS OF ALTERNATIVE SYSTEMS

(1) 2" REINFORCED CONCRETE FLOATING FLOOR ON RESILIENT QUILT WITH BOX WALLS & PARTITIONS BUILT ON FLOATING FLOOR AND CEILING SUSPENDED



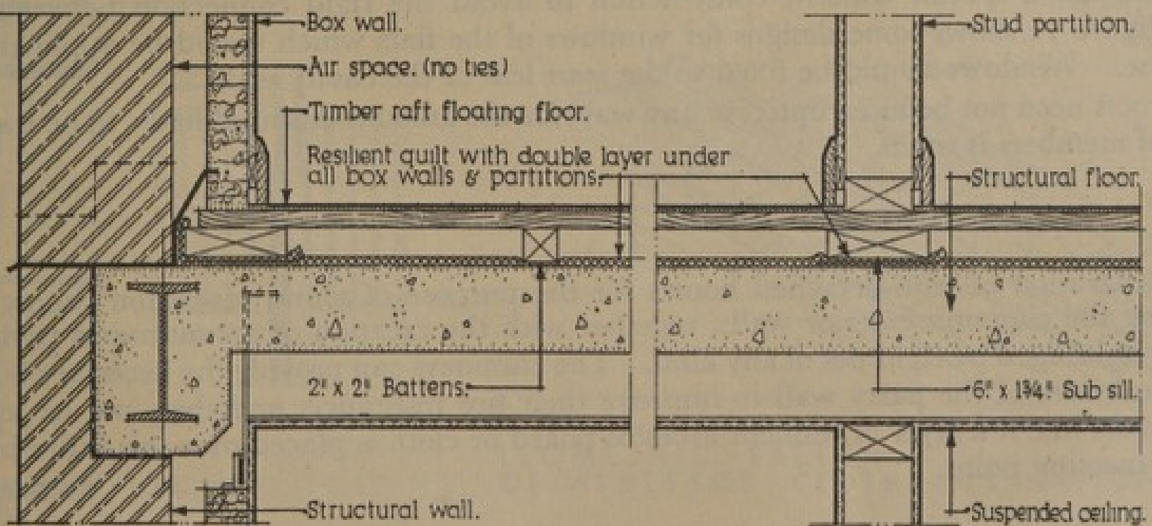
SECTION.

(2) 2" REINFORCED CONCRETE FLOATING FLOOR ON RESILIENT QUILT WITH BOX WALLS & PARTITIONS BUILT ON STRUCTURAL FLOOR AND CEILING SUSPENDED



SECTION.

(3) TIMBER RAFT FLOATING FLOOR ON RESILIENT QUILT WITH BOX WALLS & PARTITIONS BUILT ON FLOATING FLOOR AND CEILINGS SUSPENDED



SECTION.

FIGURE 15.

SCALE. 12. 9. 6. 3. 0. 1. 2. 3. FT.

assumed that the concrete foundations of the houses could be continuous, although, of course, any discontinuity that might be cheaply obtained, say, by leaving a board in place between the foundations of two houses, would probably be beneficial.

The exterior walls must be considered together with the party wall. To commence with, *the latter should have a continuous cavity separating the brickwork of the two houses.* No wall ties should be placed to connect the leaves, and the chimneys should be separate for the two houses ; the latter point is important, and probably constitutes the chief additional expense connected with this construction. It will probably be desirable to place the chimney on the party wall, however, for the lack of wall ties must be made up by the buttressing obtained from the chimneys if a party wall adequate in fire resistance is to be maintained. In all probability, if the chimneys and the two leaves of the party wall are carried *entirely separately* up to the roof line, and then made to meet above a layer of asbestos cloth, no serious harm will be done to the insulation. Very little experimental data are available on this point, but provided that the asbestos retains some slight resilience under the load of the upper part of the chimney, it seems that the amount of transmission which can take place ought to be so small that it will not do much harm. This detail is indicated, along with others for semi-detached houses, in Figure 6.

The exterior walls cannot be continuous, for this appears to be the weak point in the construction as it is normally carried out.

If the exterior walls are solid, of 9-in. or greater thickness, the break in their continuity might readily be done as indicated in Figure 6. Here the walls are continued to within a half an inch or so of one another and the space bridged by a sheet of metal much as if it were an expansion joint.

The treatment could be carried out down to the concrete of the foundations, although it is possible that little transmission takes place below the damp-proof course if the earth is in contact with this part of the wall. If this is eventually verified as being the case, the gap in the exterior walls could be omitted below the damp-proof course, but it is not wise to leave this link until its importance has been verified.

With an exterior wall in cavity construction, the cavity will have to be continuous with that in the party wall. The exterior walls, will, of course, have to have wall ties for stability. It is expected that this will cause a small loss of insulation if the exterior leaf is made continuous between the two houses, but to what exact extent the insulation will be lost has not yet been investigated. It will certainly be somewhat safer if the external leaf can be interrupted, and perhaps a satisfactory way will be by simply building into the wall a sheet of bituminous felt in a straight joint. This is also shown in Figure 16.

Any break in the exterior structural walls of semi-detached houses should not of course be covered over by rendering or stucco for it is known that this can adequately bridge the insulation.

If the exterior wall is of cavity construction, without a break at the party wall, it would be necessary to use a special window construction to avoid the rigid connection between the two leaves. Figure 12 shows some designs for windows of the flats which would be applicable to the present case. Windows should be fixed to the *inner* leaf of the cavity wall.

The roofs need not be interrupted in any way, for the amount of sound likely to be transmitted by the roof members is small.

SUMMARY

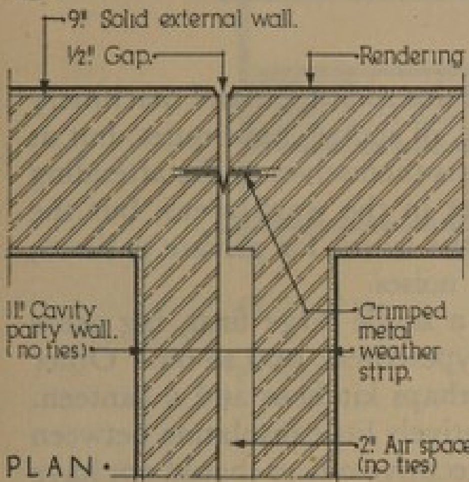
The separation of semi-detached houses for the purpose of sound insulation simply involves interrupting the common exterior walls, together with the creation of a continuous cavity in the party wall unbridged by rigid ties of any kind. The chimneys can provide the necessary buttressing for the two leaves of the party wall to improve their fire resistance, and they can be joined just below the roof line if a layer of resilient asbestos board or cloth is placed over the entire brickwork below the meeting point.

SEMI-DETACHED HOUSES

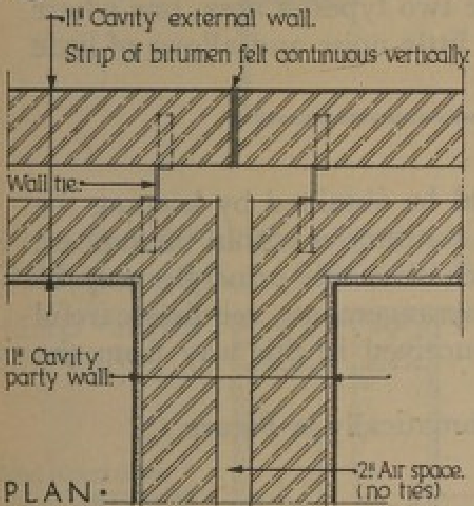
DETAILS OF SOUND INSULATION CONSTRUCTION

DETAILS OF JUNCTIONS BETWEEN EXTERNAL WALLS AND PARTY WALLS ·

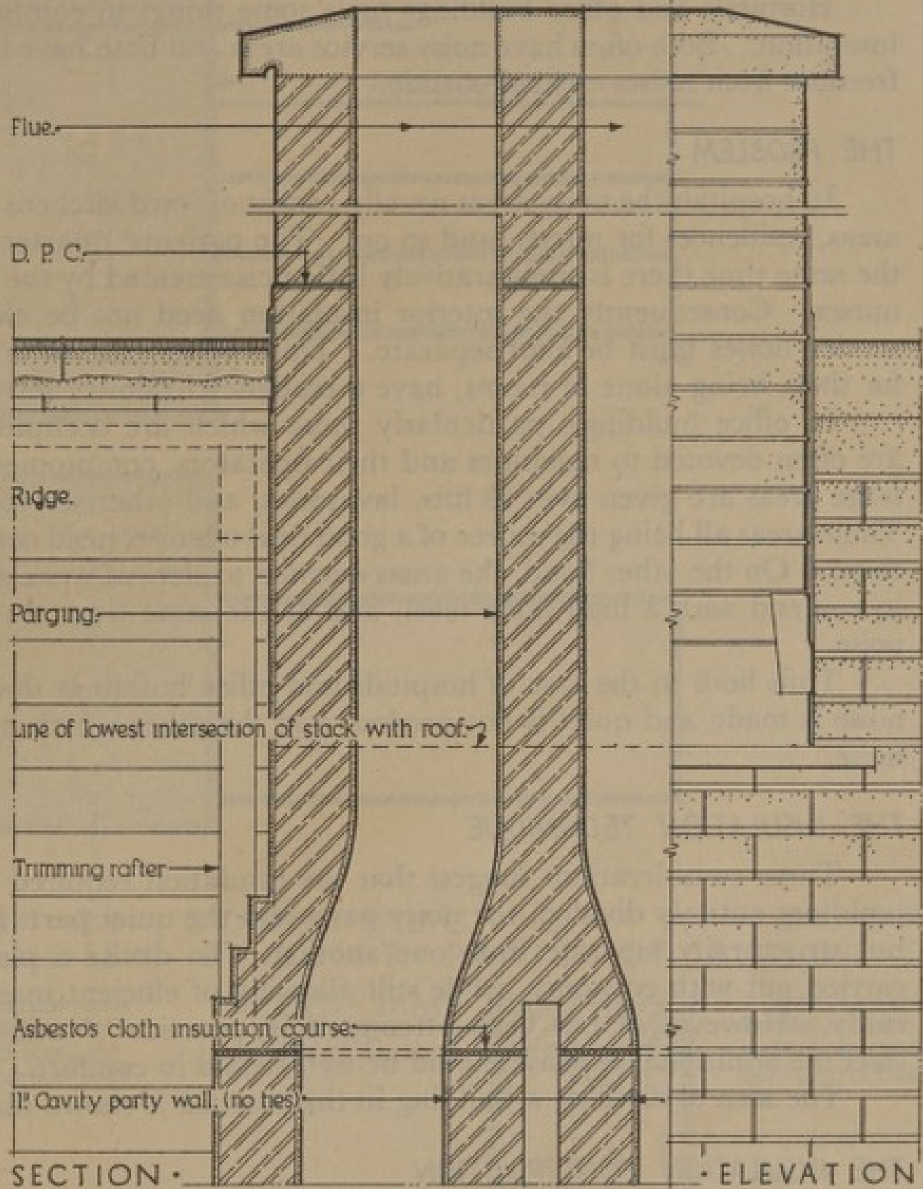
(A) 9" SOLID EXTERNAL WALL



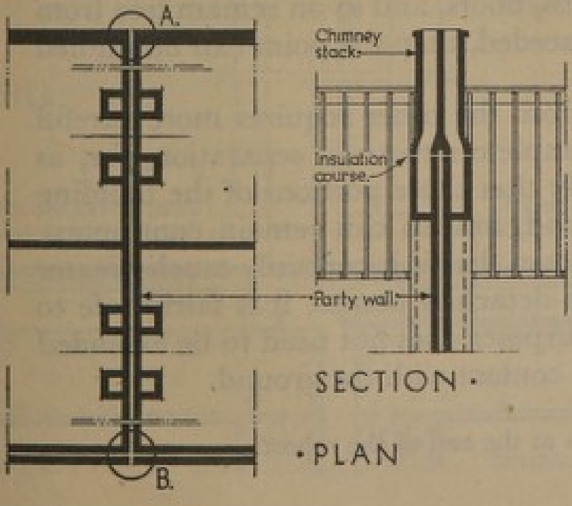
(B) 11" CAVITY EXTERNAL WALL

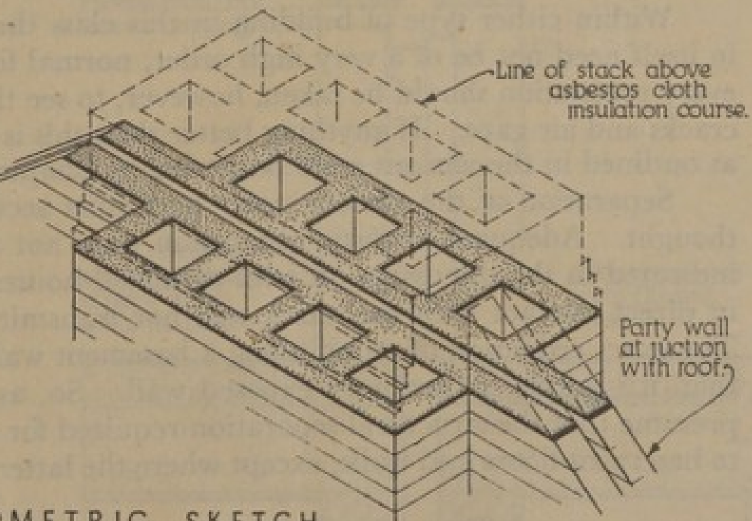


DETAILS OF CHIMNEY STACK



KEY TO DETAILS ·





ISOMETRIC SKETCH OF ASBESTOS CLOTH INSULATION COURSE

FIGURE 16.

SCALE FOR DETAILS. 12 9 6 3 0 1 2 3 FT.

DESIGNS FOR HOSPITALS AND OFFICE BUILDINGS

GENERAL

Hospitals and office buildings have some things in common from the point of view of sound insulation. Both often have noisy service areas and both have large areas for occupancy demanding freedom from noises created outside.

THE PROBLEM

In hospitals the noisy areas usually consist of ward kitchens and sluice rooms, lift and machinery areas, residences for nurses, and so on. The patients' quarters must, of course, have quiet, but at the same time there is comparatively little noise created by the patients themselves or the attending nurses. Consequently the interior insulation need not be elaborate in the ward areas, but the service noises must be kept separate. This applies particularly to the wards for private patients, for they, being alone in rooms, have a tendency to notice intruding noises.

In office buildings, particularly those which are occupied by a single large firm, big areas are often devoted to machines and their operators, comptometers, typewriters, and so on. Other large areas are given over to lifts, lavatories, and other services, perhaps kitchens and a canteen. These areas all being the source of a good deal of noise, need comparatively little insulation between them. On the other hand, the areas devoted to clerical work and executive offices should not have to contend with a high noise level, and at the same time are not themselves the source of much noise.

Thus both in the case of hospitals and office buildings there are two types of area, one where noise is made and quiet is not needed, and the other which makes little noise and allows of little noise.

THE INSULATION TECHNIQUE

These considerations suggest that the insulation required should be obtained by keeping the buildings entirely divided, the noisy parts and the quiet parts being continuous within themselves, but structurally separate from one another. To devise a plan such that this principle may be carried out with economy, while still allowing of efficient internal arrangements, requires careful study. However, it has been attempted in practice(1),* and if conceived in this way from the start the additional expense should be well repaid in comfort.

The idea of dividing a building in this manner is shown diagrammatically in Figure 17.

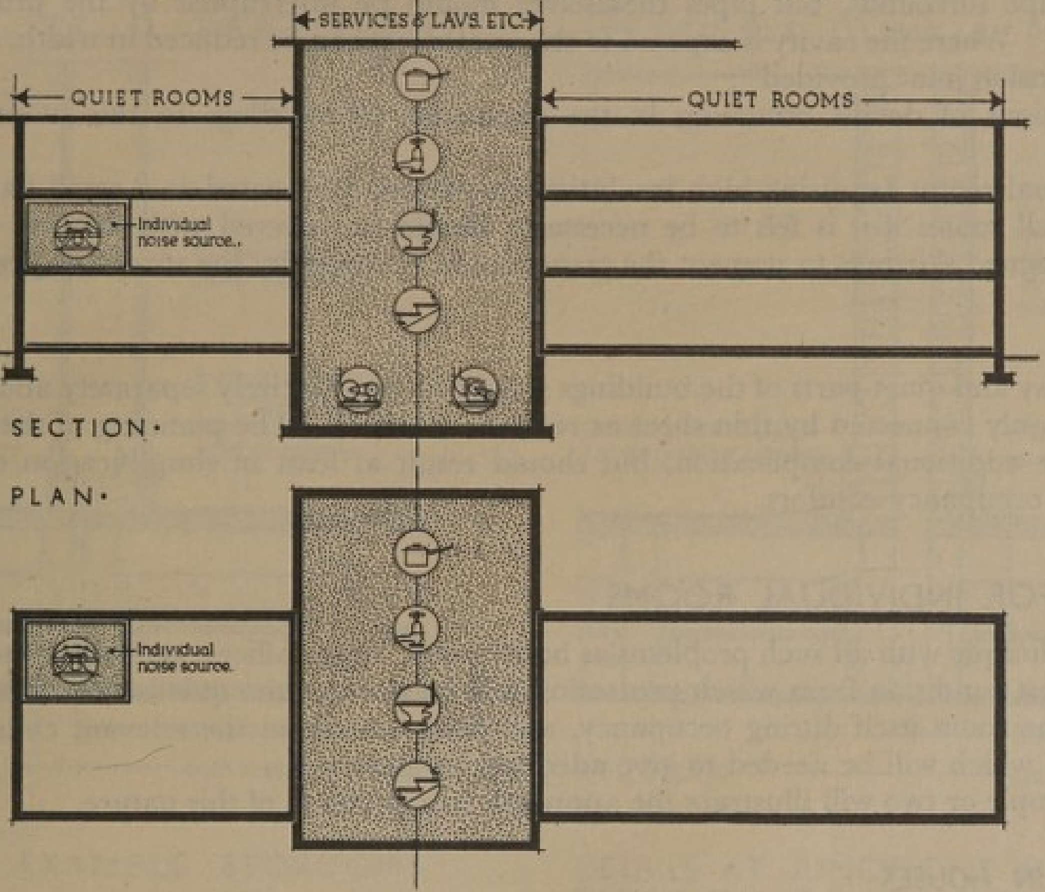
THE INSULATION CONSTRUCTION

Within either type of building in this class the internal insulation of a noisy or quiet section in itself need not be of a very high order, normal forms of construction being probably adequate ; every precaution should be taken, however, to see that the walls, doors, and so on remain free from cracks and air gaps. If anything better than this is felt to be needed, then the point can be studied as outlined in the various cases occurring in Chapter I.

Separation of the various noisy and quiet sections one from the other requires more careful thought. Adequate acoustic separation may not require complete structural separation, for, as indicated in the discussion on semi-detached houses, it is likely that those portions of the building in direct contact with the earth will not transmit much sound, and so can remain continuous. The exact reduction of sound along a basement wall is not known, but it is certainly much greater than it is along an ordinary exposed wall. So, as with semi-detached houses, it is fairly safe to presume that the structural separation required for acoustic purposes does not need to be extended to basement floors and walls, except where the latter are not in contact with the ground.

* The numbers in brackets refer to the list of references at the end of the report.

DIAGRAMMATIC LAYOUT



SUGGESTED DETAILS OF CONSTRUCTION AT DOOR OPENINGS BETWEEN NOISY & QUIET PARTS OF BUILDING

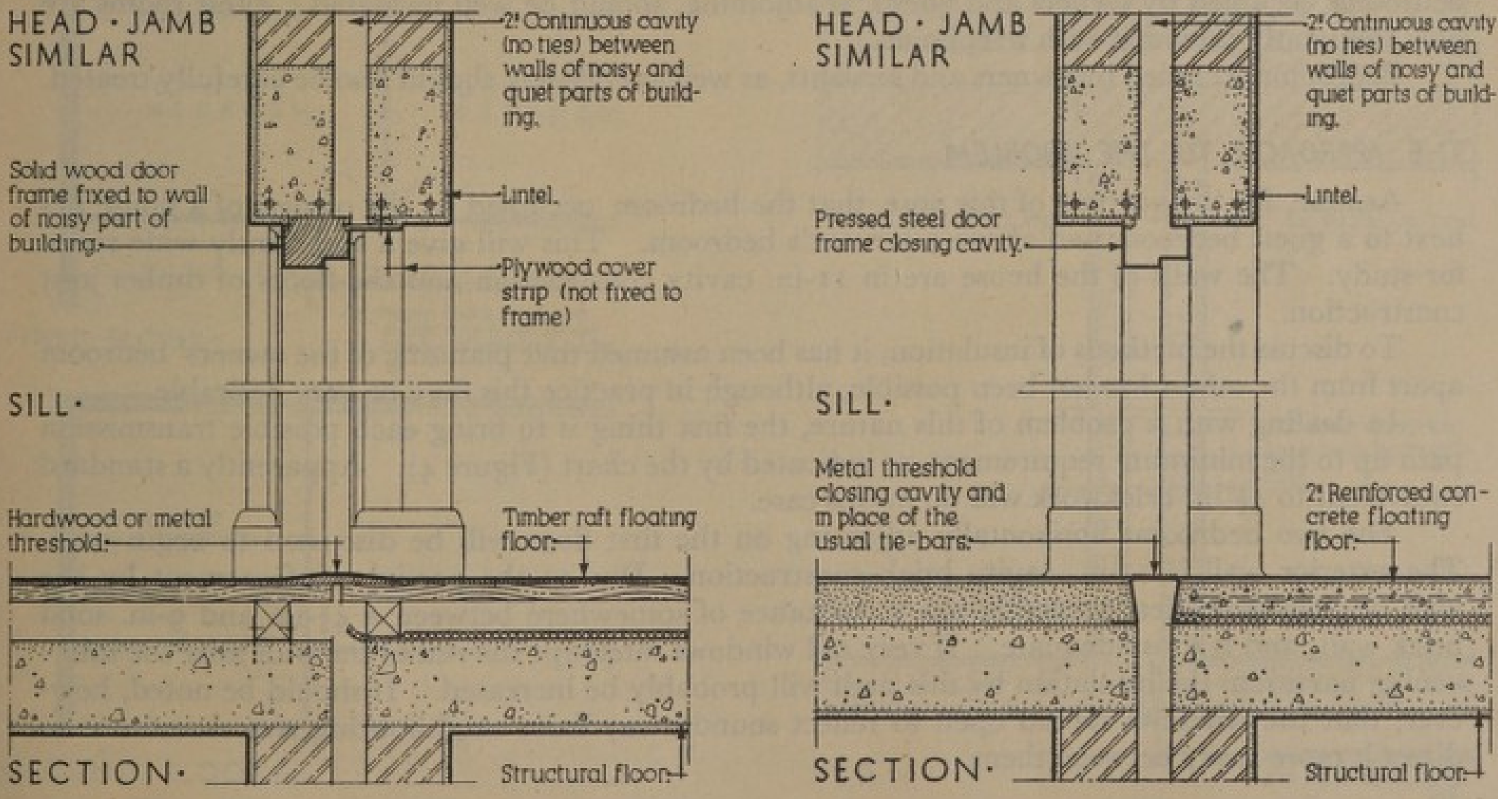


FIGURE 17.

SCALE. 12. 9. 6. 3. 0. 1. 2. 3. FT.

In general the cavity between two such sections should be about 2 in. wide and complete as to heavy and rigid materials. Thin plywood and metal may be safely used to close the gap at doorways and pipe surrounds, but pipes themselves should be interrupted by the proper length of rubber tube. Where the cavity is exposed to the weather, it can be reduced in width, and a suitable type of expansion joint provided[2].

Illustrations of details occurring in the separation of buildings in this manner constitute Figure 17.

Individual rooms requiring high insulation can simply be treated as a small flat. Corridors, or, in fact, all rooms if it is felt to be necessary, should be covered with floating floors, having properly designed skirtings to prevent the transmission of sound by the structure (see Appendix).

SUMMARY

The noisy and quiet parts of the buildings should be built entirely separately above the ground level, being only connected by thin sheet or resilient material. The planning of the building thus takes on one additional complication, but should result at least in simplification of the services and greater occupancy comfort.

DESIGNS FOR INDIVIDUAL ROOMS

The technique with all such problems as hotel rooms, single offices, bedrooms, etc., is to decide on the noisiest condition from which protection will be needed, the quietest condition likely to be desired in the room itself during occupancy, and determine from the relevant charts the type of construction which will be needed to give adequate insulation.

An example or two will illustrate the approach to a problem of this nature.

BEDROOMS IN HOUSES

It often happens that within a private house certain bedrooms should be insulated from others, despite the fact that bedrooms are not commonly the source of much noise. For instance, the bedrooms occupied by owners and guests, if adjoining, should be well insulated ; guest rooms are now frequently provided with telephones.

Bedrooms occupied by owners and servants, as well as children, should also be carefully treated.

THE APPROACH TO THE PROBLEM

Assume, for the purpose of this note, that the bedroom occupied by the owners of a house lies next to a guest bedroom and above a servant's bedroom. This will give a sufficiently wide scope for study. The walls of the house are in 11-in. cavity construction and the floors of timber joist construction.

To discuss the methods of insulation, it has been assumed that planning of the owners' bedroom apart from the others has not been possible, although in practice this may be very desirable.

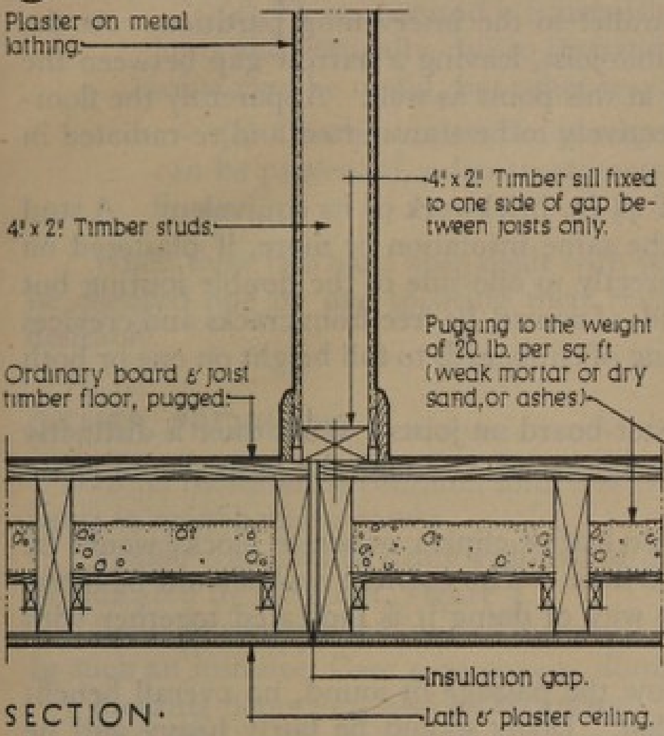
In dealing with a problem of this nature, the first thing is to bring each possible transmission path up to the minimum requirement, as indicated by the chart (Figure 4). Apparently a standard equivalent to 4½-in. brickwork will do in this case.

The two bedrooms horizontally adjoining on the first floor will be discussed to begin with. The exterior wall is 11-in. cavity brick construction. Due to the partial reinforcement by the wall ties, the inner leaf probably has a resistance of somewhere between a 4½-in. and 9-in. solid brick wall, and is thus adequate. If very tall windows interrupt the run of the wall near the intervening partition, the insulation by this path will probably be increased. It should be noted, however, that the windows should open to reflect sound away from neighbouring rooms and not to direct it more easily between them.

DETAILS OF SOUND INSULATION CONSTRUCTION

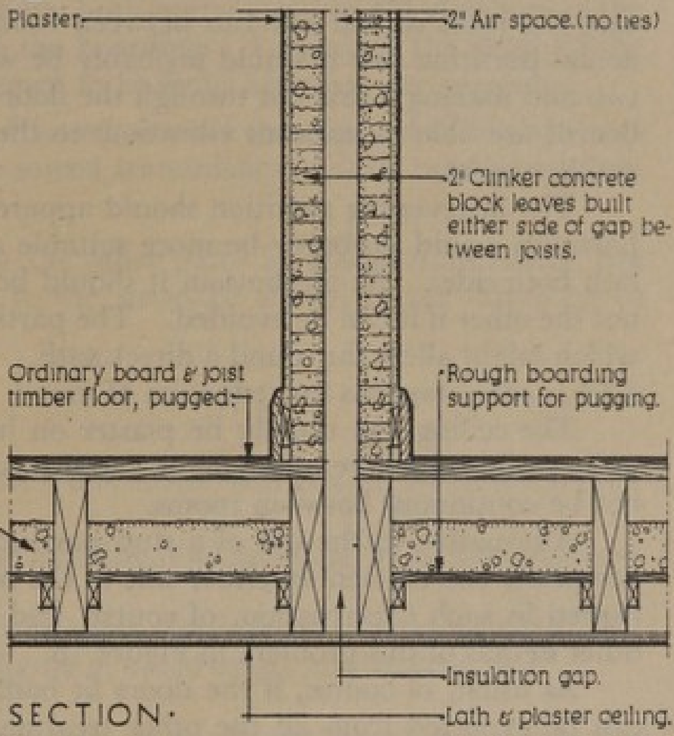
DETAILS OF JUNCTIONS OF BEDROOM PARTITIONS WITH FLOOR

(A) SINGLE STUD PARTITION



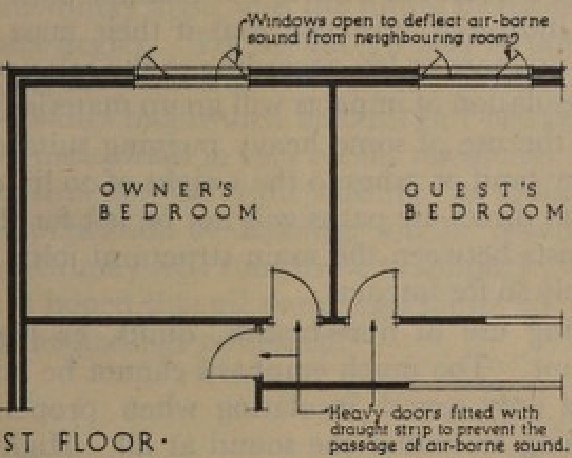
SECTION·

(B) DOUBLE CLINKER PARTITION

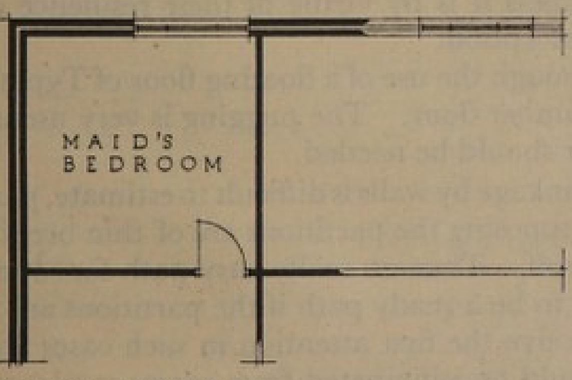


SECTION·

LAYOUT OF EXAMPLE BEDROOMS

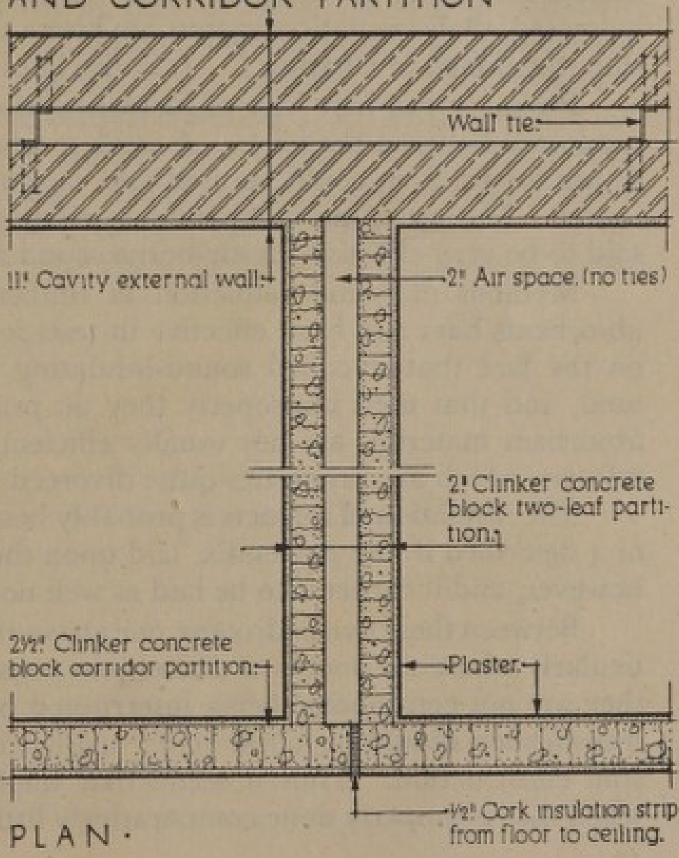


FIRST FLOOR·



GROUND FLOOR·

DETAILS AT JUNCTIONS OF CLINKER PARTITION ·B· WITH EXTERNAL WALL AND CORRIDOR PARTITION



PLAN·

FIGURE 18.   SCALE FOR DETAILS. 12 9 6 3 0   1.   2.   3 FT.

The next wall to be studied is the common corridor wall. If this is to be continuous and cannot be of 4½-in. brickwork, it should be of stud construction. If it must be of thin clinker concrete it should be interrupted where it meets the intervening partition, as it will otherwise be a ready path.

The timber joist floor is often another ready path for sound transmission. Experiments indicate that the joists should not run between rooms, but parallel to the intervening partition. At the actual partition line it would probably be wise to double-joist, leaving a narrow gap between the two and making a saw cut through the floor-boarding at this point as well. Apparently the floor-boards are able to transmit vibrations to the joists effectively to be transmitted and re-radiated in another room.

The intervening partition should apparently be of 4½-in. brickwork or its equivalent. A stud partition would probably be more suitable and give the same insulation or more, if plastered on lath both sides. At the bottom it should be nailed directly to one side of the double joisting but not the other if it can be avoided. The partition should, of course, be free from cracks and crevices which might allow the sound a direct path. The placing of cupboards to full height on one or both sides is advantageous for reduction of sound.

The ceiling will usually be plaster on lath or plaster-board on joists ; the former is distinctly to be preferred where problems of sound insulation are concerned, although the joists should again not be continuous between rooms.

Alternative to the use of a stud partition, a double leaf of clinker concrete blocks would be adequate, one erected on either side of the break in the floor. The corridor wall should be interrupted in such construction, of course, and a suitable way of doing it is indicated together with other details of this problem in Figure 18.

As usual, of course, if the doors fit badly and allow the passage of sound, no overall benefit can be expected from all the other treatments provided. Doors should be fairly heavy and be provided with a draught preventer of some kind *on all edges* to close the air paths. A very satisfactory material is a spring metal strip, marketed specially for this purpose.

Between the servant's bedroom below and the owner's bedroom above, the readiest path is almost certain to be the joist floor. Experiments have indicated, however, that if their mass is increased, their insulation against air-borne sound will go up more or less according to the relationship mentioned in Chapter I. It is also known that the insulation of impacts will go up materially.

Probably the best way of increasing the mass is by the use of some heavy pugging suitably supported between the joists. A weak mortar, or even dry sand or ashes to the weight of 20 lb. or so per square foot, could be used and carefully laid so that direct air paths will not be left for the sound. The use of an independent ceiling carried on joists between the main structural joists is said to be very effective for air-borne sound and moderately so for impacts.

Methods of sound reduction in timber floors making use of fibre-boards, quilts, or high absorbents have not been effective in tests so far carried out. Too much emphasis cannot be laid on the fact that so-called sound-insulating materials are only sound insulating when properly used, and that used improperly they do practically nothing to hinder the sound at all. Highly absorbent materials are not usually efficient insulators unless it is by virtue of their resilience or softness, which are properties quite divorced from their absorption.

The insulation of impacts is probably best obtained through the use of a floating floor of Types 3 or 4 described in the Appendix, laid upon the structural timber floor. The pugging is very useful, however, and if carpet is to be laid as well no floating floor should be needed.

Between these two bedrooms, one above the other, the linkage by walls is difficult to estimate, particularly where the floor is of timber joist construction. Supposing the partitions are of thin breeze, they are not continuous, being interrupted by the floor itself. Thus no really easy path for sound transmission should be found here ; neither is there likely to be a ready path if the partitions are of stud construction. Thus it seems that the floor must receive the first attention in such cases and when that is properly done comparatively little trouble should be anticipated from rooms so placed.

SUMMARY

Too little is known about timber joist and stud construction to make accurate recommendations. Undoubtedly there are two very weak paths which allow sound to pass readily :

(*a*) Floors : sound is transmitted very readily both horizontally in the direction of the joists and vertically, due to certain qualities in the boarding. Increasing the depth of the joists may be useful, but other treatments, known to be more effective, are suggested.

(*b*) Doors : unless the passage of air and sound around the edges of ill-fitting doors can be prevented, other treatments to reduce sound transmission will be rendered superfluous.

When these two have been dealt with satisfactorily, the other paths for sound transmission can be checked one by one to bring their resistance up to the standard shown in the charts to be desirable.

OTHER PROBLEMS

Hotel rooms are a common source of trouble, usually due either to traffic or the noise of occupants in neighbouring rooms.

Traffic noise can be dealt with first in planning the building, and secondly by special windows, as indicated by the chart, Figure 3.

Between rooms something of the order of efficiency of a 9-in. brick wall is apparently desirable. In such an instance, Case 4 on page 5, illustrated in Figure 2, could apply almost directly.

Floating floors may also be necessary.

Individual offices, and other isolated cases requiring sound insulation can all be approached in much the same way. Broadcasting studios are also amenable to this treatment.

On the information given it is in fact possible to visualize a solution for almost any problem which may arise, and the future development of the technique can probably also be anticipated to some degree. For instance, it may be possible to do away with structural floors as separate elements, using only floating floors and suspended ceilings in the comprehensive discontinuous construction. Buildings might then be built in "layers," each layer separated by a resilient. In addition there are indications in very recent researches that wall ties of certain standard types used in cavity wall construction are quite effective as sound insulators. If further tests confirm this, it seems some simplification of detailing will be possible in many cases. Other advances can also be foreseen, which may well contribute to simplicity and effectiveness in dealing with these problems. In time it is hoped that all these possibilities will be explored at the Building Research Station, and details of the findings published.

APPENDIX

IMPACT SOUND TRANSMISSION THROUGH CONCRETE FLOORS

Methods of construction—Materials for isolation—Skirtings—Floating floors commercially obtainable

In the investigations on this subject which are being conducted jointly by the National Physical Laboratory and the Building Research Station, the National Physical Laboratory being responsible for the physical measurements, four particularly successful and useful treatments of the concrete structural floor to localize noise have been developed. These are all of what may be termed the "floating floor" type, where the wearing surface is carried upon a resilient material which serves to insulate the main structure from the vibrations. The various types are illustrated in Figure 19, and, of these, Types 1 and 3 are very simple and cheap, while Types 2 and 4 give slightly better results at somewhat greater cost and are more certain to give satisfaction. Types 1 and 2 are suitable for finishing with screed and lino, cork, rubber, or wood-blocks and similar materials, while 3 and 4 are of the timber-on-batten type, having a wood finish in the usual manner.

The characteristics and details of construction of these floors are as follows :

TYPE I

CONSTRUCTION

Nominal ½-in. thick quilting of glass silk, eel grass, or slag wool is laid upon the bare structural concrete, the joints of the quilting being lapped and the whole covered with a waterproof building paper. A screed from 1½–2 in. thick, slightly reinforced in mid-section, is poured directly upon the prepared quilting. The surface is then prepared to receive the wearing finish.

COMMENT

In general, the thicker the quilting and the thicker the screed the better the insulation, although the minima suggested are quite effective. Glass silk apparently forms the best of the quilt materials tested for this purpose.

The waterproof paper is intended simply as a precaution against concrete leakages through the quilting, for these can establish rigid bridges which short-circuit the insulation.

Where very heavy point loads come upon a floor of this nature, some increase of reinforcement may be desirable. Where the insulation of very heavy impacts is needed, the overall thickness of the slab and the reinforcement also should be increased.

The cost of this treatment is normally little in excess of an ordinary screed and lino.

There is no doubt that this floor merits popularity. Its effectiveness and economy together are probably unequalled as far as present knowledge goes, and it can be adapted to suit almost any type of building.

INSULATION VALUE

This type of floor would be classified as "fairly quiet" to "quiet," depending on the type of quilting (preferably of an inorganic type) and the thickness of the slab (preferably at least 2 in.). The nature of the wearing surface affects the overall insulation only slightly, but most floor coverings produce a further small improvement.

FLOATING FLOORS & INSULATED SKIRTINGS

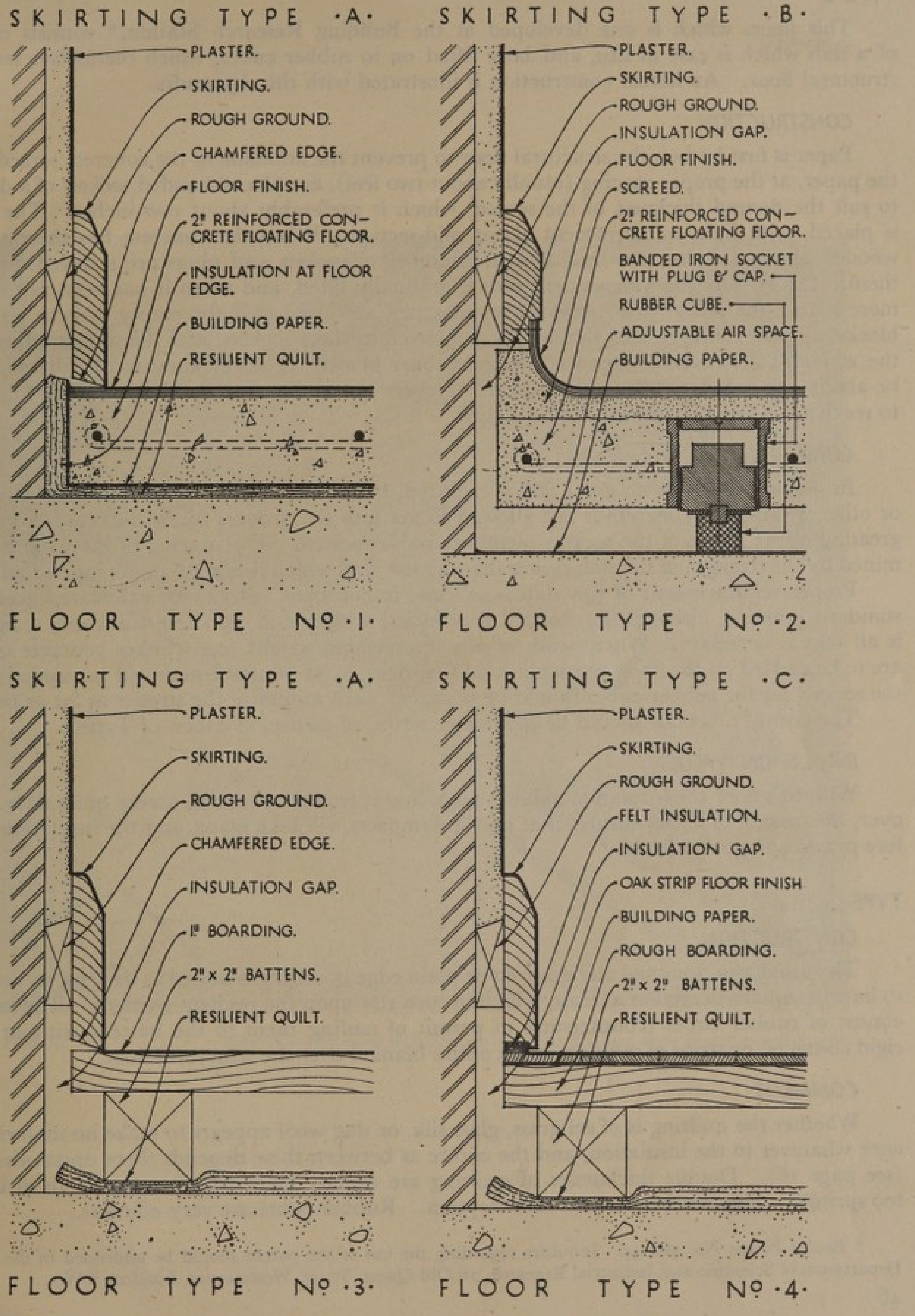


FIGURE 19. SCALE. 1 0 1 2 3 4 5 6 7 8 9 10 11 12 IN.

TYPE 2

This floor, which is one developed at the Building Research Station,* consists essentially of a slab which is cast in situ, and later lifted on to rubber cubes, which themselves rest on the structural floor. An actual construction is illustrated with this Appendix.

CONSTRUCTION

Paper is first laid on the structural floor to prevent the adhesion of the concrete screed. Upon the paper, at the proper spacing (usually about two feet), are placed banded sockets of a dimension to suit the desired thickness of the screed, which is preferably about two inches. The concrete is placed, with light reinforcement about mid-section. When the concrete has thoroughly set, wooden blocks are dropped into a *limited* number of sockets and plugs are screwed down upon them. In this way the independent slab is gradually lifted, and when it has been raised slightly more than 1 in., plugs with rubber cubes attached are inserted in the empty sockets. The wood blocks are next removed and similar plugs inserted in these sockets, and the screws adjusted until the whole floor is evenly supported on the rubber blocks. The thickness of the air-space should be about 1 in. when the floor is complete. Covers can be fitted to the sockets and a finish screed to receive the wearing surface can be placed.

COMMENT

In making this floor no great skill is required, but care should be taken to ensure by plugging or other means that concrete is not allowed to get into the grooves of the sockets. A very slight greasing of the inside of the sockets seems advisable as well. The spacing of the sockets is determined by the strength of the slab rather than by the load which is placed on the individual cubes.

Proper reinforcement of this slab is of some importance. It can be calculated according to standard practice, although for normal conditions, with a 2-in. concrete thickness, a light mesh is all that is necessary. Where walls of any appreciable weight (e.g. clinker concrete or bricks) are to be carried on the floor, particularly at the edges, extra reinforcement will be needed although the sockets for the rubber cubes should be so placed as to minimize the stresses as far as possible.

The cost of this floor should be moderate, but is, of course, in excess of Type 1.

INSULATION VALUE

With this floor the insulation value is high, and it would be termed a very quiet floor. Moreover, the process of lifting ensures that no rigid impacts will take place, and the insulation is therefore practically guaranteed.

TYPE 3

CONSTRUCTION

The usual 1-in. tongued and grooved or plain edge boarding is nailed to battens, recommended to be 2 in. square in section at least, which in turn rest upon the resilient element. The latter may consist of rubber cubes (countersunk to permit of nailing them to the battens without forming rigid contacts) or strips of quilting, or an entire blanket over the structural floor.

COMMENT

Whether the quilting is of eel grass, glass silk, or slag wool appears to make no material difference whatever to the insulation, and the choice as between these depends there upon other factors (see page 16). Double thicknesses of quilting are usually more effective, but seem to be rather too springy. Slag wool is perhaps an exception. Rubber cubes are very efficient.

* British Patent No. 466044. Inquiries regarding the use of the patent should be addressed to the Secretary, Department of Scientific and Industrial Research, 16 Old Queen Street, Westminster, London, S.W.1.

[To face p. 46

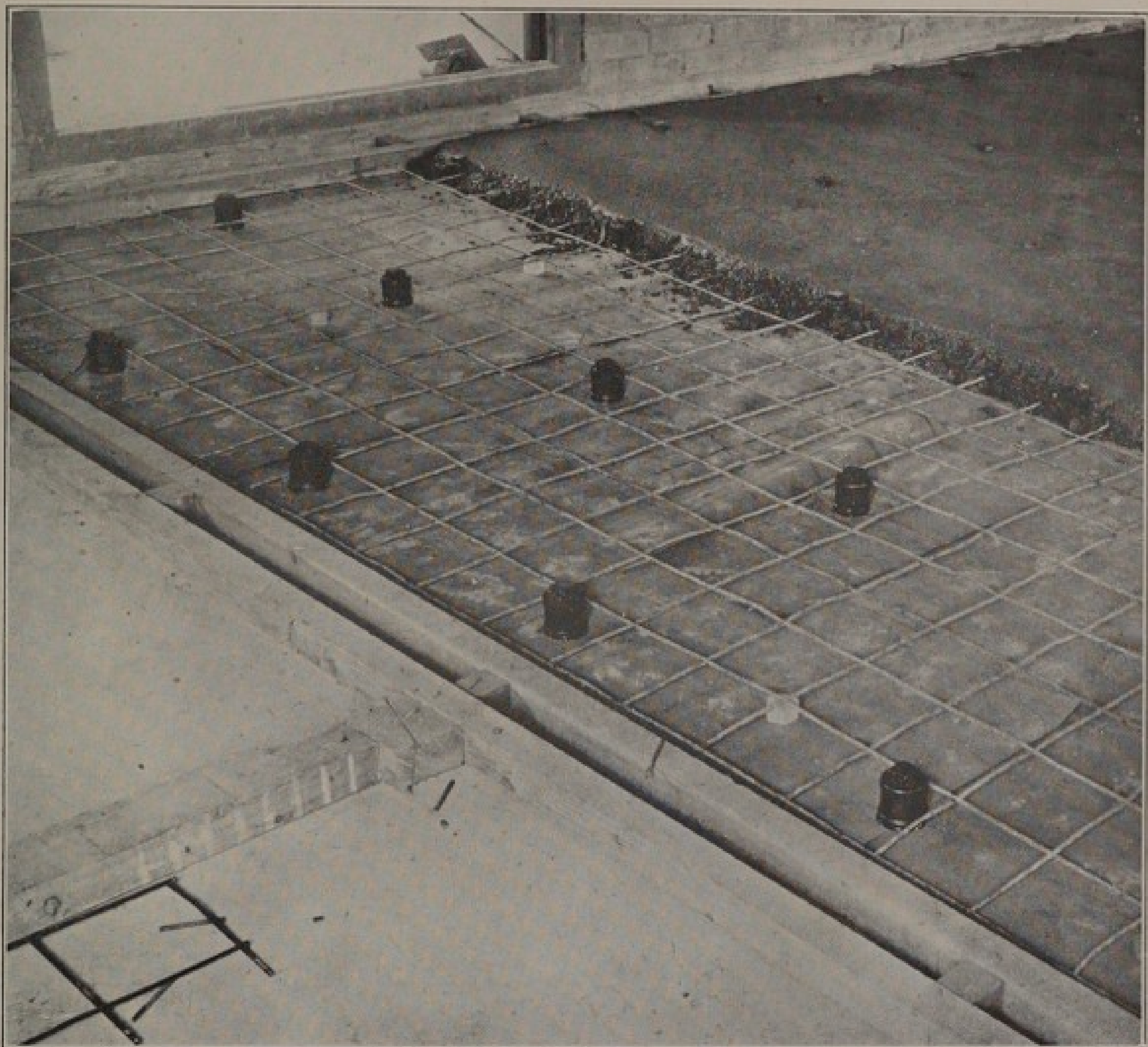


FIGURE 20. The Building Research Station's patent floating floor under construction

The cost of this floor appears to be about the same as for an ordinary method of holding the battens.

INSULATION VALUE

These floors are about the equal of Type 1 for impact noises, although not likely to give much additional relief from air-borne noise.

TYPE 4

CONSTRUCTION

This type differs from Type 3 only in the finish and is simply an alternative. In this case, the 1-in. tongued and grooved boarding can be replaced by the cheapest of rough boarding, overlaid with a stout, soft building paper and a thin strip hardwood wearing surface.

COMMENT

The rough under-boarding is probably best laid diagonally, and the wearing surface related to the walls of the room in the normal manner. This ensures that each board in each layer can cross the supporting battens. The building paper provides a certain amount of damping, and frequent secret nailing of the wearing surface to the under-boarding should not affect the insulation adversely. The cost of this floor is not excessive, and depends principally on the finish.

INSULATION VALUE

This floor appears to be slightly better than Type 3, and can, in general, be considered a quiet floor.

MATERIALS FOR ISOLATION

All these floors depend for their insulation value upon the nature of the resilients used (i.e. rubber cubes, quilting, etc.) as well as the method of construction. In general it may be said that materials should be such as " give " under impact. No test data are as yet available on the life of these materials under load, but the indication seems to be that inorganic materials are the more satisfactory and are probably less inclined to change with time than the organic types.

Rubber requires special comment. If protected from light, oils or grease, and other deteriorating elements, it can probably be depended upon to act efficiently for from twenty to forty years. It should be loaded fairly well.

In addition to rubber, glass silk, eel-grass and slag wool quilting, many other materials have been tried, including felt, clinker, cork granules, fibre-board, and asbestos, none of which, however, appears to be as desirable as the former.

SKIRTINGS

Where a floating floor adjoins solid construction its efficiency may be reduced if a skirting rigid with the structure is adopted. Skirtings have been devised, therefore, which avoid any rigid edge effect, and which incidentally do not allow access of vermin (see Figure 19).

Where the floating floors are of concrete, such as Types 1 and 2, the skirting will depend partly upon the chosen finish. Supposing this to be of lino, rubber or cork tiles, for instance, the edge of the floating portion can be treated either in the normal manner, with a skirting resting on the finish, or else can be designed to incorporate a cove skirting forming, as it were, a tray. These are represented by skirtings " A " and " B " respectively in Figure 19. In the former, the finish itself will provide the insulation, although it is to be noted that the bottom edge of the skirting board is chamfered to a point in order to reduce the area of contact, which is itself a factor. The second type, " B," is more complicated. The cove of the skirting is incorporated with the floating screed and the upper portion of the skirting is of wood, applied to the wall. The lino or rubber is continued up the cove, and is made to adhere above and below the gap between the two parts. A similar and simpler, but less satisfactory, method is to construct the entire cove skirting on the floating screed, avoiding any contact with the wall and providing an adhesive strip to cover the resulting open joint between the two. A cork skirting can probably be rigidly fixed to both floating floor and the wall without an undue effect of short circuit.

With floating floors constructed of timber, such as Types 3 and 4, a strip of felt or similar insulation material should be inserted between skirting board and floor finish. The skirting should then be pressed down to provide a clamp at the floor edge. This is illustrated in skirting " C " of Figure 19.

Skirting " A " should also be effective with timber floating floors, according to experiments made on the Continent, and it is shown in floor Type 3 as well as floor Type 1 in Figure 19. No experiments with this skirting have been tried in this country, but the effect is probably dependent in this instance on the reduction of area of contact. Metal skirtings, of pressed steel, aluminium, and other metals are available on the English market which would apparently serve the same purpose in the same way as skirting " A " does, and ought to be useful when considering the technique of insulation to which this publication is devoted.

The floating floors themselves should on no account make rigid contact with the walls. An air gap or insulation should be left between floating floor and wall.

FLOATING FLOORS COMMERCIALLY OBTAINABLE

There are a certain number of floating floor treatments commercially available. It should be possible roughly to judge their quality by comparing their construction with those described in these notes. Some of them have been tested by the National Physical Laboratory, and in such cases the company should be able to offer a copy of the relevant report. Information regarding firms able to offer floating floors can be obtained through the usual channels.

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S.O. Code No. 47-123