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A Guide Developed Under The FHA Technical Studies Program

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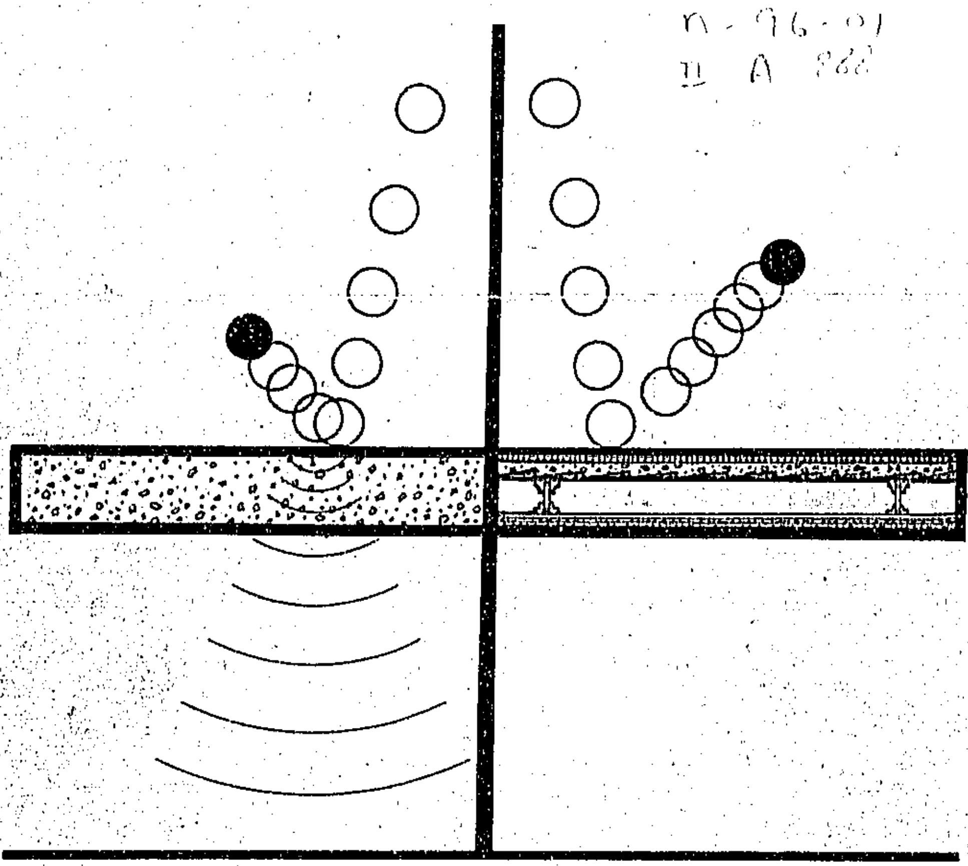

IMPACT NOISE CONTROL

IN MULTIFAMILY DWELLINGS

FHA No. 750 Federal Housing Administration, Washington 25, D.C.

A guide to

IMPACT NOISE CONTROL IN MULTIFAMILY DWELLINGS

Developed under

THE TECHNICAL STUDIES PROGRAM

of the

FEDERAL HOUSING ADMINISTRATION

by

Bolt Beranek and Newman, Inc.
Cambridge, Massachusetts

January 1963

FOREWORD

In addition to safety and durability in residential structures, FHA endeavors to stimulate built-in privacy and livability characteristics. It is toward the attainment of these latter attributes of good housing that the newly developed technical information in this guide is directed.

Neal J. Hardy

Neal J. Hardy
Commissioner
Federal Housing Administration

PREFACE

This document is offered to the FHA insuring offices, as well as to the architects and builders doing business with FHA, as a clear, concise and readily usable guide to the control of impact noise in multifamily dwellings. It does not in any way amend or supplant the Minimum Property Standards.

The Technical Study through which the guide was established is considered by prominent individuals in the field of acoustics to be a genuine pioneering effort by FHA. The work has resulted in the development of the first impact noise level criterion ever presented for use in this country. The compilation of specific noise isolation performance data and the information on proper architectural detailing resulting from the study are also the first of their kind in this country.

The scope and severity of the impact noise problem were recognized by Mr. William S. Brown of the Standards Unit who asked the Studies and Experimental Housing Unit to seek a solution. As a first step, the problem was submitted to the Technical Studies Advisory Committee appointed by the Building Research Advisory Board of the National Academy of Sciences to advise FHA on the handling of technical problems. Pursuing the advice of that Committee to contract with a well-recognized acoustics consultant, FHA selected the firm of Bolt Beranek and Newman to do the work necessary to produce this guide by the methods described herein. Direction and management of the project were provided by Messrs. James R. Simpson, Bernard T. Craun and Robert J. Miller of the FHA staff. The contractor's principal staff consultant was Dr. T. J. Schultz.

The control of impact noise in apartment units is in the interest of the occupants, the owners and FHA. Privacy and peace of mind are much enhanced for the occupants. A higher percentage of steady occupancy and better return on investments are promoted for the owners. Better protection of the Commissioner's risk results for FHA.

Included in the pages of this guide in the order shown are (1) a brief discussion of noise principles, (2) a description of the impact noise problem in multifamily dwellings and FHA's approach to a solution, and (3) tools which can be put to practical use in controlling impact noise, along with an explanation of how to use the tools. This material should serve as a valuable aid to

ACKNOWLEDGEMENTS

The final selection of material for and the preparation of this guide, including the adaptation of impact sound pressure level criteria, were accomplished by the acoustical firm of Bolt Beranek and Newman, Inc., Cambridge, Massachusetts. The staff member handling the work for the contractor was Dr. T. J. Schultz, Senior Consultant.

During the course of the Technical Study through which the guide was developed, helpful cooperation and advice were received from a number of sources as recognized in the following paragraphs.

Soon after the initiation of the study, an ad hoc committee of acoustics specialists was assembled by BRAB, in accordance with TSAC's recommendation and FHA's concurrence, to advise on the manner in which guiding criteria and information should be obtained. Suggestions made by that special committee were quite useful and were followed to a considerable extent. The individuals shown below served on the committee:

Mr. Joseph H. Abel, Architect
Washington, D. C.

Mr. Raymond Berendt, Physicist
Sound Section
National Bureau of Standards
Washington, D. C.

Dr. Richard Cook, Chief
Sound Section
National Bureau of Standards
Washington, D. C.

Mr. Ralph Huntley, Supervisor
Riverbank Acoustical Laboratories
Geneva, Illinois

Dr. T. J. Schultz
Bolt Beranek and Newman, Inc.
Cambridge, Massachusetts

At the session BRAB was represented by Messrs. Joseph A. Wilkes and I. Perry Clark while FHA was represented by Messrs. James R. Simpson, Robert J. Miller and John Woodside, Consultant.

Valuable assistance was given throughout the project by Dr. Richard Cook and Mr. Raymond Berendt of NBS, who translated, reviewed and summarized pertinent literature, arranged a symposium on the subject of impact noise control, participated in periodic discussions on the work, provided impact noise isolation measurements for certain types of construction, and reviewed and commented on a draft of this guide and the basic technical report submitted to FHA by the contractor.

CORRECTION!

THE PREVIOUS DOCUMENT(S) MAY HAVE BEEN FILMED INCORRECTLY . . .

RESHOOT FOLLOWS!

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The transmission of airborne noise through walls and floors is another recognized acoustics problem. That problem is partially dealt with in this guide inasmuch as floor-ceiling construction features useful in controlling impact noise limit the transmission of airborne noise as well. Future additional work on the control of airborne noise is contemplated.

The benefits realized by the public from this and other FHA Technical Studies are without cost to the taxpayer since FHA is an entirely self-supporting agency.

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Others contributed to the success of the study by furnishing English language, foreign language or translated foreign language publications containing a considerable amount of needed data or by calling attention to such documents. In addition to those mentioned above, the following were the chief cooperators in this respect:

Mr. J. Ederveen
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FHA's sincere appreciation is hereby expressed to all of the cooperators and particularly to Dr. Cook and Mr. Berendt.

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I NOISE PRINCIPLES

A. What Is Impact Noise?

This Guide talks a great deal about impact noise and its prevention, so first, let us clear up what we mean by "impact noise" and "impact isolation", and describe how these quantities can be assessed. We can usefully contrast impact noise with the more familiar airborne noise, which is produced by a sound source such as a musical instrument, a human voice, a dog barking, a TV or radio set or an auto horn. Inside a house, such airborne sound waves radiate outward from the source, through the air until they strike a wall, floor or ceiling which is set into vibration by the fluctuating pressure of the sound wave in the air. Because the wall vibrates, it radiates sound into the air on the other side: such sound, of course, may intrude upon the privacy of the people in the neighboring room and constitute an annoyance. This airborne transmission problem is usually minimized by making the party wall massive or of a complicated structure; very little improvement is gained by altering the surface finish of the wall (or floor).

By contrast, impact noise is caused by an object striking or sliding on a wall or floor structure, such as footsteps, dropped toys or cooking pans, moving furniture or door-slamming; it may also be caused by some appliance which communicates its own vibration to the building structure by direct mechanical contact, such as a dishwasher, toilet, bathtub, shower, food-disposal apparatus or other rotating machinery. In all of these cases the floor (or wall) is set into vibration by direct impact or mechanical contact, and sound is radiated from both sides of the floor. We will see that, for this type of noise, the surface of the floor is very critical as regards the amount of noise generated.

In this Guide we are specifically concerned with impact isolation of floor/ceiling structures, and hence with footstep-like sounds; nevertheless we will also make suggestions intended to show the principles by which all impact sound can be controlled.

B. How Do We Assess Impact Noise?

Methods for measuring impact noise and assessing impact isolation may be better understood by contrast to the procedures for measuring airborne sound, which most people grasp quickly. When we wish to measure the airborne sound attenuation of a party wall, we produce in the room on one side of the wall a steady sound which contains energy at all frequencies of interest. The sound levels are measured, at all frequencies, on both sides of the wall and the difference between the sound levels on the two sides is a measure of the isolation provided by the wall: the greater the difference, the better the isolation.

But this method doesn't work with impact noise. In fact, the airborne noise in the source room due to impacts on the floor bears little relation to the noise radiated into the room below. One can see this intuitively by considering a concrete slab on which is floated a simple plywood floor resting on a thick soft blanket of some kind: this floating plywood floor drastically reduces the sound of footsteps communicated to the room below because of the soft blanket, but the free-floating plywood may actually amplify the sound of the impacts on it as heard in the upper room. On the other hand, the addition of carpeting to the slab, instead of the floated plywood, would reduce the impact sound in both upper and lower rooms. Obviously, then, the difference in airborne sound levels on the two sides of a floor is not a valid measure of impact isolation.*

We use instead a standard means of generating constant and known impacts. By international agreement**, the isolation against impact noise provided by a given floor/ceiling construction is determined by means of a standard "tapping machine", which produces a series of uniform impacts at a uniform rate on the floor under test. The Impact Sound Pressure Level (ISPL, measured in decibels, or "db") produced in the "receiving room" below by this standard tapping on the floor is measured and analyzed into different bands of frequency, so that a curve can be plotted showing how the sound energy in the receiving room is distributed over the audible frequency range: the lower the sound levels in the room below, the better the floor/ceiling construction. It is assumed that a construction which will transmit little noise with the standard tapping machine will also give low noise with other types of impacts.

Until a standard for the measurement of impact noise is adopted for the United States, the FHA will use the ISO standard mentioned above.

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* Nevertheless, this scheme was used for several years by competent laboratories.

** ISO Recommendation #140-1960 "Field and Laboratory Measurements of Airborne and Impact Sound Transmission."

II THE IMPACT NOISE PROBLEM AND FHA'S APPROACH TO A SOLUTION

A. The Reasons for This Guide

The current building trend to lightweight structures, the increasing concentration of dwellings, particularly in urban areas, and the increasing noisiness of our environment have led to a growing number of complaints to the FHA of inadequate sound isolation in multifamily dwellings. As people become more aware of the problem and more sophisticated in their appreciation of the benefits which careful attention to noise control can provide, they will expect and demand more privacy in their homes and greater freedom from the intrusion of noise from neighboring dwellings.

Through the development and preparation of this Guide, FHA has taken the initiative in providing architects, designers, contractors, builders and public housing officials with needed assistance in meeting the growing public demand, particularly with respect to the control of one of the most annoying kinds of noise: the sound of footsteps, dropped objects, and other impacts, which are transmitted throughout a multifamily dwelling by vibration of the building structure. These provisions are the first serious impact noise control measures to be promoted in the U.S.A.

The control of airborne sound (radio/TV, talking, traffic noise, etc.) is also very important, but since less information on impact noise is currently available in this country, this problem will be dealt with first. It should be noted, however, that some of the measures recommended to reduce impact noise will also help to control the transmission of airborne noise through the floor/ceiling construction.

B. <u>How Much Isolation Should A Floor/Ceiling Construction Provide?</u>

The United States is one of the few highly developed countries of the world which do not have in their building codes some kind of requirement for the control of noise. In earlier times, here as well as abroad, building constructions were heavier, multifamily dwellings were fewer, and privacy and noise problems were not severe. Since 1938, however, more and more countries abroad have become concerned over the intrusion of noise and its effect on the health and happiness of their people, and have instituted control measures, based on the results of careful and extensive programs of study. Measurements of the existing impact noise isolation in actual dwellings have been compared with the results of detailed interviews with the tenants in literally thousands of cases.* From this information, the various countries have established requirements which differ somewhat in detail but which are basically similar.

Lacking data which bear immediately on the situation in the United States, the FHA has sponsored a careful examination of these foreign codes and studies** and has adapted

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* Two thousand in England, 500 in Sweden, and 1280 in the Netherlands, to mention the best documented studies.

** The codes most influential in the development of the FHA recommendation were the German (2) and (3), the British (1), and the Swedish (6) (the numbers in brackets refer to items in the bibliography); but codes and studies from the following countries were also considered and taken into account, both in the selection of an impact noise criterion and in the estimation of performance data for American floor constructions: Austria, Bulgaria, Canada, Czechoslovakia, Denmark, Finland, France, Netherlands, Norway, and USSR.

the results to the needs of the American people, considering the significant differences in population density, living habits, noise environment, tolerance for noise, construction costs, etc.

First we have acknowledged that Americans do in fact enjoy, and are conscious of enjoying, a higher standard of living in most things than their European counterparts. It is appropriate that this fact should be reflected in the acoustical comfort of their homes: in the present case, more freedom from impact noise from adjacent dwellings.

On the other hand, the number of inhabitants per multi-family dwelling in this country is less than in Europe, so that the amount of occupants' impact noise to be combatted may also be less --- except that there is reason to suspect that American children tend to be rowdier and their parents more addicted to high listening levels for hi-fi, TV and radio than their European cousins.

While living habits are quite different on the average between this country and Europe, these differences apply least of all to apartment dwellers, particularly to those with children. It is a stay-at-home life: people stay at home to make noise and to be annoyed by it.

We must distinguish here between two types of noise. The first is the ambient noise environment: the quiet, neutral, background noise from flowing traffic or air-conditioning equipment to which we rapidly become accustomed and soon do not notice at all. This background noise is an exceedingly important element in all noise control situations for it helps to mask the sporadic intruding sounds. For example, an intruding noise which would be intolerable in a quiet country village might go completely unnoticed in an apartment on a busy street, where the continuous hum of traffic masks out the noises from next door without itself seeming unpleasant. <u>It is a major failure of all existing codes that this fact is not taken into consideration</u>; they all, in effect, specify a maximum amount of impact sound which, they imply, will be admissible in any dwelling, whatever the ambient noise. The FHA has not yet undertaken the extensive psycho-acoustical research that would be required to tell us how we can "trade off" floor performance for differences in background noise; but we want to emphasize that such a concept is valid and to state that the recommendations given here are intended to apply in dwellings where the ambient noise lies between NC-20 and NC-25.*

In selecting a noise-control criterion, the character of the intruding noise environment itself is also a very important factor, and it has changed radically in recent years. We must not, then, compare the American noise environment of today with that of Europe today --- these, in fact, are quite similar --- but rather with that of Europe when the Codes were written on which the present recommendations are based. The current European codes were adapted to deal with a way of life which included few stereo systems, dishwashers, garbage disposal units and other noise-producing luxuries; and with an era when children were accustomed to a less permissive view of parental discipline. The trend is,

* See the chapter on Sound Control in the ASHRAE Guide (American Society for Heating, Refrigeration and Air Conditioning Engineers); or Chapter 20 in L.L.Beranek's "Noise Reduction," McGraw-Hill, 1960. An ambient noise "between NC-20 and NC-25" is typical of apartments in moderately quiet suburban neighborhoods. For quieter areas, floor construction better than normal (INR= +5; see § III-A-4) should be used, while poorer construction (INR= -5) may be tolerable in noisy urban districts.

both here and abroad, toward more intruding noise to be guarded against in apartments and an increased sensitivity to annoyance from noise. In Europe this is evidenced in present efforts to tighten some of the codes. In this country, moreover, the increasing movement from suburban areas back into city apartments will introduce to apartment noises a large number of people long accustomed to the quiet of their private houses. We can expect an increase of complaints from these people.

The problem is weighty because of the serious implications of any factor that would increase building construction costs. For Americans, the answer seems clear. We have for many years largely ignored the problems of noise control in our apartment buildings. It is this fact, coupled with our noisier lives and our higher expectations of comfort, that has prompted the many complaints leading to the development of this Guide. It is not surprising that, as a result of years of building construction in this country without either restrictions or guidance from our building codes in the area of noise control, many of the floor/ceiling constructions which are "typical" --- almost habitual --- in the United States are inadequate. We must anticipate, therefore, that it will entail some increase in construction cost to bring our building practices into line with our aspirations. However --- and this is of prime importance --- <u>the amount of this increase in cost will be small if noise control is considered early in the initial planning of our buildings</u>. Noise control is almost always expensive to apply after a building is completed; it can be surprisingly inexpensive (and can be designed to yield other benefits as well -- for example, thermal insulation) if it is considered early in the design stage.

It is among the purposes of this Guide to steer the reader away from constructions which will not work and cannot readily be "fixed" and to urge consideration of new ways to apply the principles of impact noise control.

At this point two words of caution are in order:

1) Both the recommended impact noise curve and the impact performance to be expected from typical U.S. floor/ceiling constructions, as presented here, have been derived chiefly from European sources. Although a careful effort has been made to adapt them to American conditions, this procedure is subject to uncertainty. This Guide recognizes the tentative nature of the conclusions by "recommending" rather than "requiring" the proposed standards of impact isolation performance. The FHA is aware that the clear statement, in numerical terms, of an acoustical performance requirement encourages in the sales-oriented branches of the industry a competitive "1/2 decibel hassle." We flatly warn that the data presented here are not sufficiently accurate to justify any such judgment. The fact is that a floor which just passes the recommendation will probably be indistinguishable, subjectively, from one which just fails. The present Guide is intended to help conscientious designers provide acoustically adequate homes for reasonable tenants, and not to justify quibbles over small differences.
2) On the other hand, although the present Guide may be considered tentative in nature, it represents the best effort in the present state of an art that is steadily advancing. It should, therefore, be taken seriously.

FHA plans to follow up the present recommendation with a field study of American multifamily dwellings, which will involve making impact noise performance measurements of actual floor/ceiling constructions throughout the country, as well as conducting "depth-interviews" with the corresponding occupants. This will permit us to check whether the FHA's recommended performance curve actually represents the "borderline" dividing satisfactory from unsatisfactory impact isolation in this country. It will also permit us to refine the performance information on typical U.S. constructions as given here in data sheets which were based mainly on measurements made on similar European constructions.

At this time, the most important points to establish beyond question are: 1) that a significant improvement in impact isolation is needed immediately in American dwellings; and 2) that the main concepts --- the necessary tools --- are correct as provided here, though later refinements may modify them in the details.

C. How This Guide Will Help: Three Tools

The closeness of the individual units in an apartment house leads to problems of noise control more severe than are usually met in single houses; nevertheless, it is technically quite possible nowadays to construct floors in such a way as to be practically impenetrable to sounds from adjacent dwellings. The trouble is that such "impenetrable" constructions are expensive: to install them throughout many apartment houses would involve an enormous increase in building cost, and would provide more isolation than is actually required in most cases.

As the result of an extended technical study in which the various data, factors and needs discussed under II-B were taken into account, FHA developed and presents herein three practical and essential tools for use in the control of impact noise:

Tool #1) A curve of recommended maximum impact sound pressure level for floor/ceiling constructions. This will show how much impact isolation you will need to provide. It constitutes a criterion of acceptable, but not excessive, isolation against impact noise in multifamily dwellings.

Tool #2) A collection of impact performance curves characteristic of typical U.S. floor/ceiling constructions. Each curve is presented in such a way as to allow direct comparison with the recommended maximum curve mentioned above. These constructions are all classified as to whether they do or do not provide the recommended isolation. This presentation readily permits: a) the avoidance of all unsatisfactory floor/ceiling constructions; b) a choice of constructions which will just meet your needs; or c) the selection of better-than-average constructions for use in higher quality buildings.

Tool #3) A check list of precautions and suggestions, supplemented by a collection of rough sketches of architectural details, which will promote the fullest possible benefit from the construction you have chosen by pointing out how the effect of a basically good floor construction is often spoiled by inadvertence or oversight in matters of detail.

These three tools should help you deal adequately with the problems of impact noise control before they show up in the completed building.

III TOOLS FOR USE IN CONTROLLING IMPACT NOISE

A. A Recommended Curve of Maximum Impact Noise Sound Pressure Level for Floor/Ceiling Constructions

1. The Recommendation

Figure 1 presents FHA's recommended curve, which shows for each frequency the maximum acceptable Impact Sound Pressure Level, (ISPL) due to "thumping" a floor overhead with the standard tapping machine; the measurements are to be made in the field and normalized to a receiving-room reverberation time of $T_o = 0.5$ sec (see section 2 below). The shaded area of Figure 1 represents the range covered by the impact noise curves recommended or required by the various existing European codes. It can be seen that the FHA recommendation, taking account of the factors discussed earlier, falls into the lower part of the range, along with the stricter of the European codes (British Grade 1 and Swedish Grade 1), which today appear to be giving satisfactory isolation despite the increased noise environment. A floor/ceiling construction which provides enough isolation that the Impact Sound Pressure Levels (ISPL) in the room underneath the test floor are at all frequencies less than or equal to the values shown by the curve in Figure 1, meets the recommendation <u>absolutely</u>. Permissible deviations will be discussed later, in section III-A-3, below. Note that we have not assigned any rating for the amount of isolation provided by the floor (i.e., how much it would diminish <u>any</u> given noise) but instead have indicated how much noise it may acceptably transmit when tapped with a standard source of impacts. (See section I-B for methods of determining impact noise isolation performance.)

Since the floor constructions under consideration will occur in a wide variety of acoustical environments, however, the measurements which establish compliance with the recommendation must all be made compatible with one another, or "normalized", as described in the following section.

2. "Normalizing" The Measurements

The amount of noise produced in the downstairs room by "standard tapping" on the floor above depends not only on the quality of the floor/ceiling construction but also on the amount of sound-absorbing material in the lower room: if there are many carpets, draperies, upholstered chairs and the like, the sound levels will be much less than if the room were bare or only sparsely furnished. Since the field measurements of floors will be made in all sorts of furnished apartments, there is always built into the raw data a certain amount of variation in measured values due only to differences in the amount of absorption present in each case. In the present Guide, this kind of variation has been eliminated for the purposes of uniform presentation of the data, by correcting all of the ISPL curves to the values they would have had if they had been measured with the same standard condition of absorption in the lower room.* Moreover,

* Some countries use 10 sq meters (=107.6 sq ft) of total absorption A_o as the "normal" absorption; others normalize to a standard reverberation time T_o of 0.5 sec. The FHA has formally adapted normalization to a standard reverberation time, $T_o = 0.5$ sec., since this avoids the necessity for calculating the volume of the receiving room. The curves given with the data sheets indicate in each case which normalization has been used. For rooms of ordinary size (1100 cu ft) the two methods are equivalent, and for the purposes of this Guide the difference may be ignored.

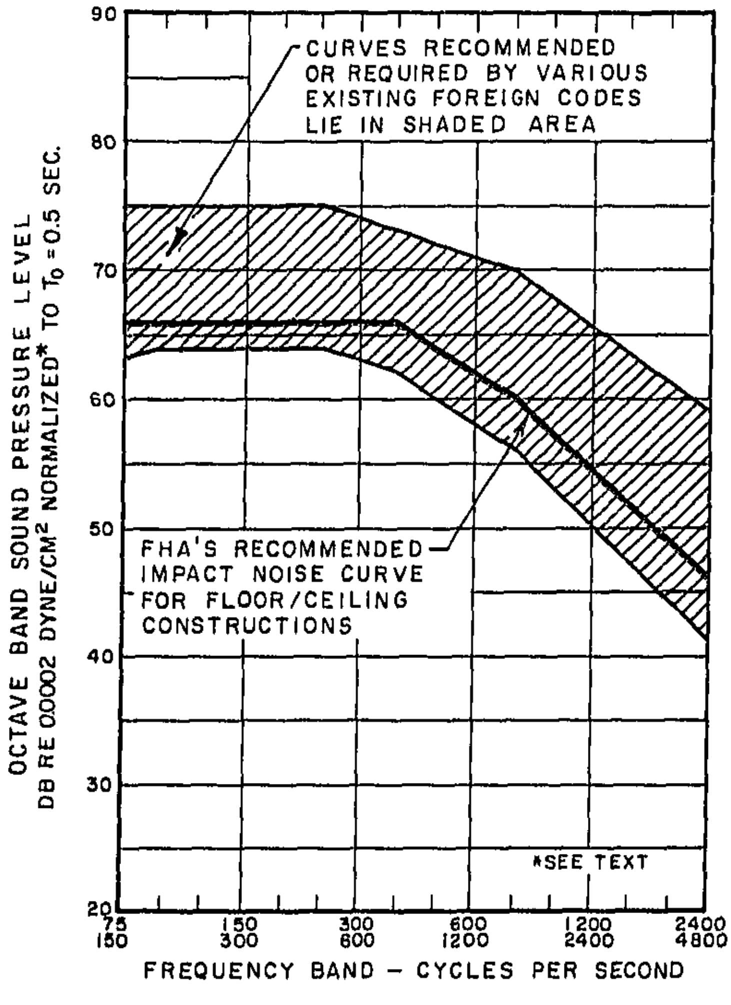

Fig. 1 Field Measurements of Sound Pressure Levels in the room underneath a floor construction on which a standard tapping machine is operating should not exceed this curve by more than the tolerances specified in section III-A-3 of the text.

the recommended curve has also been presented in normalized form, as stated above. Thus the "normalized" ISPL curves for different floor constructions can be freely intercompared amongst themselves and may be directly compared with the FHA's recommended curve to establish compliance.

3. Margin of Error

In carrying out measurements of impact noise, the currently available techniques entail some uncertainty in the final result. It would impose an extreme restriction, therefore, if the impact isolation recommendations were interpreted absolutely, as stated above. For example, the construction under test might exceed the maximum permissible ISPL at only one or two frequencies, possibly due to slight errors in measurement, and thus formally fail to meet the recommendation, when in fact the floor might very well provide satisfactory isolation in practice. To eliminate this possibility, the following tolerances have been allowed: if the mean amount by which the measured ISPL curve for a floor exceeds the recommended curve is 2 db or less (as averaged over the 16 1/3-octave frequency bands between 100 and 3200 cps), then that floor construction is considered to meet the recommendation.* This is illustrated in Figure 2, where the recommended curve is replotted from Figure 1 along with the "normalized" measured ISPL curves for four different floor/ceiling constructions. Construction "A" obviously meets the recommendation at all frequencies. For Construction "B", the mean excess ISPL is (reading from lower to higher frequencies) $\frac{2+3+4+5+7+4+2}{16} = 1.7$ db and the construction therefore passes the recommendation since the mean excess ISPL is

* A further restriction is described later.

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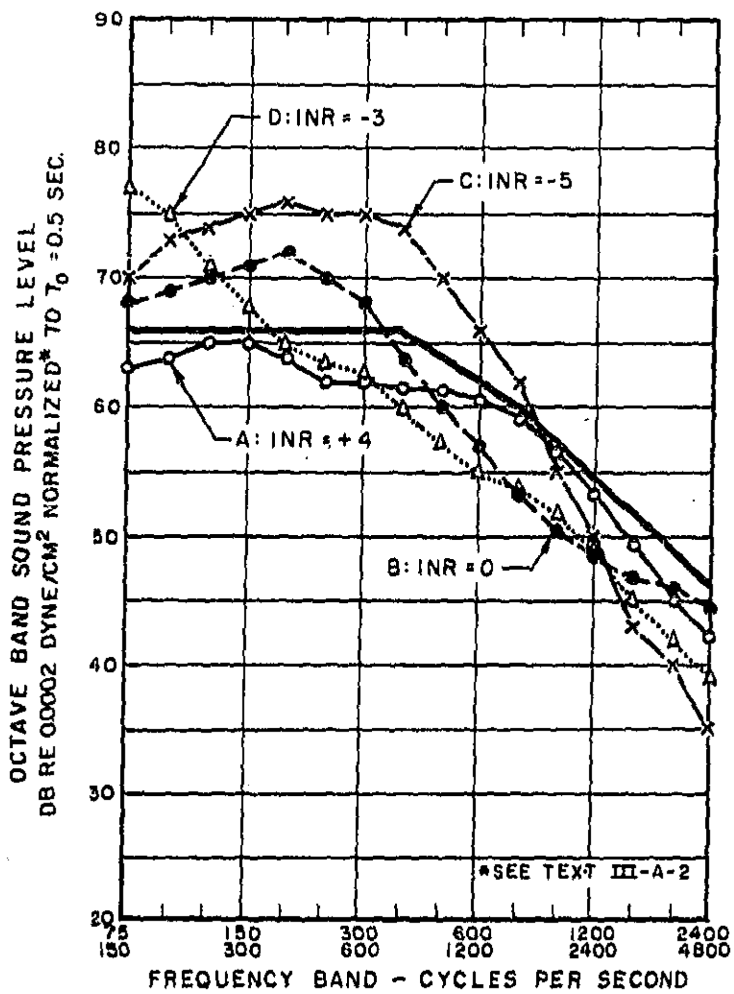


Fig. 2 Single Number Impact Noise Rating. A Replot of the FHA Recommendation Curve with the Measured ISPL of Four Typical Constructions (See Section III-A-4 of the Text).

less than 2 db. For Construction "C" the mean excess ISPL is $\frac{4 + 7 + 8 + 9 + 10 + 9 + 9 + 8 + 6 + 4 + 2}{16} = 4.25$ db and the floor fails. No allowance is made for the fact that at some frequencies the construction may be better than it needs to be; only unfavorable deviations are counted.

Note that this tolerance in terms of an average deviation might permit a construction to pass the recommendation if its curve lay below the FHA recommended curve at nearly all frequencies, but greatly exceeded the recommended curve at a few frequencies. Curve "D" of figure 3 illustrates this situation; the mean excess ISPL is $\frac{11 + 9 + 5 + 2}{16} = \frac{27}{16} = 1.69$ db and by this test the construction would pass the recommendation. But the excessive noise transmitted below 200 c/s would be very annoying. Therefore, to eliminate constructions of this type we impose a further restriction: the measured curve for the floor must not exceed the FHA recommended curve by more than 8 db at any frequency.

4. A Single Number Impact Noise Rating for Floor/Ceiling Constructions

For some purposes it is useful to know more than simply whether a construction meets the recommendations or not. For example, one might wonder whether a floor barely achieves or much exceeds the requisite isolation. Or, if one is designing a "luxury" building or even "somewhat higher class" apartments, it would be useful to have a quantitative means of comparing various satisfactory constructions by means of a single number. Such a rating scheme is provided as follows:

Notice in Figure 2 that, if the measured ISPL curve for the "C" construction were shifted downward by 5 db at all frequencies, the floor would then meet the recommendation, within the permitted tolerances. We, therefore, assign to this construction an Impact Noise Rating (INR) of -5. On the other hand, the measured ISPL curve for construction "A" could be shifted upward by 4 db and still meet the recommendation, within the allowed tolerances. Thus, we assign to construction "A" an INR of +4. Construction "B" barely passed the recommendation with no shift, so it has an INR of 0. Construction "D" must be shifted 3 db down to meet the 8 db tolerance on maximum deviation, so it rates INR = -3. (Curve shifts of fractions of a decibel are not permitted.) The INR thus provides a means of rank-ordering a large number of different constructions: the higher the INR, the better impact isolation the structure provides.

With the criterion and instructions of section III-A one can determine the suitability of any floor/ceiling construction for which the standard type of measurement already described can be obtained. Such measurements are given for many configurations in the section which follows. Also, by the procedure previously outlined, impact noise ratings can be assigned to constructions so that they may be compared directly with listed constructions.

B. A Collection of Impact Sound Pressure Level Curves Characteristic of Typical U.S.Floor/Ceiling Constructions

1. The Data Sheets: What They Tell

Impact performance curves are presented in section 4 below for several types of floor/ceiling constructions commonly used in this country, both bare and in combination with common floor coverings. Each such combination appears on a separate data sheet, which shows not only whether the floor meets or fails the FHA recommendation of section III-A, but also gives the Impact Noise Rating for the construction. In addition, each data sheet carries on the right hand margin an INR Index Mark corresponding to the INR: the higher the Index Mark on the page, the greater the INR; the data sheets are arranged in order of increasing INR, so that floor/ceiling constructions of highest quality appear near the end.

It should be emphasized that the impact noise isolation performance shown for the various floor/ceiling configurations can be obtained only if care is taken in the architectural planning and detailing, as suggested in sections C and D below.

2. Summary of the Information Appearing on Each Data Sheet:
   a) "Test Reference" identifies the test measurements from which the ISPL curve is derived: the first numbers refer to the item(s) in the bibliography (p 84) from which the data were taken; the number in parenthesis indicates approximately how many measured samples the data represent, where this is known.
   b) A description of the floor/ceiling construction, with dimensions of structural and non-structural elements, and with comments on any unusual aspects of the structure.
   c) A sketch of the floor/ceiling/covering configuration, to aid in quick identification. Note: no attempt was made to maintain the same scale on all data sheets.
   d) A curve of Impact Sound Pressure Level in decibels (re 0.0002 dynes/cm^2) as measured in the field (except where indicated) and normalized to either

a standard amount of absorption (A_o = 10 m^2) or a standard reverberation time (T_o = 0.5 sec) in the room below; the label for ordinates states which type of normalization is used. As mentioned above, for rooms of ordinary size, there is no difference between the two normalizations for the purposes of this Guide.

e) The Recommended Curve for Maximum Acceptable Impact Sound Pressure Level, which the measured curve (item d) should not exceed, within the tolerances described in the text (section III-A-3).

f) The Impact Noise Rating, which permits rank-ordering the various constructions (see section III-A-4). A higher INR means better impact noise isolation; 5 db increase is a significant improvement.

g) An INR Index Mark, in the righthand margin, which permits quick location of floor constructions having an INR of the desired amount.

From this set of Data Sheets and the summary which follows them, the architect can quickly select configurations which are as good as the recommendation or better by a desired amount, depending on his needs. He can also see how to avoid inadequate configurations which are unfortunately in common use nowadays and which have given rise to enough complaints to spur the preparation of this Guide.

The Data Sheets will also help FHA field personnel to determine whether or not a proposed floor/ceiling construction will provide adequate impact isolation; and if not, what additional improvement will be required to make it satisfactory.

3. Field Measurements vs Laboratory Measurements

Most of the data here came from European sources. Wherever possible, the measurements which were used to define the impact performance for the various constructions have been made in actual installations in the field. Such data were not available for all cases, however, and it was sometimes necessary to use data taken in the laboratory. In these cases, a correction was sought to account for the fact that impact sounds in the field are likely to be carried to the room below by paths other than the one directly through the floor/ceiling construction. Thus one might expect the impact sound pressure levels to be higher in the field than would be measured for the same floor/ceiling in the laboratory. A careful study of the available data, however, indicates that any such consistent difference between laboratory and field impact noise measurements is small enough to be obscured by scatter in the data, so we have decided for the present to treat them as equivalent.

4. Data Sheets for Floor/ceiling Constructions Typical of the U.S.A.

The data sheets for typical floor/ceiling constructions appear in the following pages; there is a Summary on pages 69 to 71.

TEST REF: 24,12a & 12b; 25II, VI-A-36, VI-A-37; 22, #23, #25, #32, #37; (10)

SAMPLE DESCRIPTION:

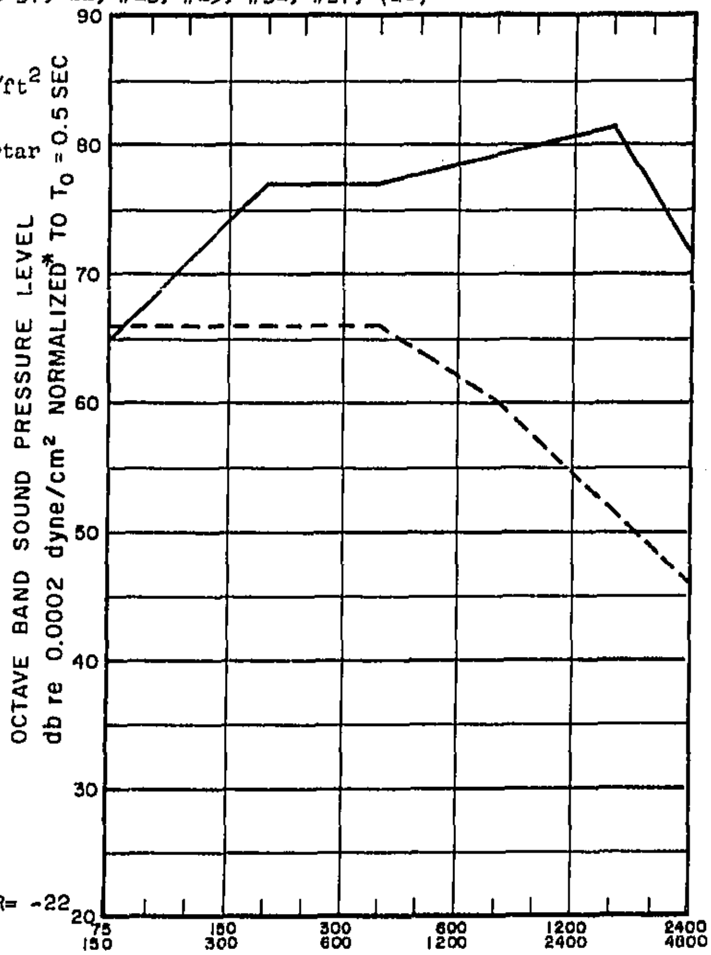
HOLLOW CONCRETE BEAM

Total thickness 7", total weight 44 lb/ft^2

Basic Construction: Hollow concrete block $5\frac{1}{2}$" thick and cement mortar

Floor Finish: 3/4" finish cement

Ceiling: 3/8" plaster



*SEE TEXT

1

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, S-57; (1)

SAMPLE DESCRIPTION:

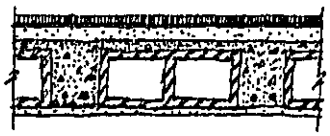
CONCRETE RIBBED SLAB WITH FILLER BLOCKS

Total thickness $8\frac{1}{2}$", total weight 70 lb/ft^2

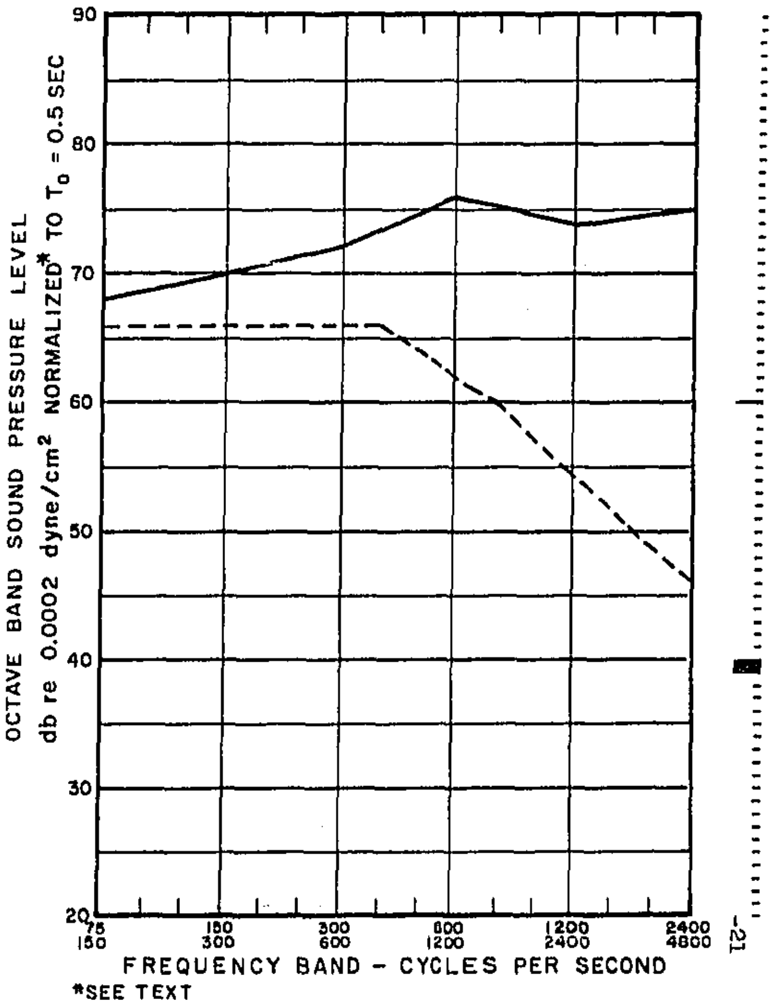
Basic Construction: 6" concrete slab with hollow filler blocks

Floor Finish: 5/8" pitch mastic over thin felt underlay on $1\frac{1}{2}$" sand-cement screed.

Ceiling: two-coat plaster



INR= -21



*SEE TEXT

-23-

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, S-58; (1)

SAMPLE DESCRIPTION:

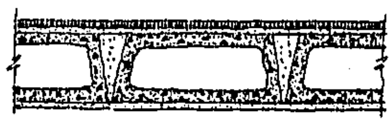
HOLLOW CONCRETE BEAM

Total thickness $7\frac{1}{2}$", total weight 55 lb/ft^2

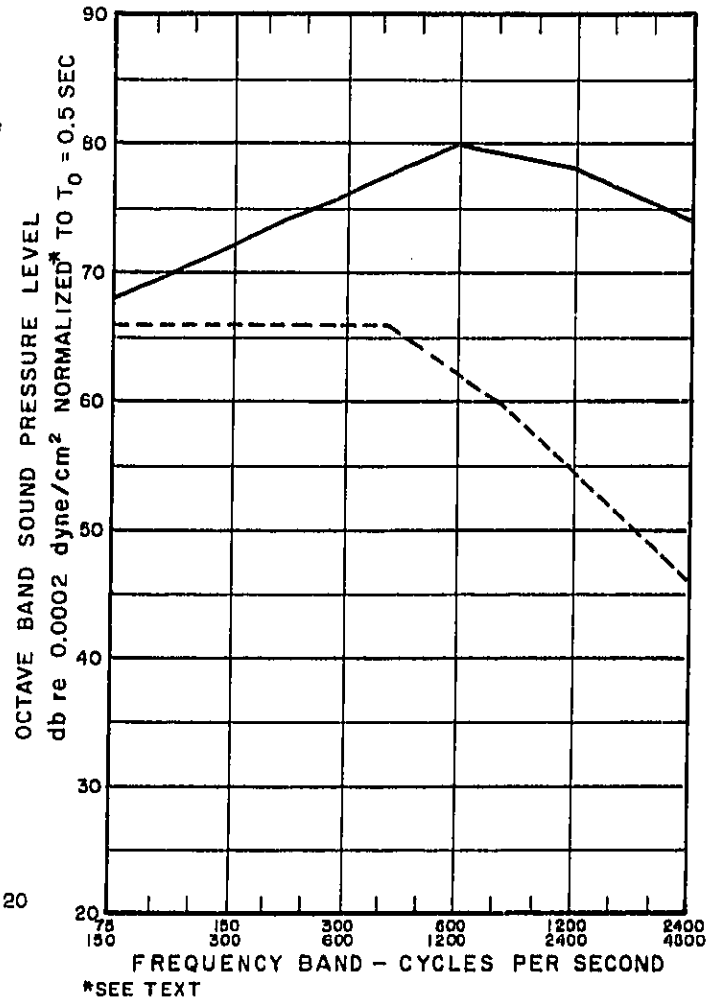
Basic Construction: Precast hollow concrete beam, 6" deep and $14\frac{1}{2}$" wide.

Floor Finish: 1/2" pitch mastic on 1/2" sand-cement screed.

Ceiling: two-coat plaster.



INR= -20



-20

3

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, Fig. 71, S-288-290; (7)

SAMPLE DESCRIPTION:

WOOD JOIST: "THIN" CEILING & "THIN" WALLS (see remarks)

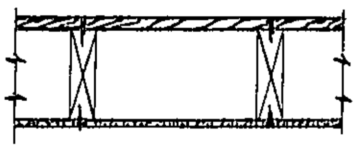
Total thickness $8\frac{1}{2}$", total weight 7 lb/ft^2

Basic Construction: 2" x 8" wood joists with 7/8" T & G floor boards nailed to joists.

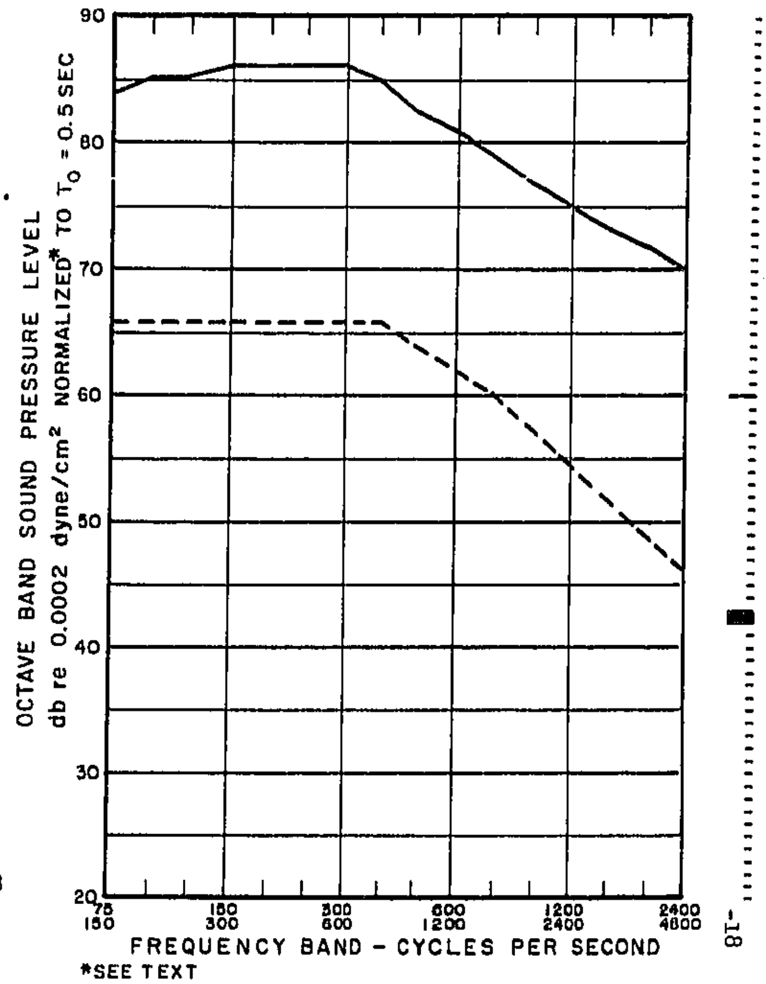
Floor Finish: none

Ceiling: 3/8" plasterboard nailed to joists, joints sealed.

Remarks: Two of the supporting walls were $4\frac{1}{2}$" thick, the other two were 9" thick or less. Heavier supporting walls would restrain the floor structure and improve the impact isolation. Compare with data sheets #9 (p.30) and #22 (p.43).



INR= -18



*SEE TEXT

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 32, 728-A; (1) Laboratory measurement.

SAMPLE DESCRIPTION:

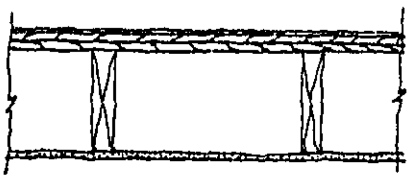
WOOD JOIST, VINYL TILE

Total thickness 11", total weight unknown

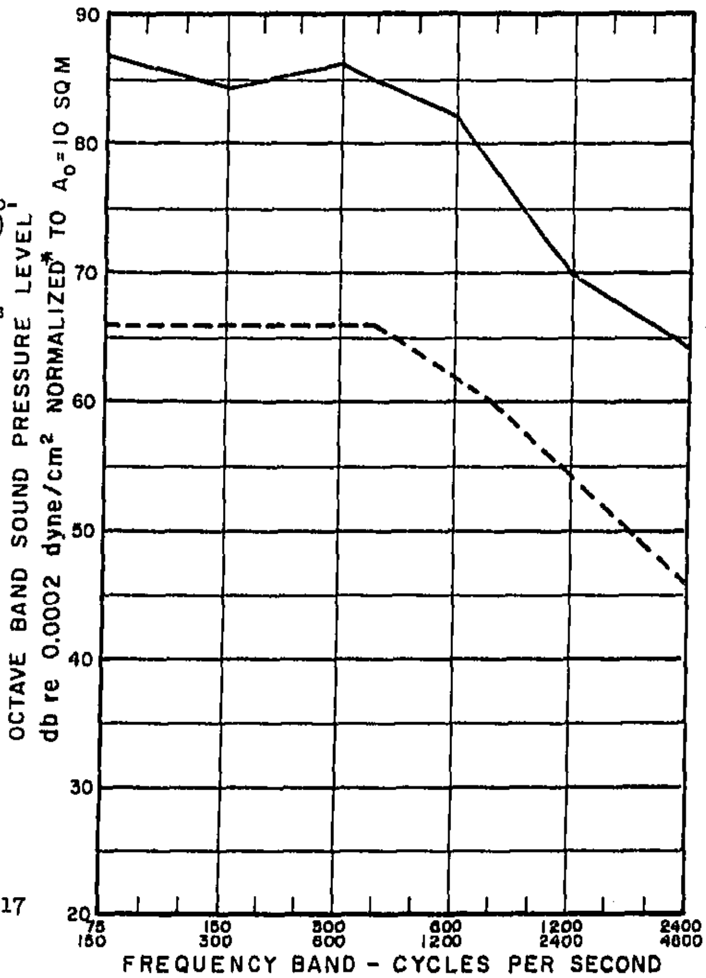
Basic Construction: 2" x 10" wood joists, 16" o.c.; 5/8" fir plywood sub-floor nailed 8" o.c. to joists; ½" fir plywood covering sub-floor (joints staggered) and nailed through to joists.

Floor Finish: 9" x 9" vinyl plastic asbestos tiles, 1/8" thick, applied with adhesive.

Ceiling: ½" gypsum wallboard nailed to joists; joints taped and sealed.



INR= -17



*SEE TEXT

-17

TEST REF: 20, Fig.3; and 17, Fig. 8; (17)

SAMPLE DESCRIPTION:

FLAT CONCRETE SLAB

Total thickness 6½" to 9½", total weight 70 - 100 lb/ft².

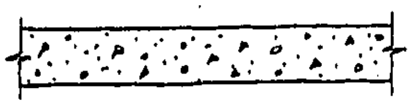
Basic Construction: Reinforced concrete slab.

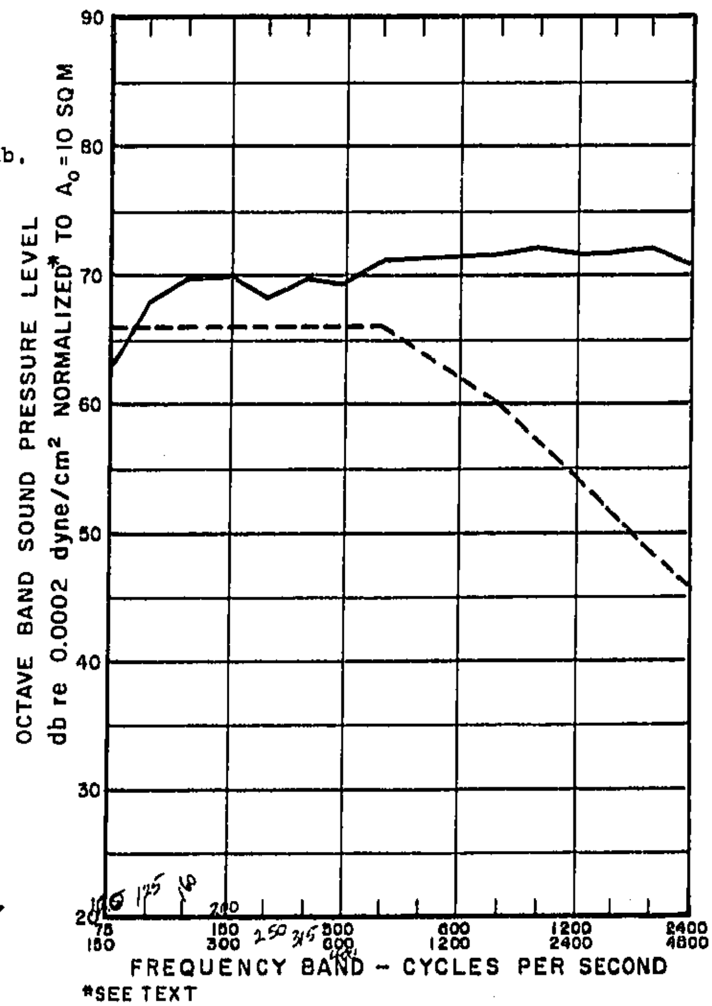
Floor Finish: Either 5/8" pitch mastic, 5/8" composition or none.

Ceiling: Either ½" plaster or none.

Remarks: There is wide variability in impact isolation due to random factors rather than showing correlation with thickness, weight, floor finish or ceiling finish within the ranges mentioned above. The performance data given here are median values.

-27-





INR= -17

-17

TEST REF: 25 II, VI-A-38; 24, 12-c; (8)

SAMPLE DESCRIPTION:

RIBBED CONCRETE

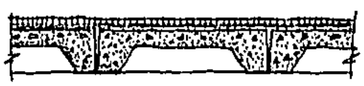
Total thickness 6½"; total weight 27.5 to 33 lbs/ft²

Basic Construction: ribbed concrete floor; 2½" slab; (see remarks); ribs 20" o.c.

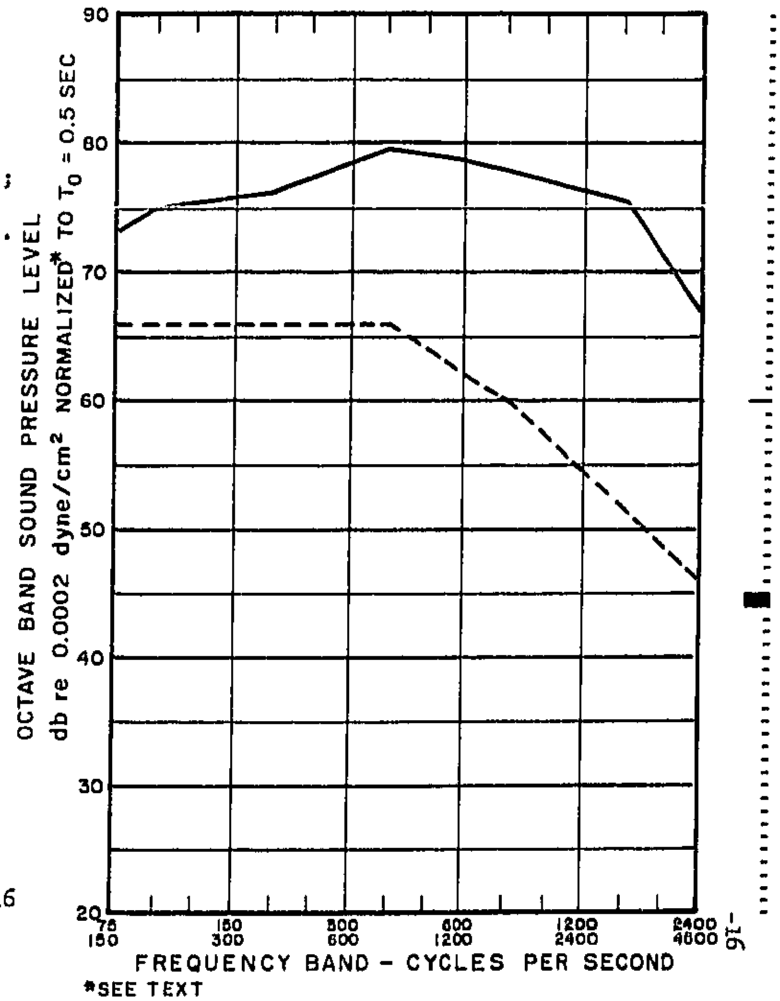
Floor Finish: Finish cement over grout fill.

Ceiling: none

Remarks: Measurements were actually made on constructions built up of prefabricated concrete channel beams and cement mortar; results for poured concrete ribbed slab of same weight and dimensions should be similar.



INR= -16



GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 32, #727; (1) Laboratory measurement

SAMPLE DESCRIPTION:

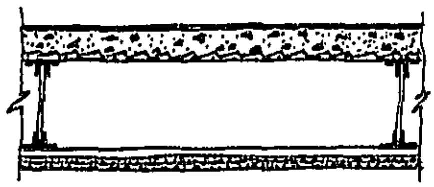
CONCRETE SLAB ON STEEL BAR JOISTS - SUSPENDED CEILING

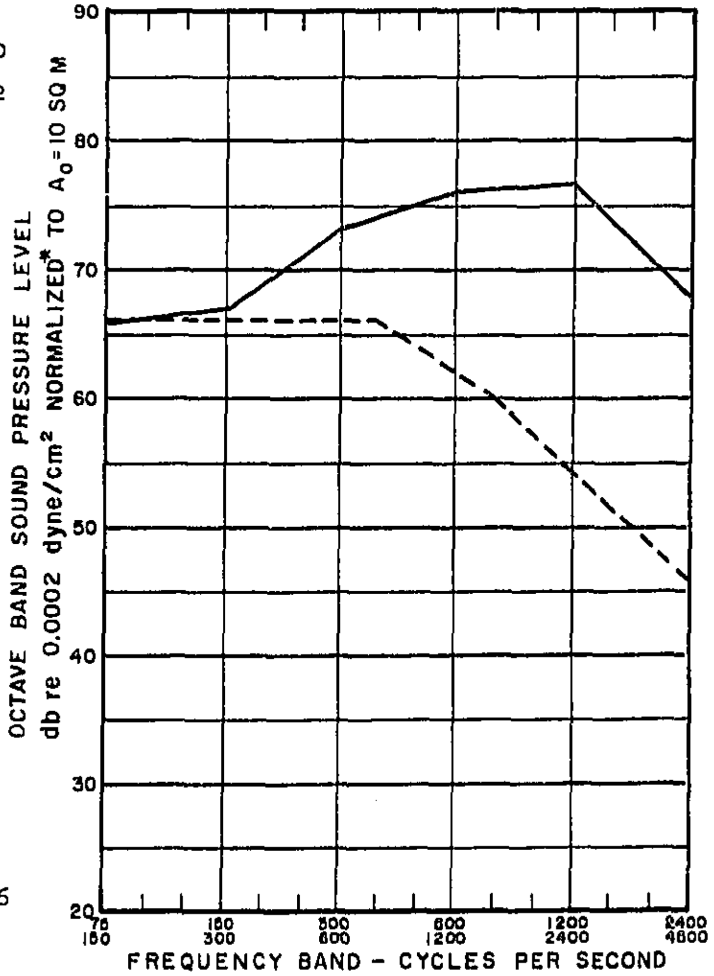
Total thickness 11", total weight 38.2 lb/ft^2

Basic Construction: 7" steel bar joists, 27" o.c.; on top of bar joists: 2" concrete floor slab on 3/8" rib lath.

Floor Finish: none

Ceiling: 3/4" furring channels, 16" o.c. wire tied to bottom of joists; 3/8" gypsum lath attached to furring channels by clips; 7/16" sanded plaster and 1/16" coat of lime putty finish.





INR= -16

*SEE TEXT

-16

TEST REF: 17, Fig. 71, S-292-294; (5)

SAMPLE DESCRIPTION:

WOOD JOIST: "THICK" CEILING & "THIN" WALLS (see remarks)

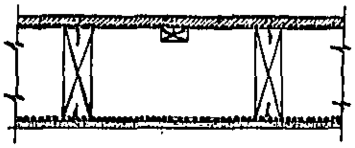
Total thickness 8½"; total weight 13 lb/ft^2

Basic construction: 2" x 8" wood joists with 7/8" T & G floor boards screwed to joists; the boards were also screwed to 1" x 2" battens running midway between the joists.

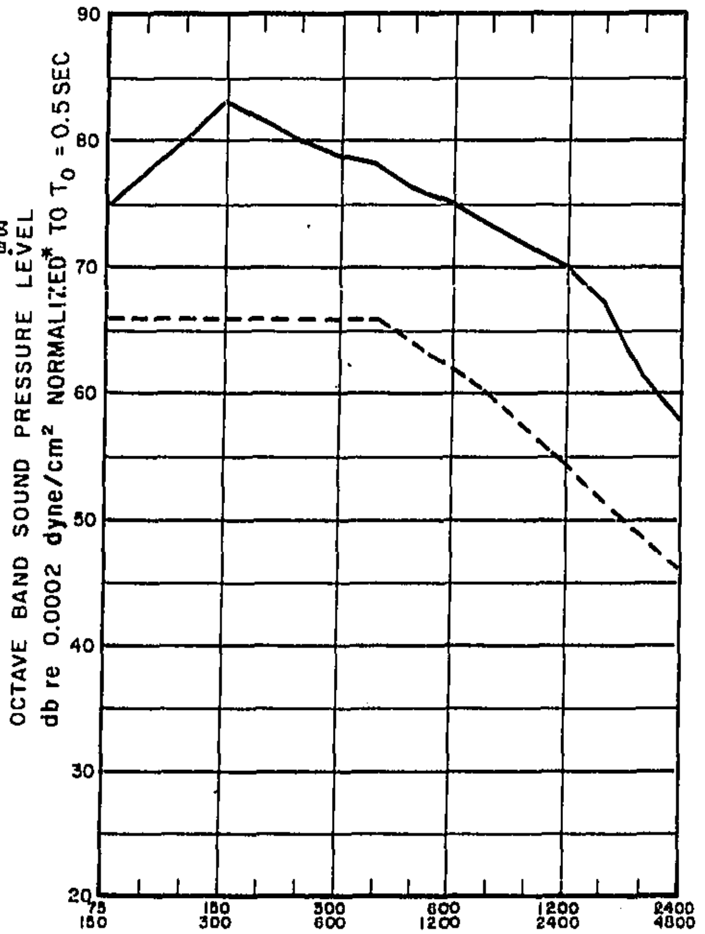
Floor Finish: none

Ceiling: three-coat plaster on expanded metal lath.

Remarks: The heavy plaster ceiling yields some improvement over the thin 3/8" plasterboard ceiling, but the thin walls (two of them 4½" thick, the other two 9" or less) appear to constitute a weakness of this structure. Heavier supporting walls would restrain the floor structure and improve the impact isolation. Compare with data sheets #4 (p.25) and #22 (p.43).



INR= -12



FREQUENCY BAND - CYCLES PER SECOND

*SEE TEXT

-12

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 32, 723A; (1) Laboratory measurement.

SAMPLE DESCRIPTION:

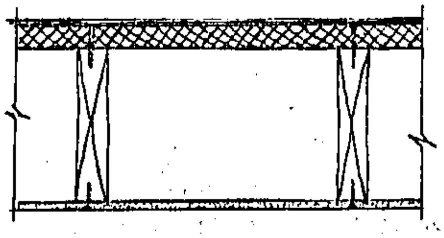
WOOD JOIST - FLOATED WOOD RAFT, VINYL TILE

Total thickness 11-3/4", total weight 15 lb/ft^2

Basic Construction: 2" x 10" wood joists, 16" o.c., with 1-11/32" planks of compressed homogeneous paper pulp building board, nailed 8" o.c. perpendicular to joists.

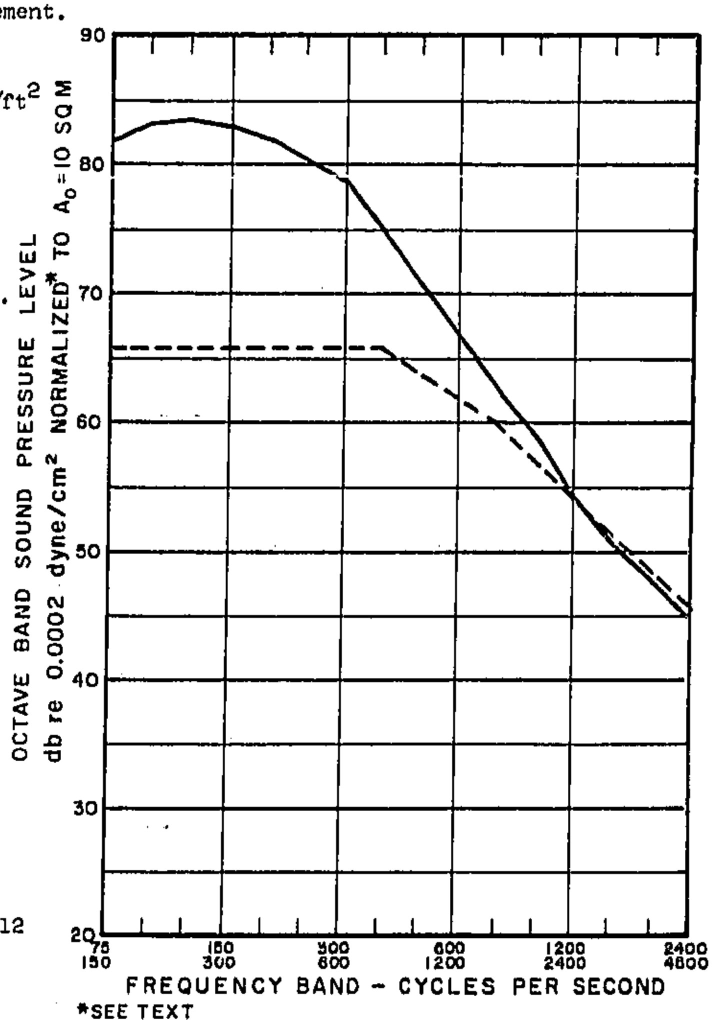
Floor Finish: 1/8" hardboard cemented to planks, with 15 lb. felt paper cemented to the hardboard, and covered with vinyl astestos tile, cemented to the felt paper.

Ceiling: ½" sheetrock, nailed 12" o.c. to joists; joints taped and sealed.



10

INR= -12



*SEE TEXT

-12

TEST REF: 32, #721 A (1) Laboratory measurement

SAMPLE DESCRIPTION:

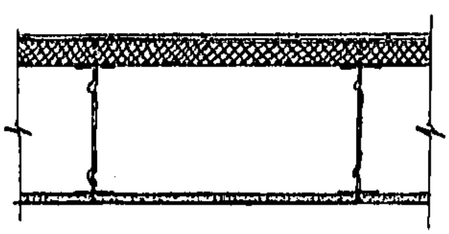
BUILDING BOARD ON STEEL JOISTS - THIN VINYL TILE - SUSPENDED CEILING

Total thickness 10½", total weight unknown.

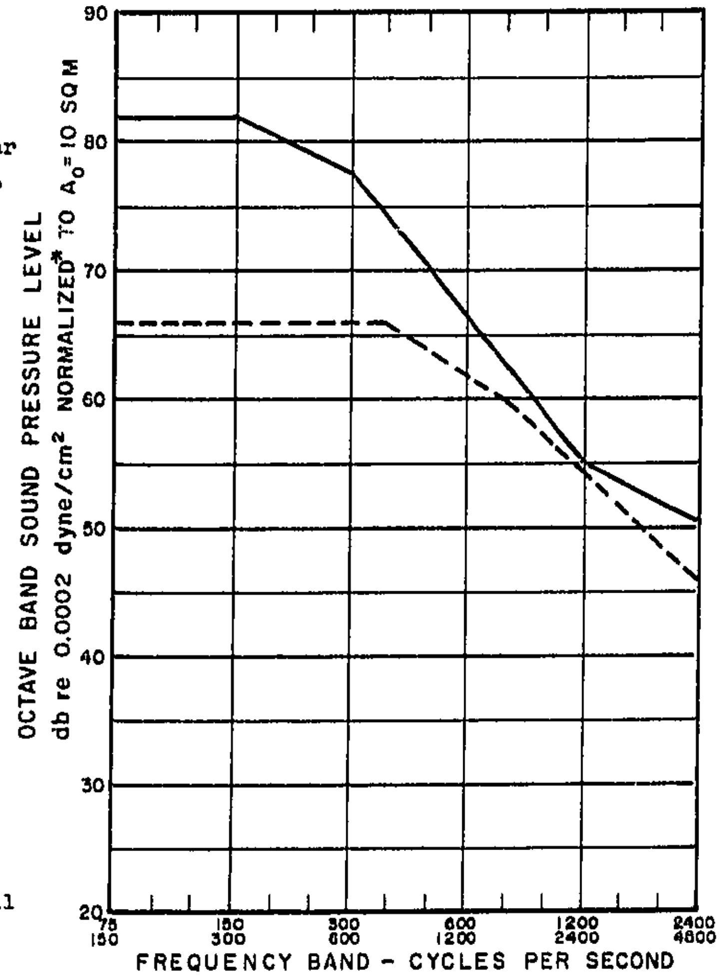
Basic Construction: 8" steel joists, similar to I-beams, 16" o.c., with 1-11/32" planks of compressed homogeneous paper pulp building board (26 lb/ft²), nailed 8" o.c. perpendicular to the joists.

Floor Finish: 1/8" hardboard cemented to planks; 15 lb. felt paper cemented to hardboard; 1/8" vinyl asbestos tile cemented to felt paper.

Ceiling: ½" sheetrock, nailed 12" o.c. (to joists?), joints taped and sealed.



INR= -11



*SEE TEXT

11

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 25 III, Fig. 34; (?)

SAMPLE DESCRIPTION:

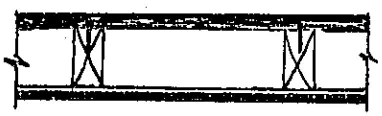
WOOD JOIST - LINOLEUM

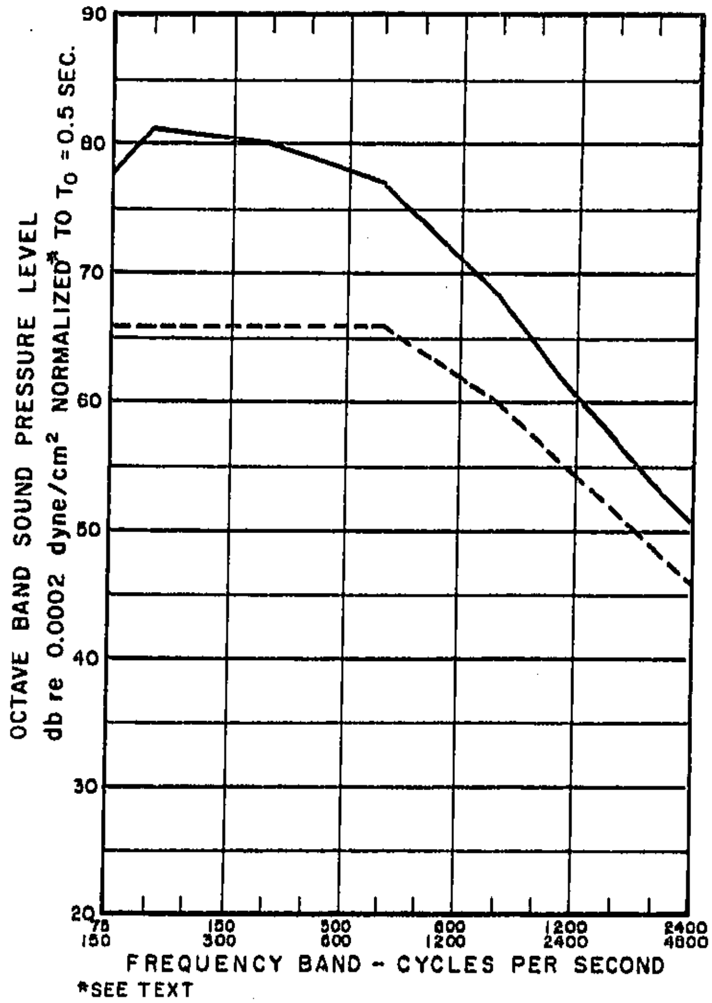
Total thickness 9½", total weight 12 lb/ft^2

Basic Construction: 2" x 7" wood joists 24" o.c. with 1" floor boards, nailed.

Floor Finish: 3/32" linoleum, cemented.

Ceiling: plaster on wood lath on furring.





INR= -10

-10

TEST REF: 32, #727 A; (1) Laboratory measurement

SAMPLE DESCRIPTION:

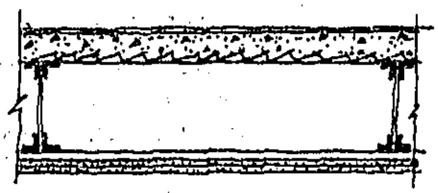
CONCRETE SLAB ON STEEL BAR JOISTS - VINYL TILE
SUSPENDED CEILING

Total thickness 11", total weight 39 lb/ft^2

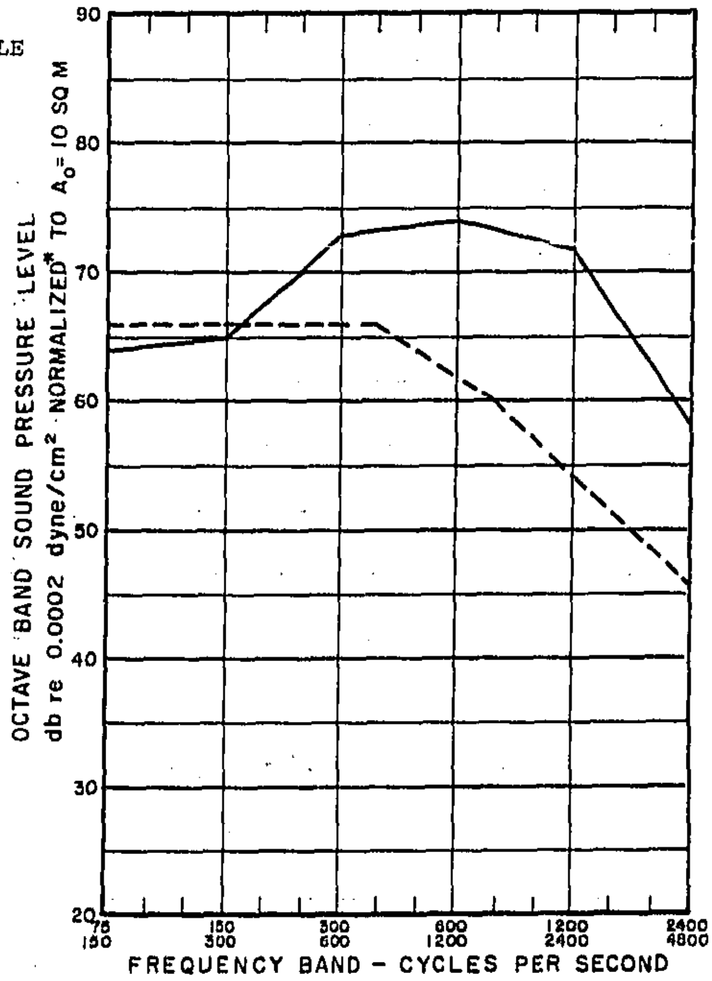
Basic Construction: 7" steel bar joists, 27" o.c.; on top of bar joists: 2" concrete floor slab on 3/8" rib lath.

Floor Finish: 1/8" vinyl asbestos tile cemented to concrete with linoleum paste.

Ceiling: 3/4" furring channels, 16" o.c. wire tied to bottom of joists; 3/8" gypsum lath attached to furring channels by clips; 7/16" sanded plaster and 1/16" coat of lime putty finish.



INR= -10



*SEE TEXT

-10

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 25 III, 39b; (?)

SAMPLE DESCRIPTION:

HOLLOW TILE BEAM - LINOLEUM

Total thickness 6-3/4"; total weight 50 lb/ft^2

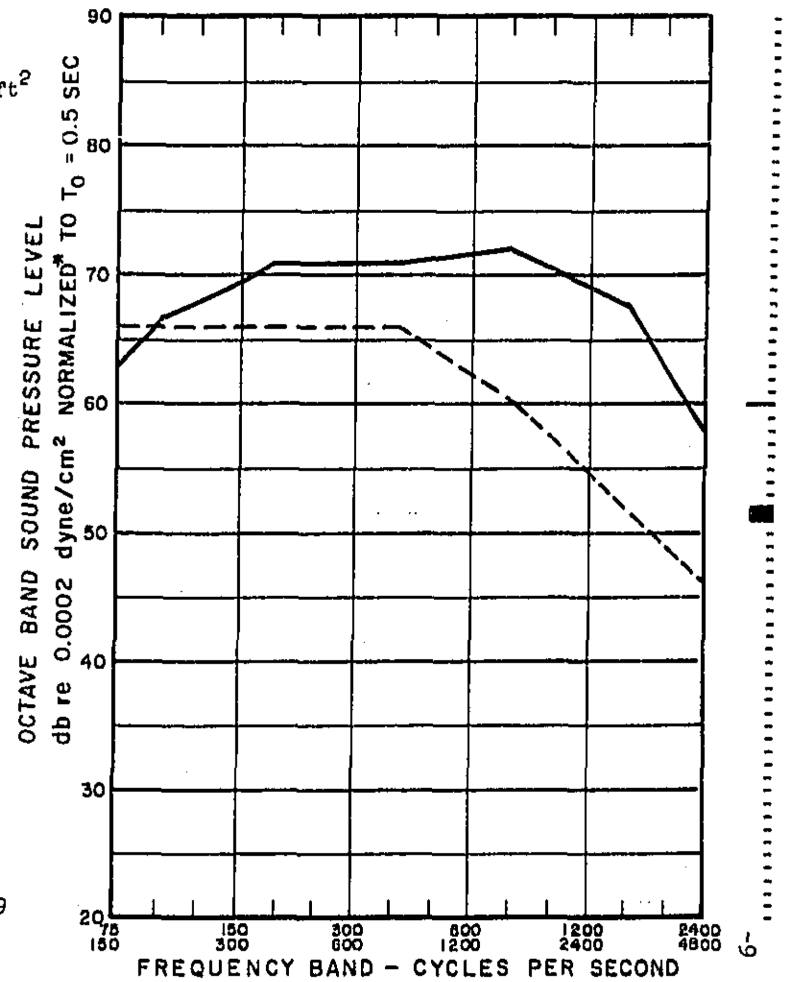
Basic Construction: Hollow tile beam, 5-1/8" thick, with steel reinforcement; 3/4" cement on upper surface.

Floor Finish: linoleum, cemented.

Ceiling: 3/8" plaster.

-35-

INR= -9



*SEE TEXT

TEST REF: 17, S-117; (4)

SAMPLE DESCRIPTION:

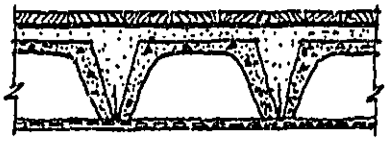
RIBBED CONCRETE - WOOD BLOCK FLOORING - SUSPENDED CEILING

Total thickness 10"; total weight 65 lb/ft^2

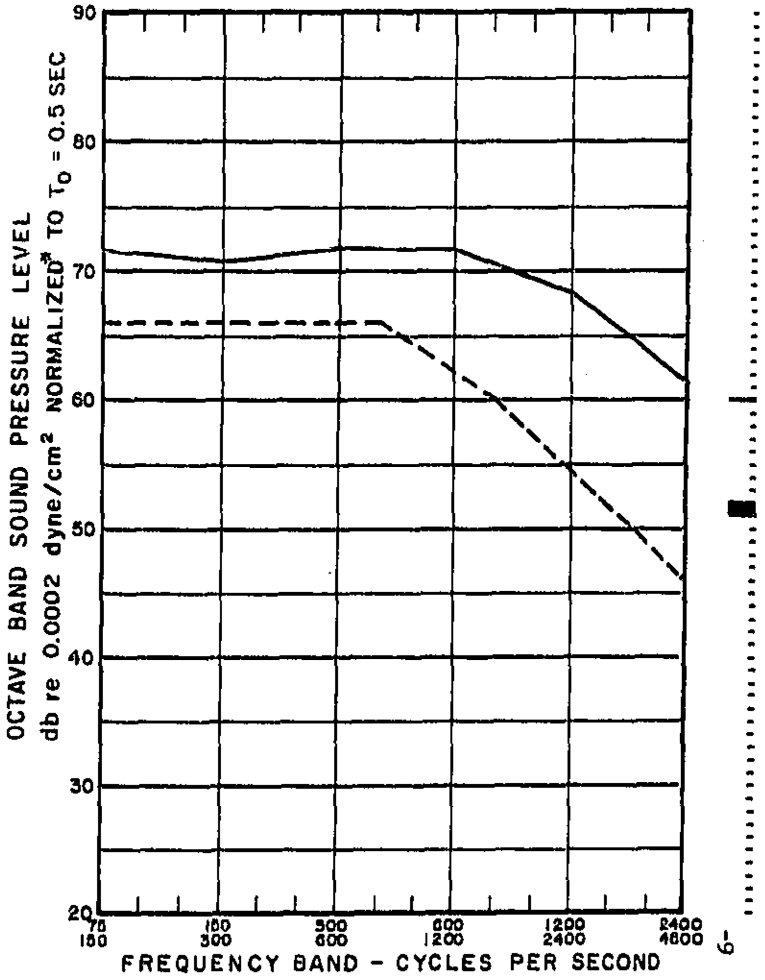
Basic Construction: Precast concrete channels, 1" thick; ribs 15" o.c.

Floor Finish: 1" wood blocks in continuous mastic bed over 1½" sand-cement screed.

Ceiling: Plaster on expanded metal lath wired to ribs.



INR= -9



*SEE TEXT

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, Fig. 73, S-306-310, S-311-312; (12)

SAMPLE DESCRIPTION:

WOOD JOIST - FLOATED WOOD RAFT

Total thickness 9", total weight 8 lbs/ft^2

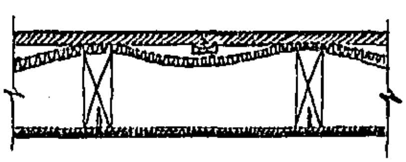
Basic Construction: 2" x 7" wood joists, 16" o.c.

Floor Finish: 7/8" square-edge floor boards nailed on 2" x 1" battens; the whole raft floating on 1" glass fiber blanket.

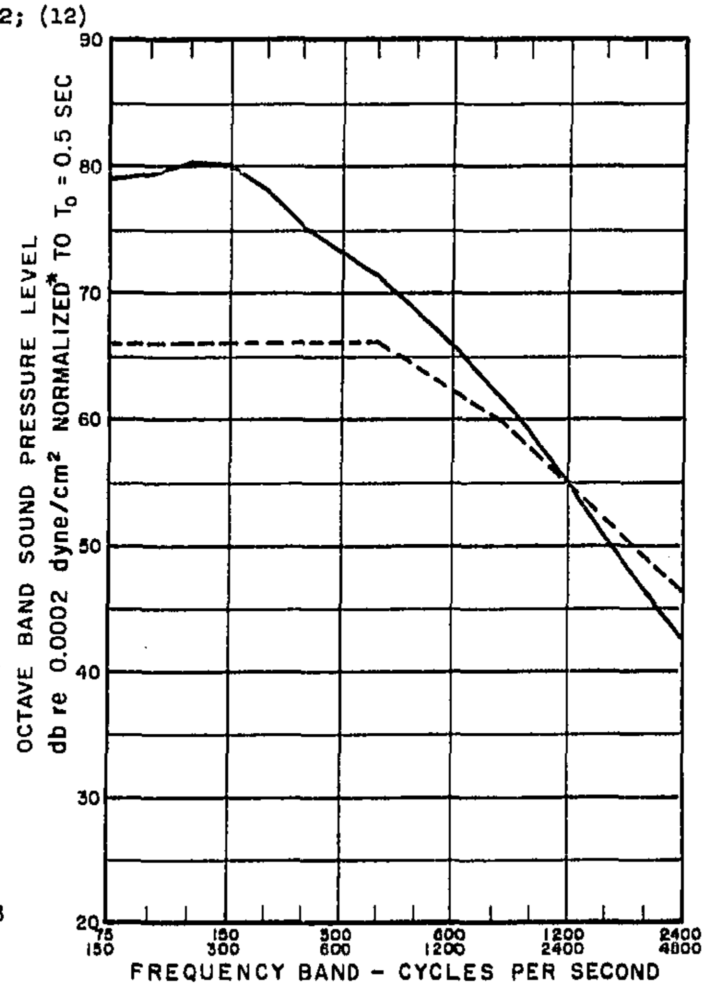
Ceiling: 3/8" plasterboard, finished with plaster skim coat.

Remarks: The INR could be improved to -4 if a heavy plaster ceiling were used. The performance of this structure tends to deteriorate with time.

-37-



INR= -8



*SEE TEXT

-8

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 25 II, IV-A-21; (3)

SAMPLE DESCRIPTION:

RIBBED CONCRETE - SUSPENDED CEILING

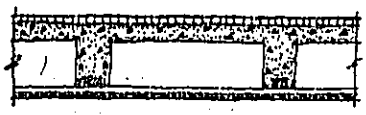
Total thickness 9½"; total weight 50 lb/ft²

Basic Construction: Ribbed concrete floor: slab 2" thick, ribs 22" o.c., and 5¼" deep; nailing strips cast into lower surface of ribs.

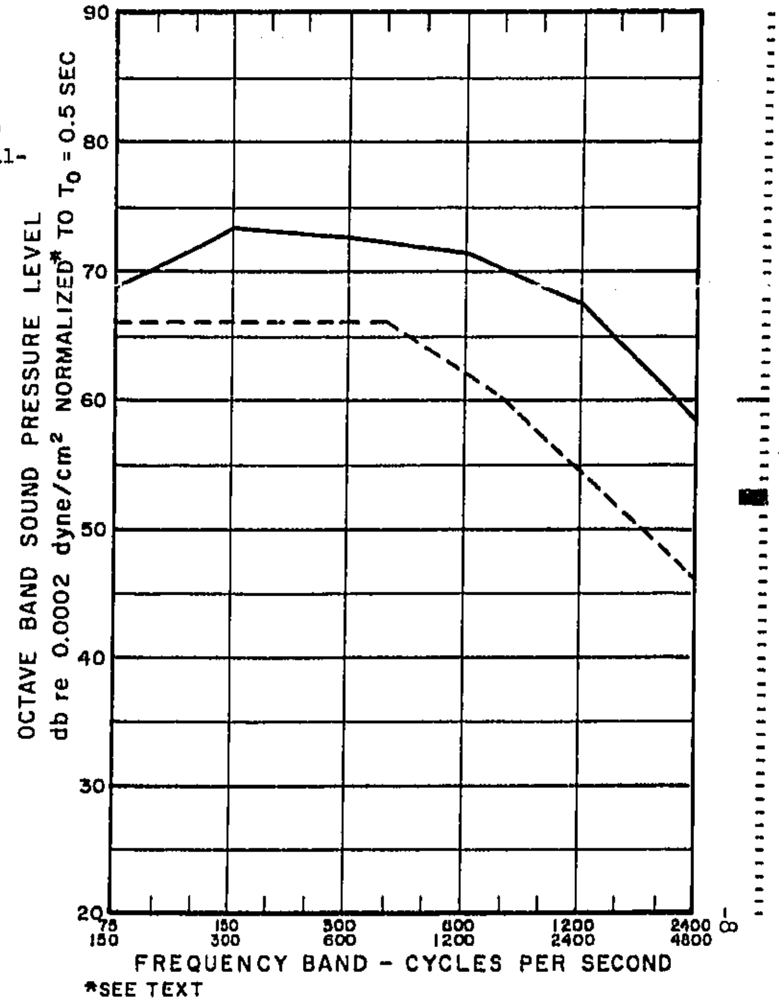
Floor Finish: 3/4" cement

Ceiling: Plaster on wood lath on wood furring.

-38-



INR= -8



GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, S-59, S-60, S-62, S-63; (4)

SAMPLE DESCRIPTION:

CONCRETE RIBBED SLAB WITH FILLER BLOCKS - WOOD

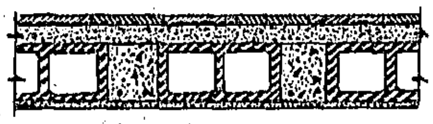
Total thickness 8", total weight 65 lb/ft^2

Basic Construction: $5\frac{1}{4}$" concrete ribs and hollow-tile filler blocks topped with $1\frac{1}{2}$" sand-cement screed.

Floor Finish: 3/4" or 7/8" wood block laid in mastic, or floor boards nailed to screed.

Ceiling: two-coat plaster

-39-



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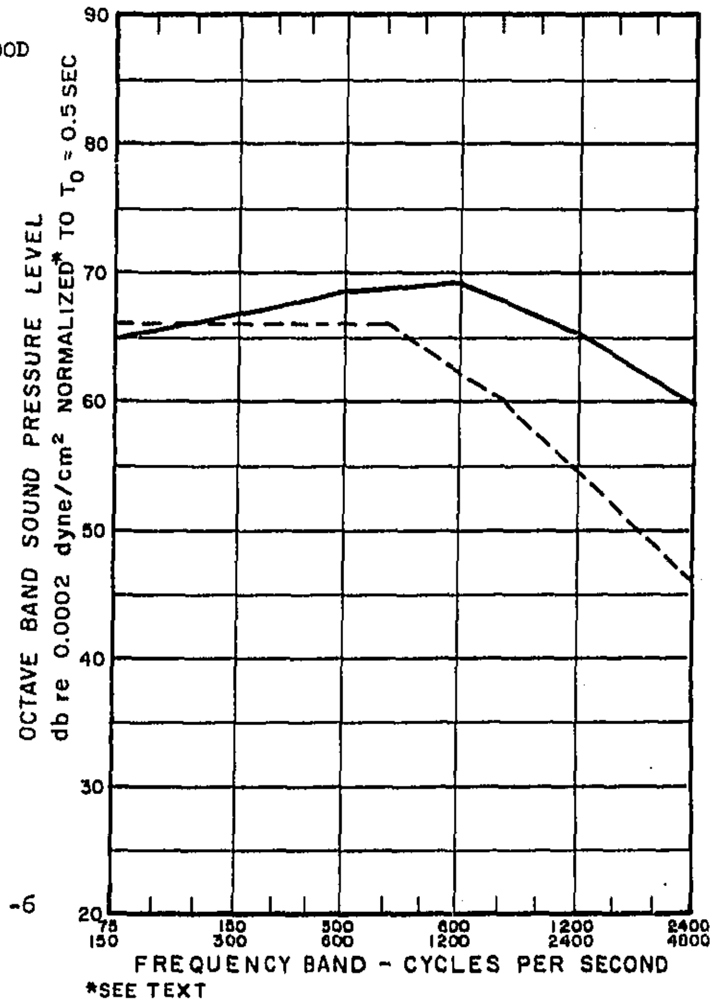


-6

TEST REF: 32, 717; (1) Laboratory measurement

SAMPLE DESCRIPTION:

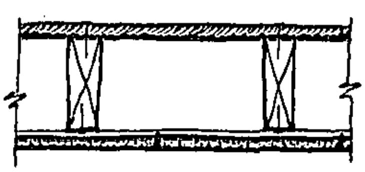
WOOD JOIST - RESILIENT SUSPENDED CEILING

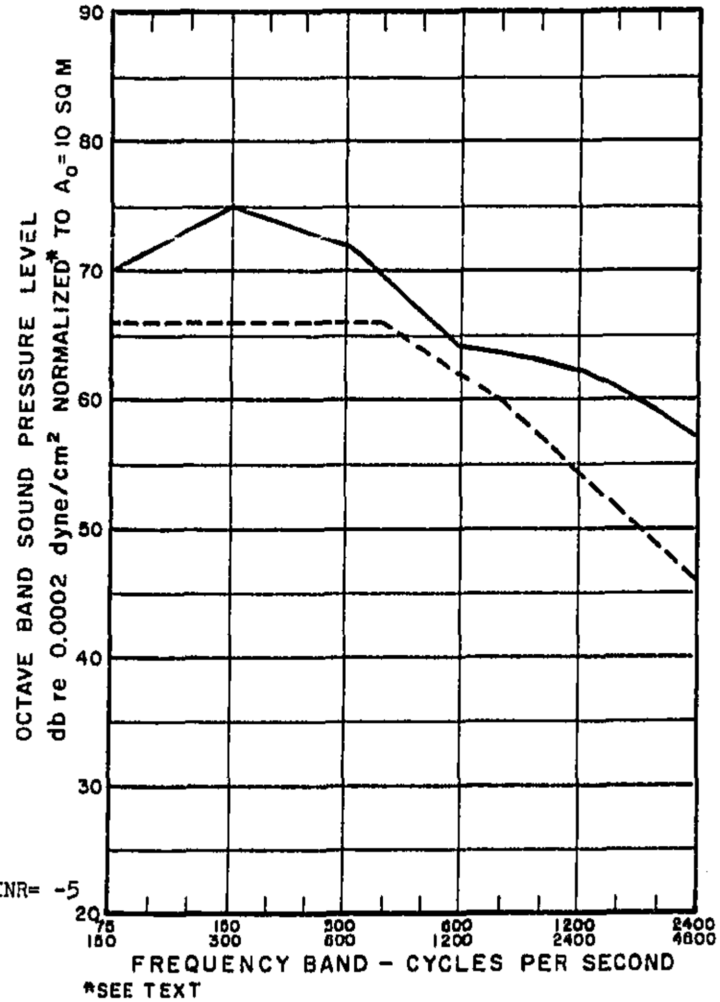
Total thickness 9", total weight 10 lb/ft^2

Basic Construction: 2" x 8" wood joists, 16" o.c. with 3/4" T & G fir flooring, nailed.

Floor Finish: None

Ceiling: 5/8" sheetrock screwed to resilient metal runners, nailed to and bridged across joists, 12" o.c. Joints taped and finished.





INR= -5

*SEE TEXT

-5

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, S20 and S21; (2)

SAMPLE DESCRIPTION:

FLAT CONCRETE SLAB - WOOD FLOORING

Total thickness 7", total weight 70 lbs/ft²

Basic Construction: 5" concrete and filler-joist structural floor; filler joists 30' o.c.

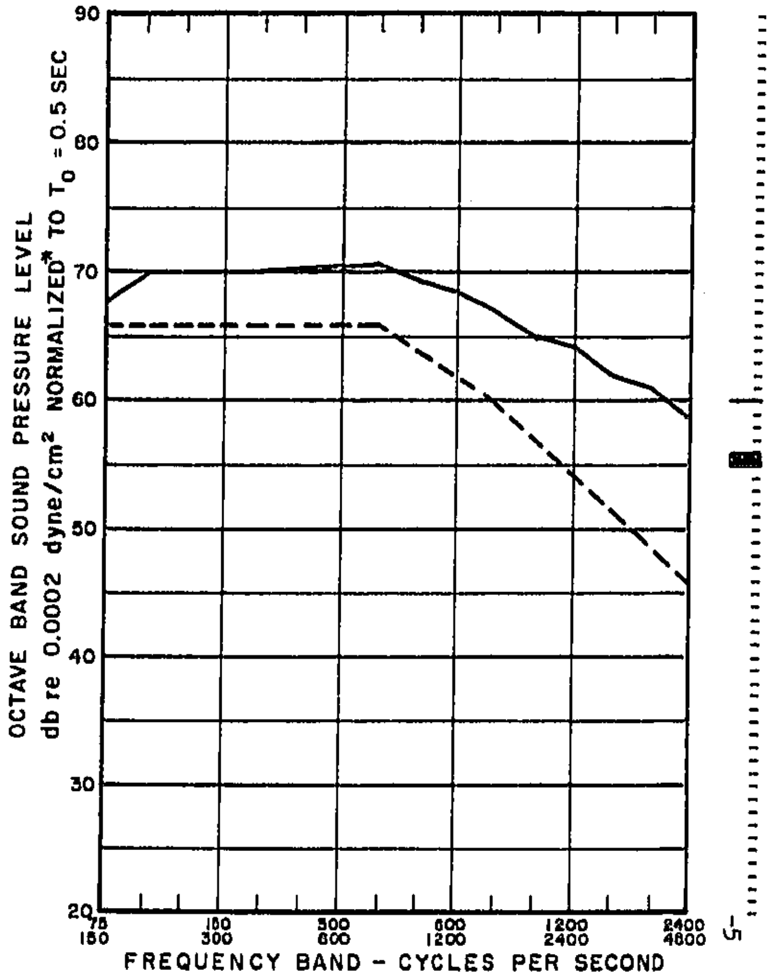
Floor Finish: 7/8" floor boards nailed to 1" clinker concrete screed.

Ceiling: two-coat plaster

Remakrs: A reinforced cement slab with wood block (parquet) floor finish would probably give similar results; the steel filler joist probably does not affect the impact performance greatly.

-41-

INR= -5



*SEE TEXT

TEST REF: 25 II, IV-C-27;

SAMPLE DESCRIPTION:

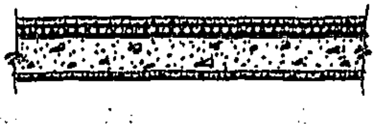
FLAT CONCRETE SLAB - FLOATED CONCRETE FLOOR

Total thickness 6-3/4", total weight 65 lb/ft²

Basic Construction: 4½" reinforced concrete slab.

Floor Finish: ½" bitumen layer in which is laid ½" soft wood fiber board; this is covered with a thin layer of bitumen and a 3/4" screed of cement.

Ceiling: ½" plaster



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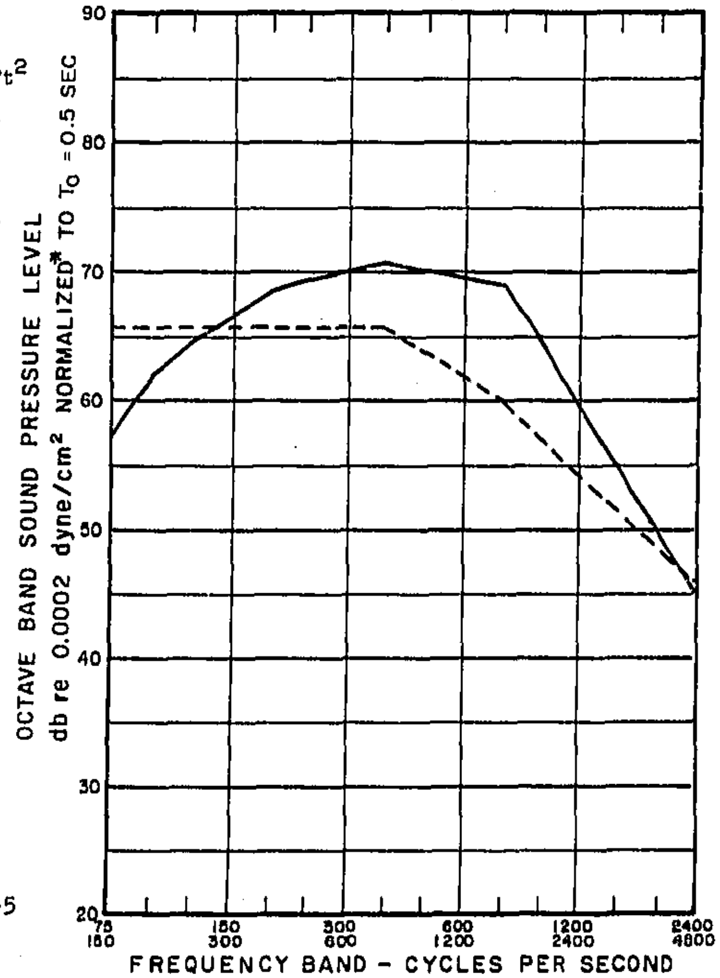


*SEE TEXT

TEST REF: 17, Fig. 71, S-295-299; (12)

SAMPLE DESCRIPTION:

WOOD JOIST: "THICK" CEILING & "THICK" WALLS (see remarks)

Total thickness $10\frac{1}{2}$", total weight 12 lb/ft^2

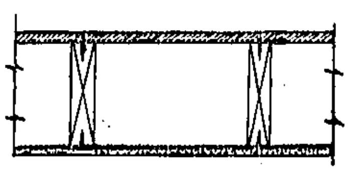
Basic Construction: 2" x 9" wood joists with 7/8" T & G floor boards nailed to joists.

Floor Finish: none

Ceiling: wood lath and plaster.

Remarks: The supporting walls were all 9" thick or more, which act to restrain the vibration of the floor, compared to the examples with thin supporting walls; it still fails to meet recommended curve for impact isolation. Compare with data sheets #4 (p.25) and #9 (p.30).

-43-



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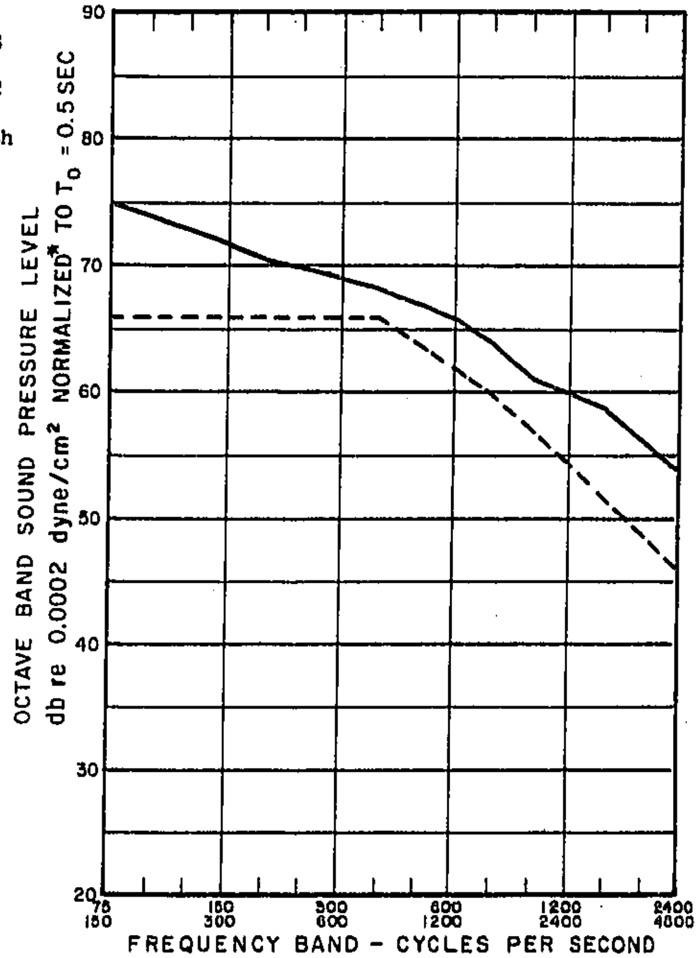


*SEE TEXT

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, S-5; and 5, Fig. 37a, b and d; (4)

SAMPLE DESCRIPTION:

FLAT CONCRETE SLAB - LINOLEUM

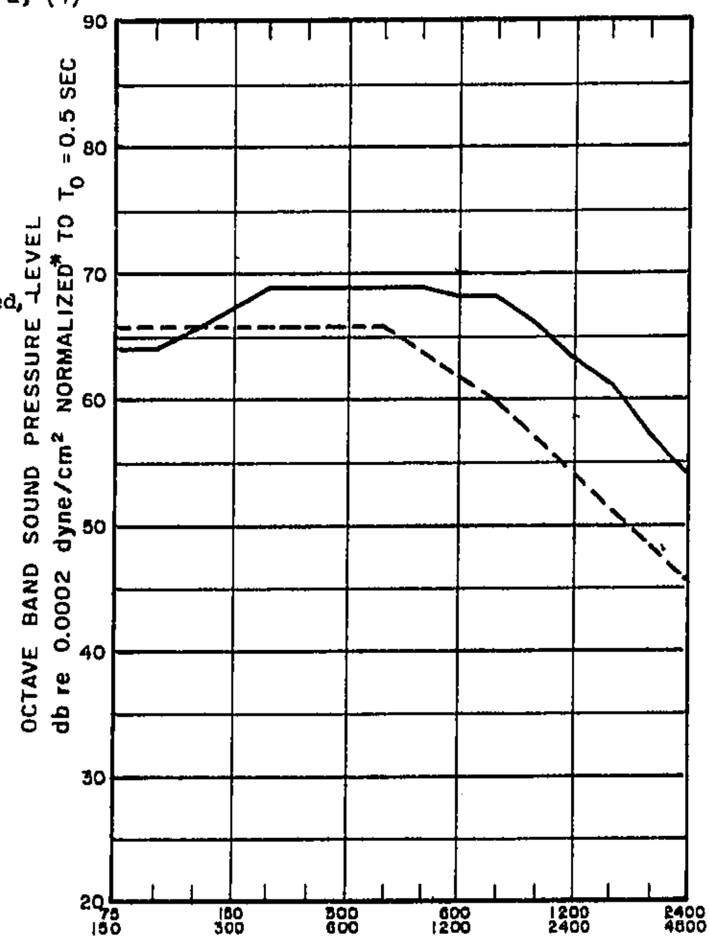
Total thickness 6¼", total weight 64 lb/ft²

Basic Construction: 6" reinforced concrete slab.

Floor Finish: 1/8" linoleum cemented to bitumen felt underlay cemented to slab.

Ceiling: 1/2" plaster.

Remarks: If the floor finish is not cemented, the ISPL increases at high frequencies and the floor sounds "clicky". A thicker or softer underlay improves the isolation but is subject to indentation from point loads (sharp heels).



INR= -4

*SEE TEXT

TEST REF: 25II, IV -B-22; (1)

SAMPLE DESCRIPTION:
FLAT CONCRETE SLAB - SUSPENDED CEILING

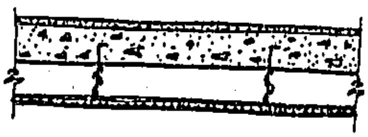
Total thickness 9", total weight 62 lb/ft^2

Basic Construction: 4½" reinforced concrete slab.

Floor Finish: 3/4" finish cement.

Ceiling: Gypsum lath and plaster (1") suspended on 4" wire hangers.

-45-



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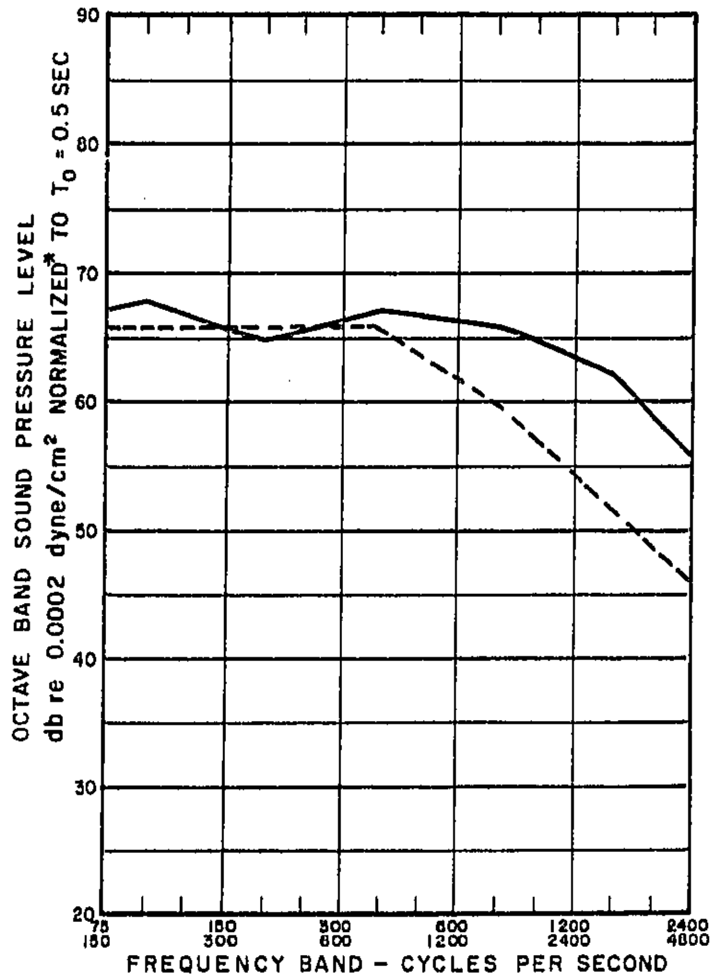


*SEE TEXT

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 22, 133-136; (4)

SAMPLE DESCRIPTION:

HOLLOW CONCRETE BEAMS - CORK TILE

Total thickness 10", total weight 56 lb/ft^2

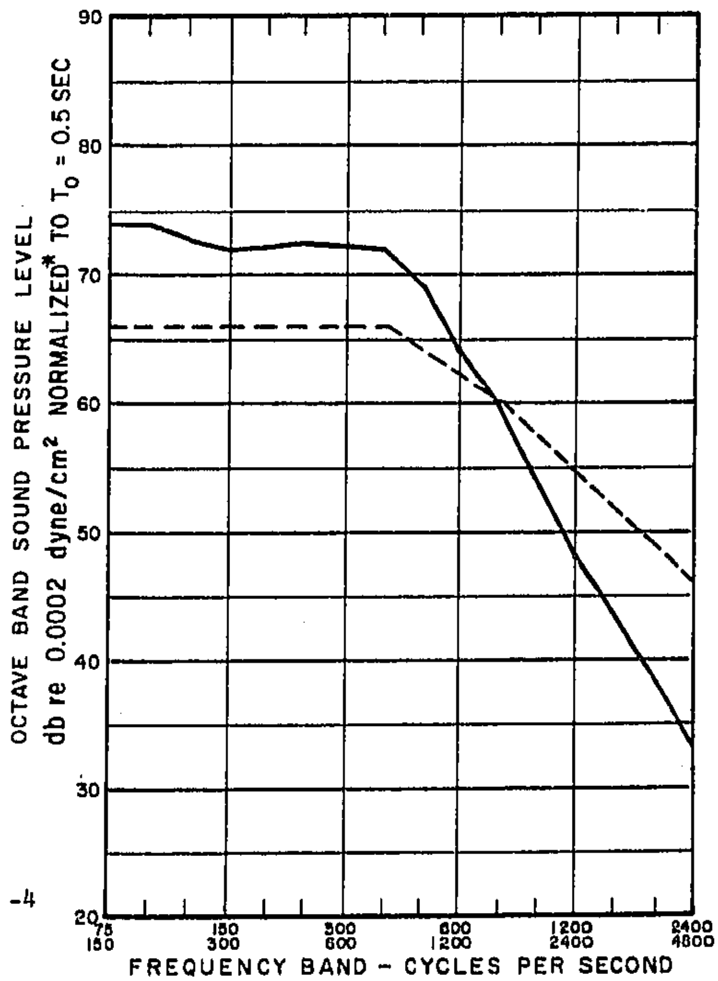
Basic Construction: Precast hollow concrete beams, upper shell 2" thick, lower shell 1¼" thick.

Floor Finish: ⅛" cork tiles on mastic cement.

Ceiling: none

-46-

INR= -4



*SEE TEXT

TEST REF: 17, S-66, S-67, S-68; (12)

SAMPLE DESCRIPTION:

CONCRETE RIBBED SLAB WITH FILLER BLOCKS - FLOATED CONCRETE FLOOR

Total thickness 8", total weight 65 lb/ft^2

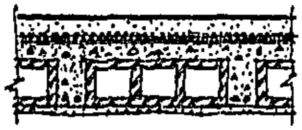
Basic construction: 5½" concrete ribbed slab and hollow-tile filler blocks.

Floor Finish: Floating floor of thermoplastic tile, on 1½" reinforced concrete screed, on building paper on 1" bitumen-bonded glass fiber blanket.

Ceiling: 1/2" plaster

Remarks: In some tests slightly better results were obtained using glass fiber blanket without the bitumen bonding for floating the screed, but the results were not consistent.

-47-



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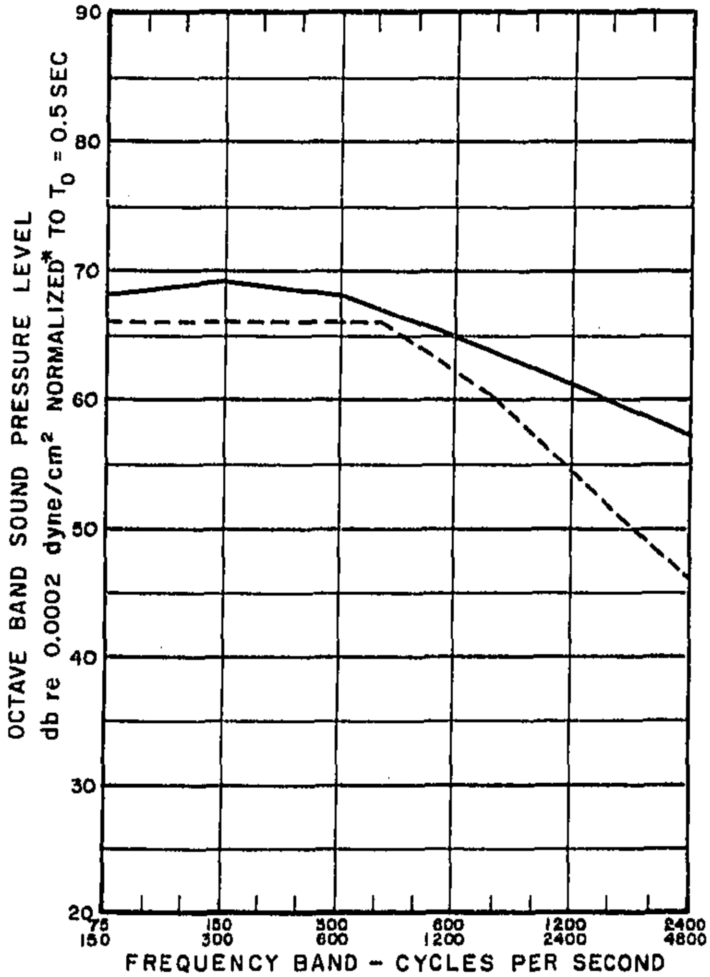


*SEE TEXT

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 25 III, Fig. 34 f; (?)

SAMPLE DESCRIPTION:

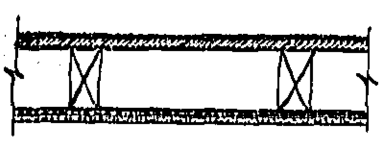
WOOD JOIST - COCOMAT

Total thickness 9-3/4", total weight 13 lb/ft^2

Basic Construction: 2" x 7" wood joists 24" o.c., with 1" floor boards, nailed.

Floor Finish: Cocomat, loosely laid.

Ceiling: Plaster on wood lath on furring.



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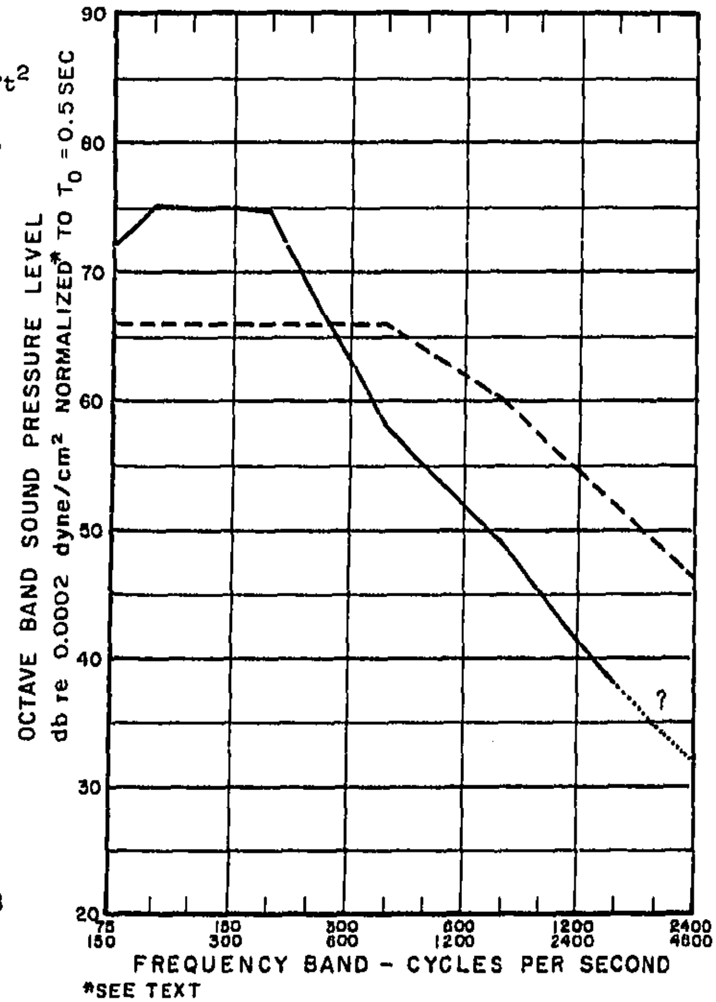


-3

TEST REF: 25 III, 39 g;

SAMPLE DESCRIPTION:

HOLLOW CONCRETE BEAM - FURRED CEILING

Total thickness 8", total weight 52 lb/ft^2

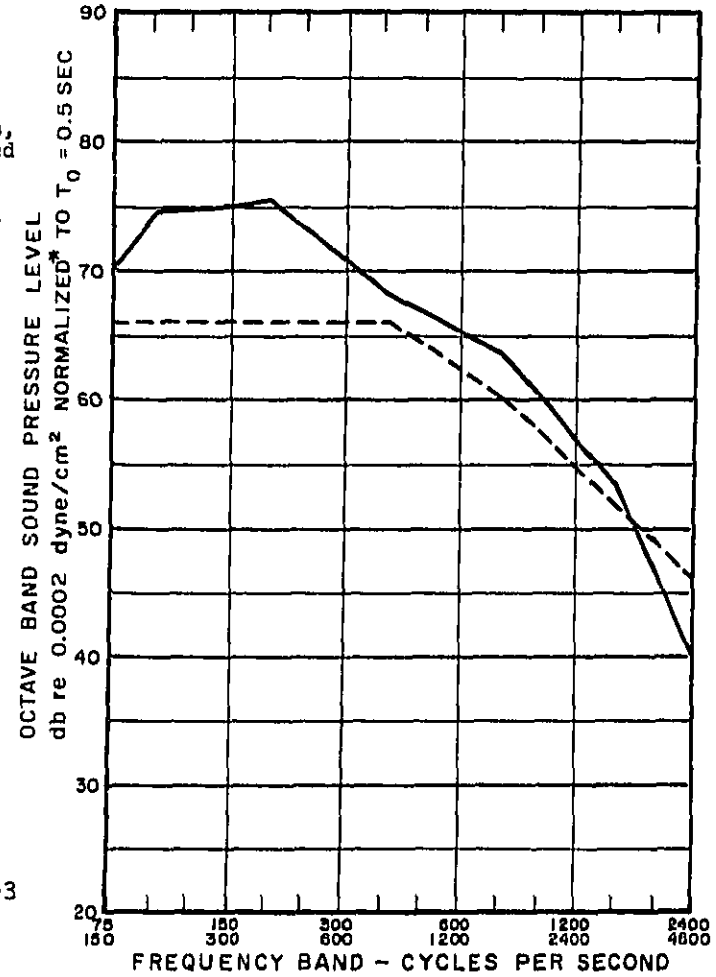
Basic Construction: "Perfora" hollow bricks, 5-1/8" thick, reinforced with steel, cement mortar fill in joints; topped with 3/4" finish cement.

Floor Finish: Double layer of wood "tiles" 1/8" thick, glued together overlapping, laid loose on basic floor.

Ceiling: 3/4" plaster on reed, on 3/4" laths, nailed to 3/4" nailing strips.

-49-

Remarks: A thin layer of straw board under the wood blocks improves this construction to INR= +1 when new, but this deteriorates with time, particularly in the presence of moisture.



*SEE TEXT

INR= -3

-3

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, S-64; (1)

SAMPLE DESCRIPTION:

HOLLOW CONCRETE BEAM - WOOD RAFT FLOOR

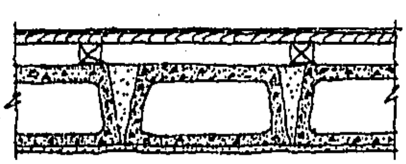
Total thickness 10", total weight 45 lb/ft^2

Basic construction: 7" precast hollow concrete beam 14½" wide, cement mortar fill in joints.

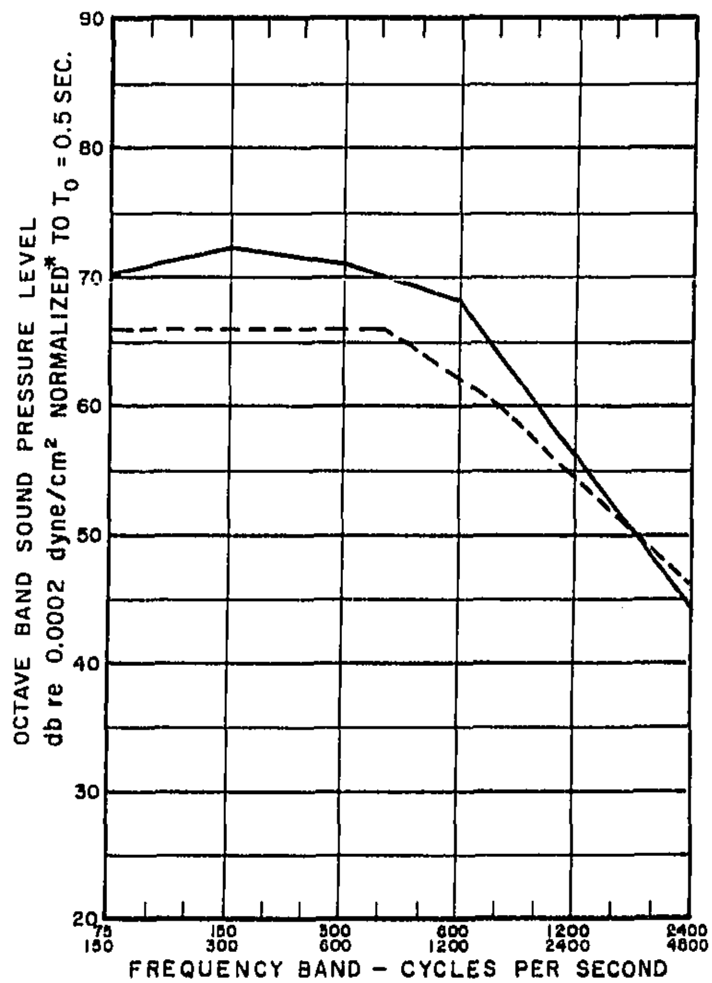
Floor Finish: 7/8" T & G boards nailed to 2" x 2" battens and covered with linoleum. Battens rest directly on the basic floor.

Ceiling: two-coat plaster.

-50-



INR= -3



*SEE TEXT

-3

TEST REF: 32,#718; (1) Laboratory measurement

SAMPLE DESCRIPTION:

WOOD JOIST - FLOATING WOOD RAFT - RESILIENT SUSPENDED CEILING

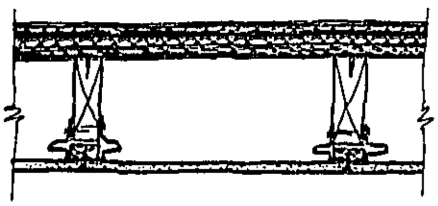
Total thickness 9", total weight unknown

Basic Construction: 2" x 6" wood joists, 16" o.c. with 5/8" fir plywood subfloor nailed to joists 6" o.c.

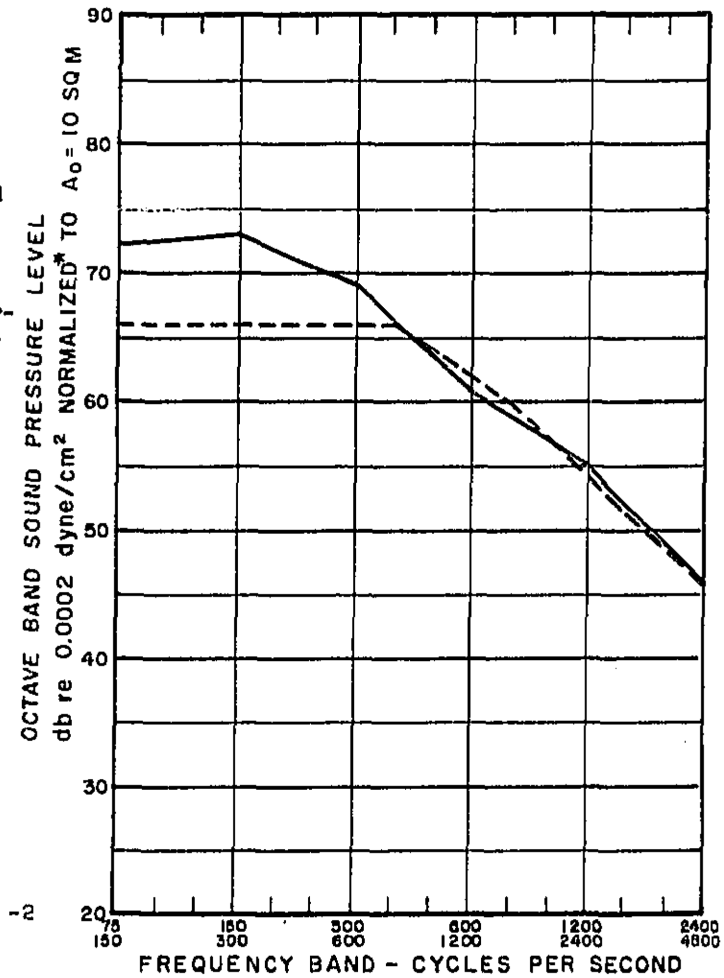
Floor Finish: ½" porous wood fiber board, stapled to subfloor, 12" o.c. over entire surface; to this was cemented ½" plywood underlayment, to which 3/32" vinyl linoleum was cemented.

Ceiling: 1" x 2" furring strips attached to resilient metal clips which were nailed parallel to joists; 5/8" gypsum wallboard was screwed 12" o.c. to the resiliently suspended furring strips; joints taped and sealed.

-51-



INR= -2



*SEE TEXT

TEST REF: 22, 129-132; (4)

SAMPLE DESCRIPTION:

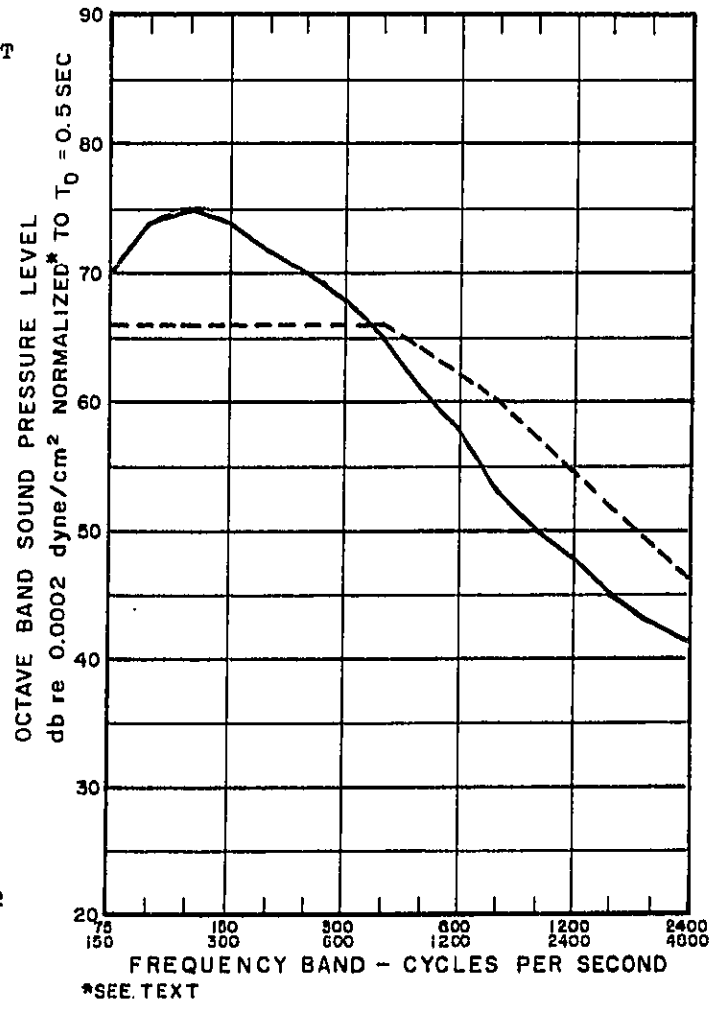
THIN HOLLOW CONCRETE BEAM - FLOATED WOOD RAFT

Total thickness 10", total weight 52 lb/ft^2.

Basic Construction: $6\frac{1}{2}$" hollow concrete beams, with cement mortar.

Floor Finish: Wood floor boards (7/8"?) on battens on $\frac{1}{2}$" soft wood fiber board.

Ceiling: none.



INR= -2

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 32, #727 D; (1) Laboratory measurement.

SAMPLE DESCRIPTION:

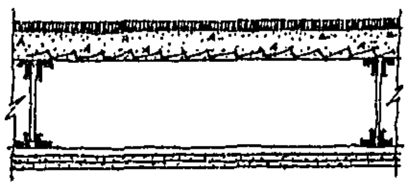
CONCRETE SLAB ON STEEL BAR JOISTS - CORK TILE - SUSPENDED CEILING

Total thickness 11", total weight 39 lb/ft^2

Basic Construction: 7" steel bar joists, 27" o.c.; on top of bar joists: 2" concrete floor slab on 3/8" rib lath.

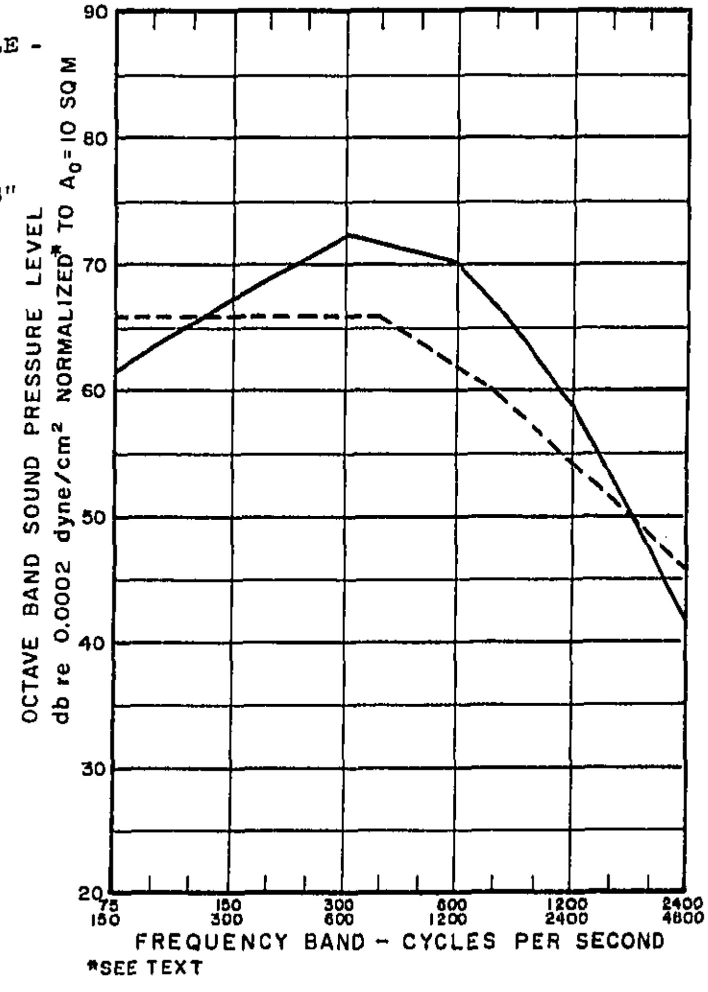
Floor Finish: ¼" cork tile cemented to concrete with linoleum paste.

Ceiling: 3/4" furring channels, 16" o.c. wire tied to bottom of joists; 3/8" gypsum lath attached to furring channels by clips; 7/16" sanded plaster and 1/16" coat of lime putty finish.



32

INR= -2



-2

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 22, 81-112; (32)

SAMPLE DESCRIPTION:

RIBBED CONCRETE - FLOATED WOOD RAFT

Total thickness(est.) 8"; total weight (avg.) 55 lb/ft^2

Basic Construction: Ribbed concrete floor (see remarks) slab $2\frac{1}{4}$" thick, ribs $3\frac{1}{2}$" deep, 10" o.c.

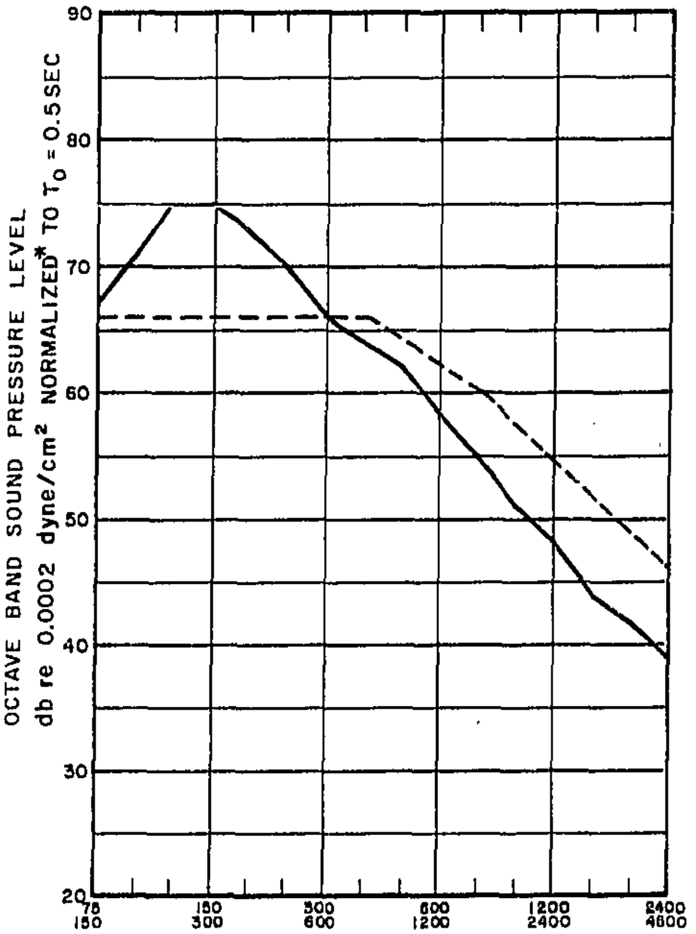
Floor Finish: Floating raft of floor boards on battens on layer ($\frac{1}{2}$") of soft wood fiber board.

Ceiling: none

Remarks: Measurements were actually made on constructions built up of prefabricated concrete channel beams and cement mortar; results for poured concrete ribbed slab of same weight and dimensions should be similar. In some of these constructions, weight was added in the form of dry sand between the battens, but the raft did not rest on the sand. The sand had little effect on impact noise isolation, though it helped reduce airborne sound.

-54-

INR= -1



*SEE TEXT

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, S-115 (2)

SAMPLE DESCRIPTION:

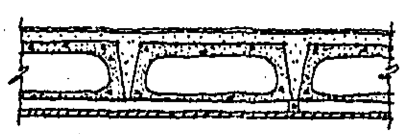
HOLLOW CONCRETE BEAM - CORK TILE - SUSPENDED CEILING

Total thickness 8"; total weight 50 lb/ft^2

Basic construction: Precast hollow concrete beams, 15" wide, 5" deep

Floor Finish: 3/16" cork tiles on 1" sand-cement screed.

Ceiling: 3/8" plasterboard on 1" x 2" battens in metal clips.



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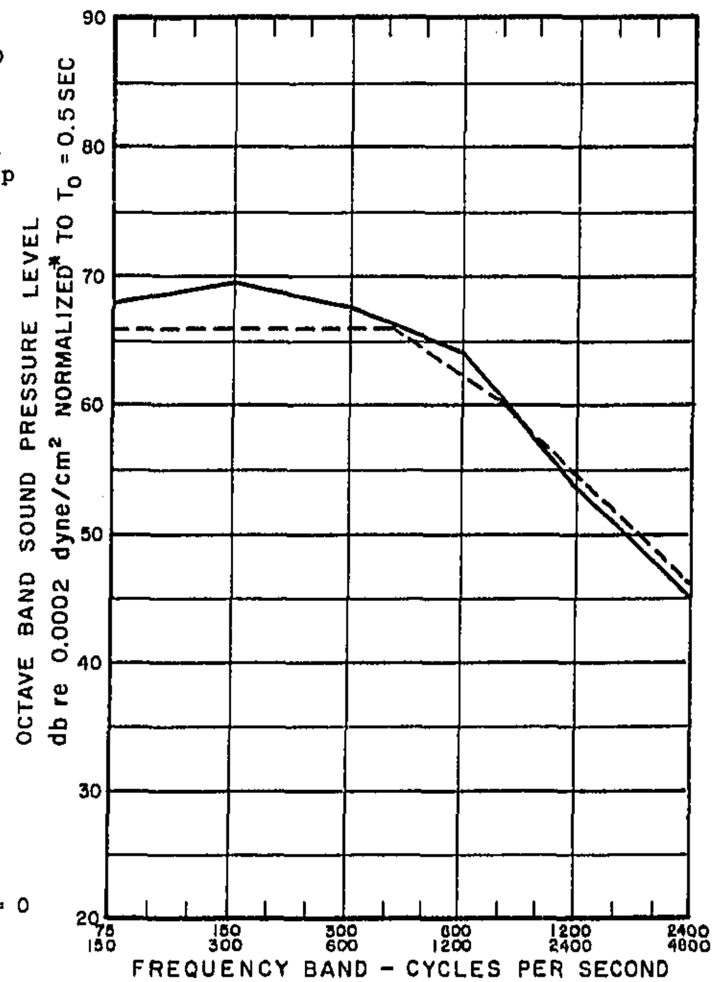


*SEE TEXT

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, Fig 14; (19)

SAMPLE DESCRIPTION:

FLAT CONCRETE SLAB - FLOATED CONCRETE FLOOR

Total thickness 9", total weight 95 lb/ft^2

Basic Construction: 5" reinforced concrete slab.

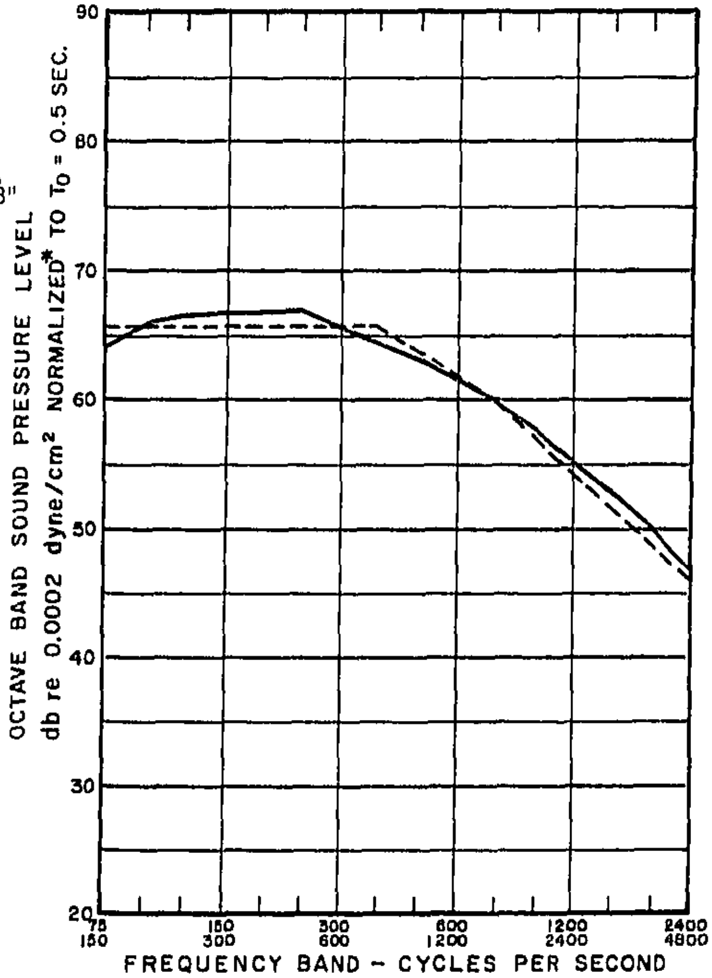
Floor Finish: 2" reinforced concrete screed, on 1" glass fiber blanket; 1/8" linoleum cemented to screed.

Ceiling: ½" plaster.

Remarks: This construction, but without linoleum, is the one which formed the basis for the Grade I requirement in the British Code. Without the linoleum, this floor would not pass FHA recommendations.

35

INR= +1



TEST REF: 17, S-78, S-79, S-80; (6)

SAMPLE DESCRIPTION:

THIN HOLLOW CONCRETE BEAMS - FLOATED WOOD RAFT FLOOR

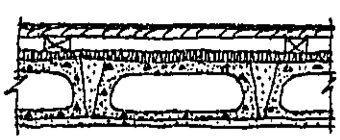
Total thickness 8½", total weight 42 lb/ft^2

Basic construction: Precast hollow concrete beams, 5" thick and 14½" wide, with cement mortar fill in joints.

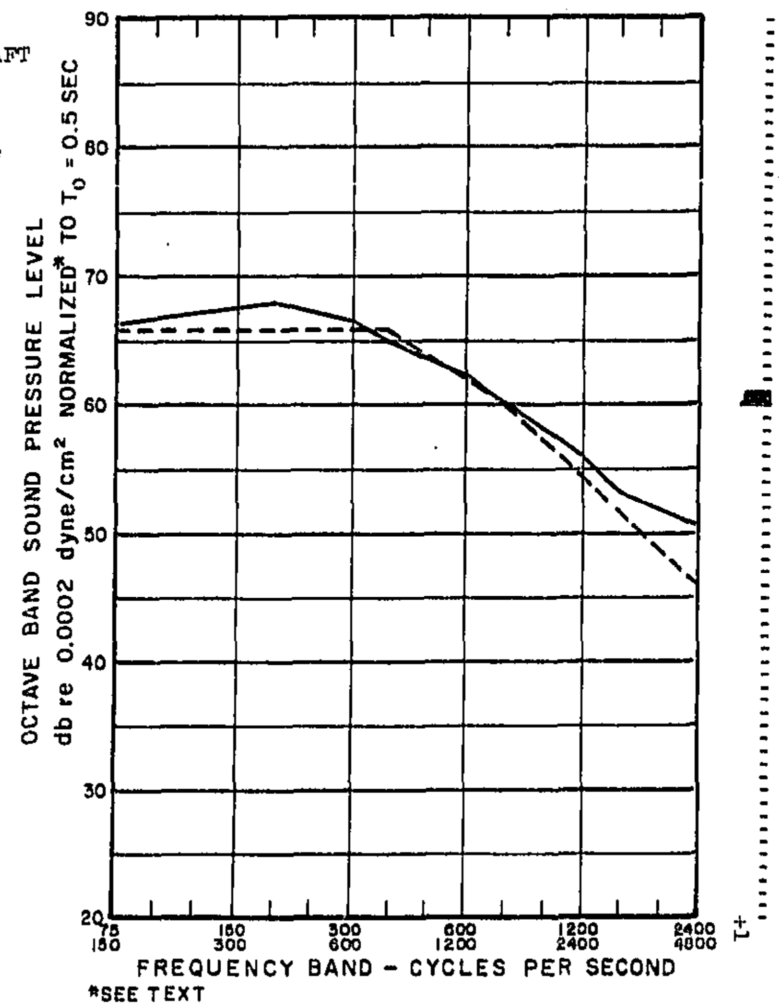
Floor Finish: Floating floor of 7/8" T & G floor boards on 2" x 1½" battens, resting on 1" glass fiber blanket; linoleum cemented to floor on one sample only.

Ceiling: ½" plaster

Remarks: No apparent effect of linoleum on the one sample where it was used.



INR= +1



*SEE TEXT

TEST REF: 17, S-110, S-111, S-112; (12)

SAMPLE DESCRIPTION:

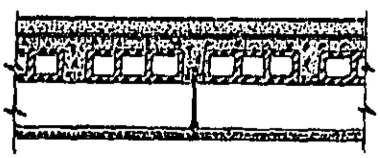
CONCRETE RIBBED SLAB WITH FILLER BLOCKS - FLOATED CONCRETE FLOOR - SUSPENDED CEILING

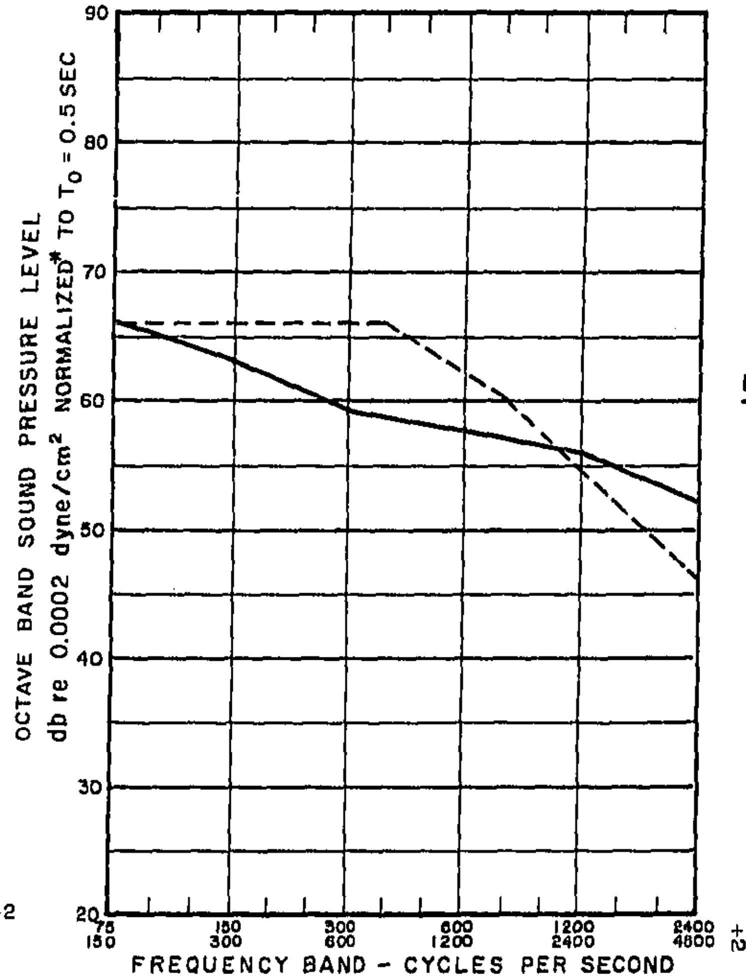
Total thickness 16", total weight 70 lb/ft^2

Basic construction: 5½" ribbed concrete slab with hollow-tile filler blocks.

Floor Finish: Floating floor of thermoplastic tiles on 1½" concrete screed on wire mesh, on building paper, on 1" bitumen-bonded glass fiber blanket.

Ceiling: ½" plaster on ribbed expanded metal lath suspended 6" below basic floor on ¼" steel rods 4 ft o.c.





*SEE TEXT

INR= +2

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: TR 17, S-116; (1)

SAMPLE DESCRIPTION:

RIBBED CONCRETE - FLOATED WOOD RAFT - SUSPENDED CEILING

Total thickness 10½"; total weight unknown.

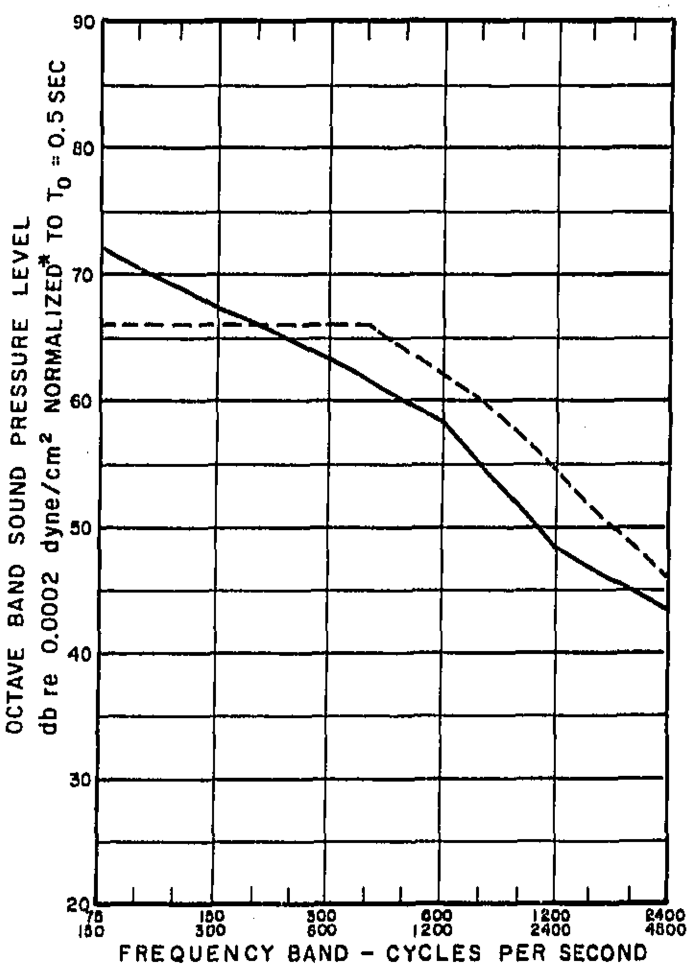
Basic Construction: Precast concrete channels 1½" thick; ribs 15" o.c., and 3½" deep.

Floor Finish: Floating raft of 7/8" T & G floor boards nailed to battens on glass fiber blanket on 3/4" sand-cement screed.

Ceiling: 3/8" plasterboard with plaster skim coat, nailed to 1" x 2" battens on ribs.

-59-

INR- +2



+2

*SEE TEXT

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, S-165, S-166, S-167; (5)

SAMPLE DESCRIPTION:

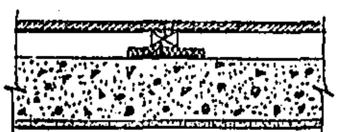
FLAT CONCRETE SLAB - FLOATED WOOD RAFT

Total thickness 9½", total weight 80 lb/ft²

Basic Construction: 6" reinforced concrete slab.

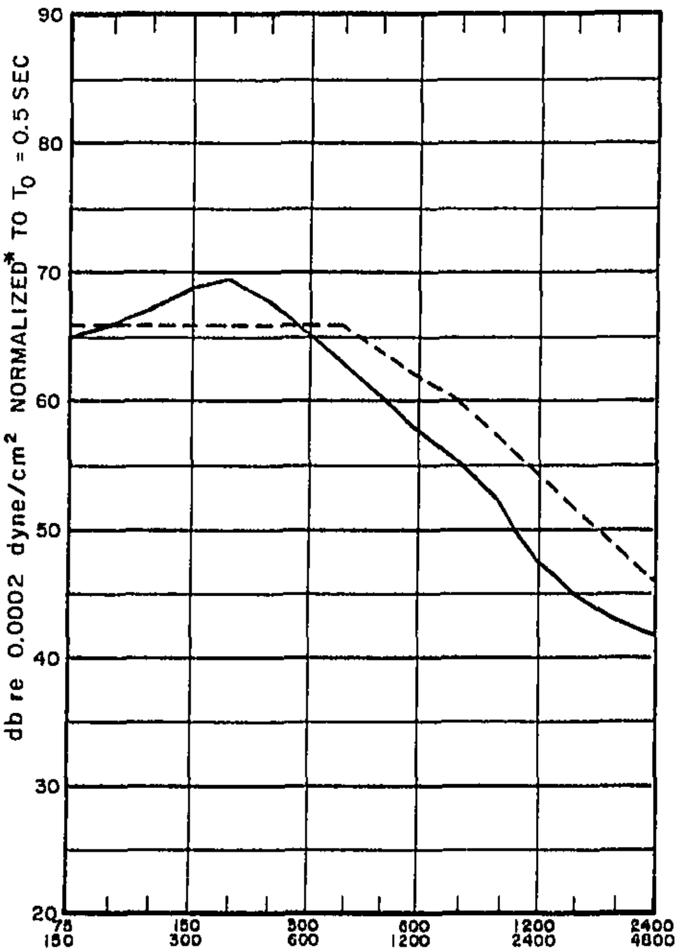
Floor Finish: 3/4" T & G floor boards on 1½" x 2" battens, resting on ½" pads of soft fiber-board, asbestos or cork.

Ceiling: Two-coat plaster.



39

INR= +3



+3

TEST REF: 22, 137-140 (4)

SAMPLE DESCRIPTION:

THICK HOLLOW CONCRETE BEAM - FLOATED WOOD RAFT

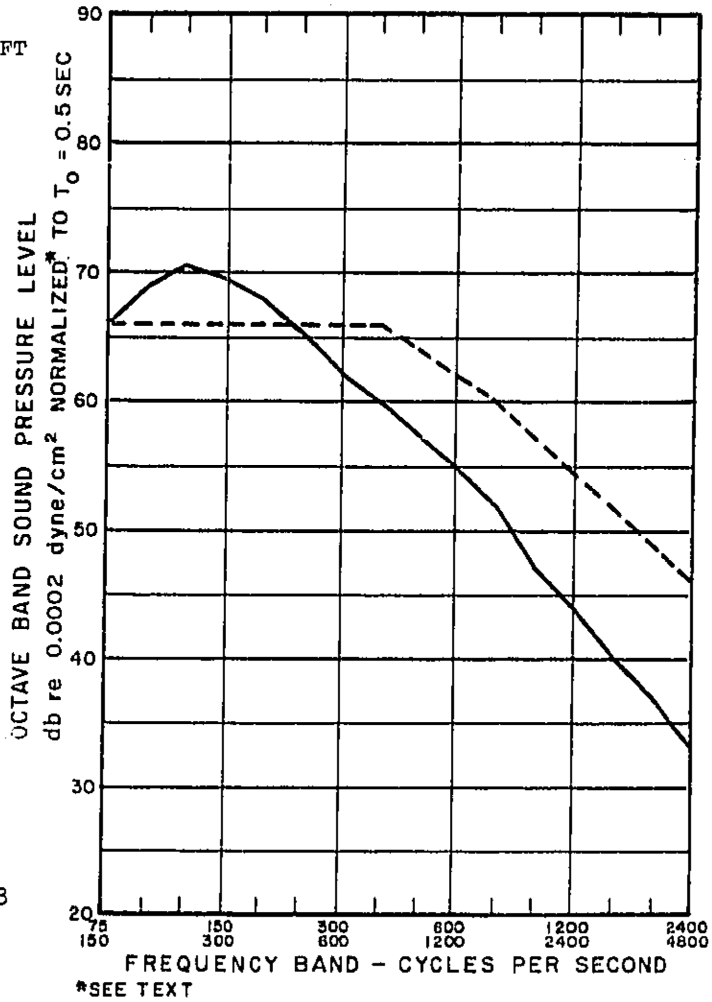
Total thickness 11", total weight 68 lb/ft^2

Basic Construction: 7-1/4" hollow concrete beams, with cement mortar.

Floor Finish: Wood floor boards (7/8") on battens on ½" soft wood fiber board.

Ceiling: None

INR= +3



+3

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GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: None

SAMPLE DESCRIPTION:

FLAT CONCRETE SLAB - CORK TILE - FURRED CEILING

Total thickness 6-3/4", total weight 65 lb/ft^2

Basic Construction: $6\frac{1}{2}$" reinforced concrete slab.

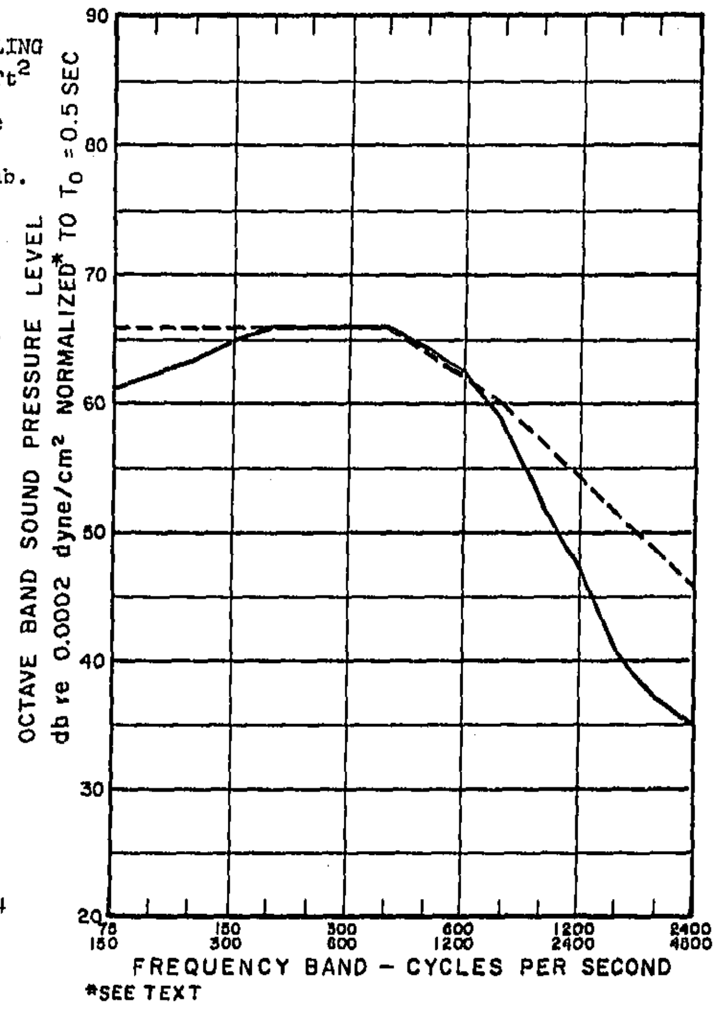
Floor Finish: $\frac{1}{4}$" cork tile, cemented to slab.

Ceiling: $\frac{1}{2}$" plasterboard on metal clips on furring strips.

Remarks: We have no measured data on this configuration, but have estimated (from similar constructions) that the performance is as shown in the curve.

-62-

INR= +4



+4

TEST REF: 32, 728-B; (1) Laboratory measurement.

SAMPLE DESCRIPTION:

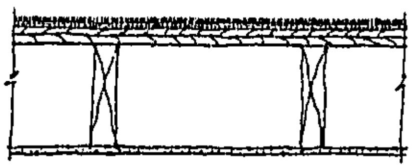
WOOD JOISTS - CARPET ON FOAM PAD

Total thickness 11", total weight unknown.

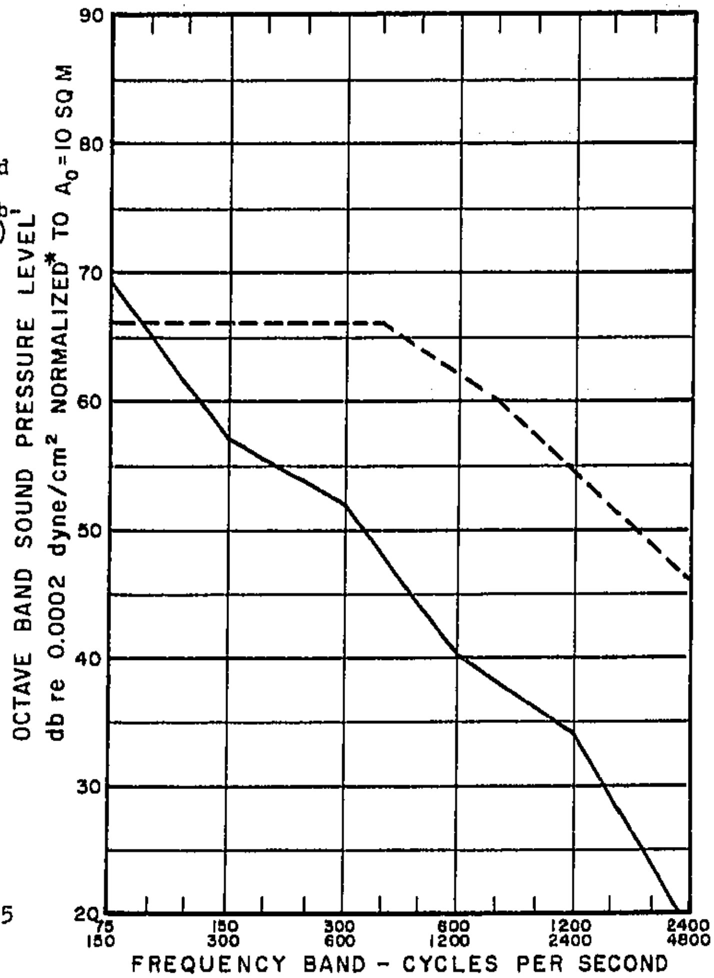
Basic Construction: 2" x 10" wood joists, 16" o.c.; 5/8" fir plywood sub-floor nailed 8" o.c. to joists; ½" fir plywood covering sub-floor (joints staggered) and nailed through to joists.

Floor Finish: 3/8" nylon carpet (¼" pile) on ¼" foam rubber pad.

Ceiling: ½" gypsum wallboard nailed 12"o.c. to joists; joints taped and sealed.



INR= +5



*SEE TEXT

+5

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, S-53 & S-55; (6)

SAMPLE DESCRIPTION:

FLAT CONCRETE SLAB - FLOATED WOOD RAFT

Total thickness 9½", total weight 83 lb/ft²

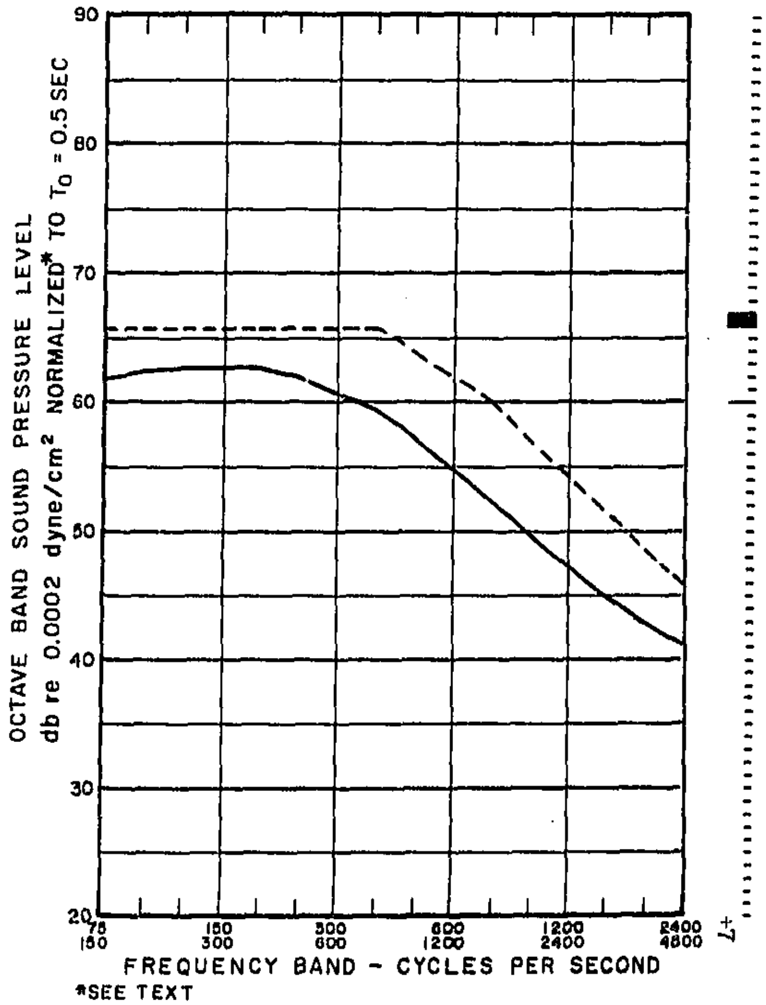
Basic Construction: 6" reinforced concrete slab.

Floor Finish: Floor of 3/4" T & G boards on 1½" x 2" battens, on 1" glass fiber blanket.

Ceiling: two-coat plaster.

43

INR= +7



*SEE TEXT

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 17, S-76, S-77; (8)

SAMPLE DESCRIPTION:

THICK CONCRETE RIBBED SLAB WITH FILLER BLOCKS - FLOATED WOOD RAFT FLOOR

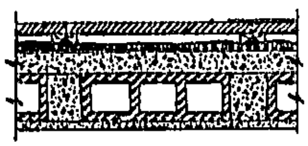
Total thickness 10", total weight 56 lb/ft^2

Basic Construction: 4" concrete ribs, hollow-tile filler blocks, 2" concrete screed.

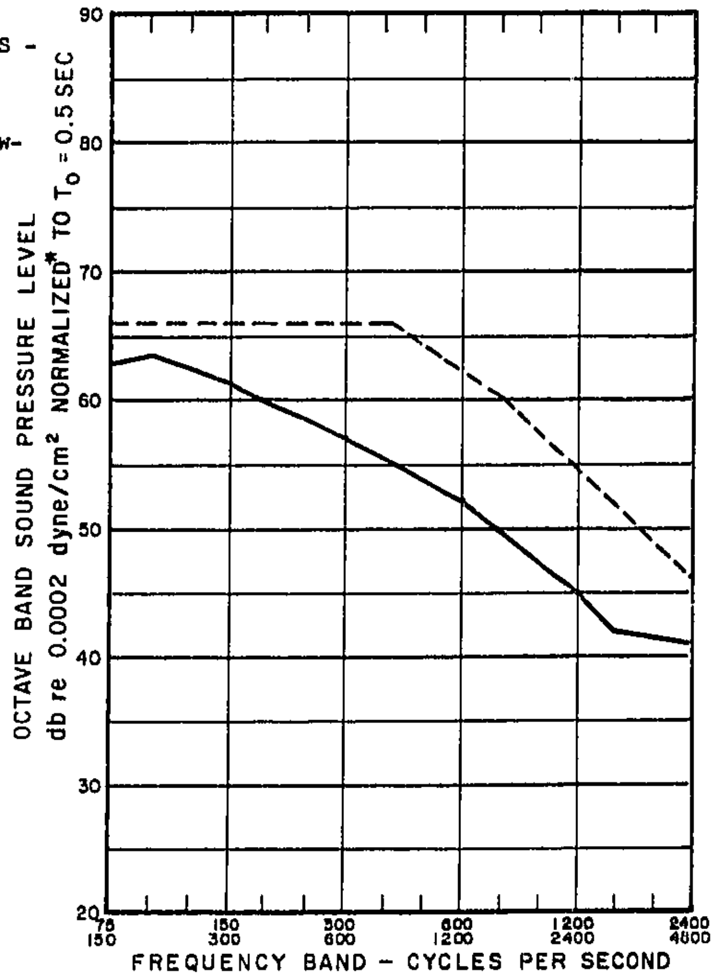
Floor Finish: Floating raft of 7/8" floor boards on battens on glass fiber blanket.

Ceiling: 5/8" plaster.

-65-



INR= +9



*SEE TEXT

+9

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 25 III, Fig. 36 f;

SAMPLE DESCRIPTION:

FLAT CONCRETE SLAB - COCOMAT OR CARPET

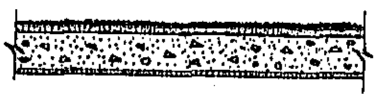
Total thickness 5-3/4", total weight 61 lb/ft^2

Basic Construction: 4½" reinforced concrete slab, with 3/4" plaster screed.

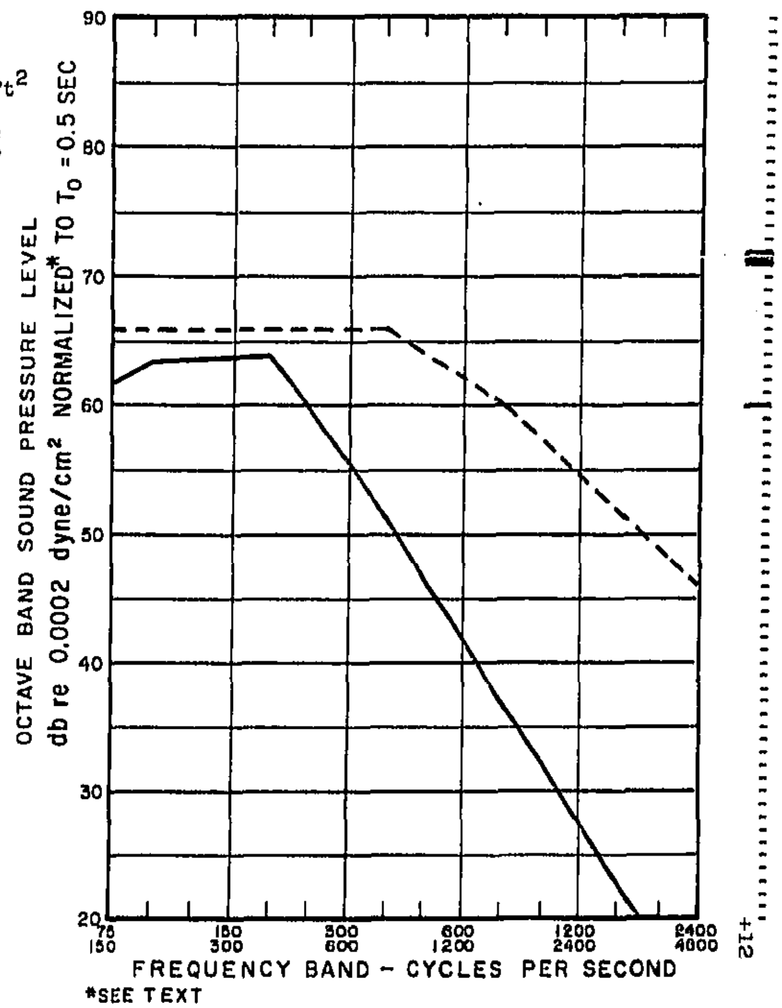
Floor Finish: Cocomat floor cover or 3/8" carpet (no pad), loosely laid.

Ceiling: 3/8" plaster.

-99-



INR= +12



GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 25 III, Fig 39 f;

SAMPLE DESCRIPTION:

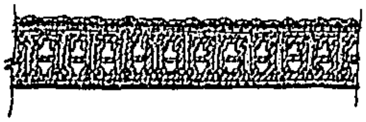
HOLLOW TILE BEAM - COCOMAT OR CARPET

Total thickness 6-3/4", total weight 50 lb/ft^2(?)

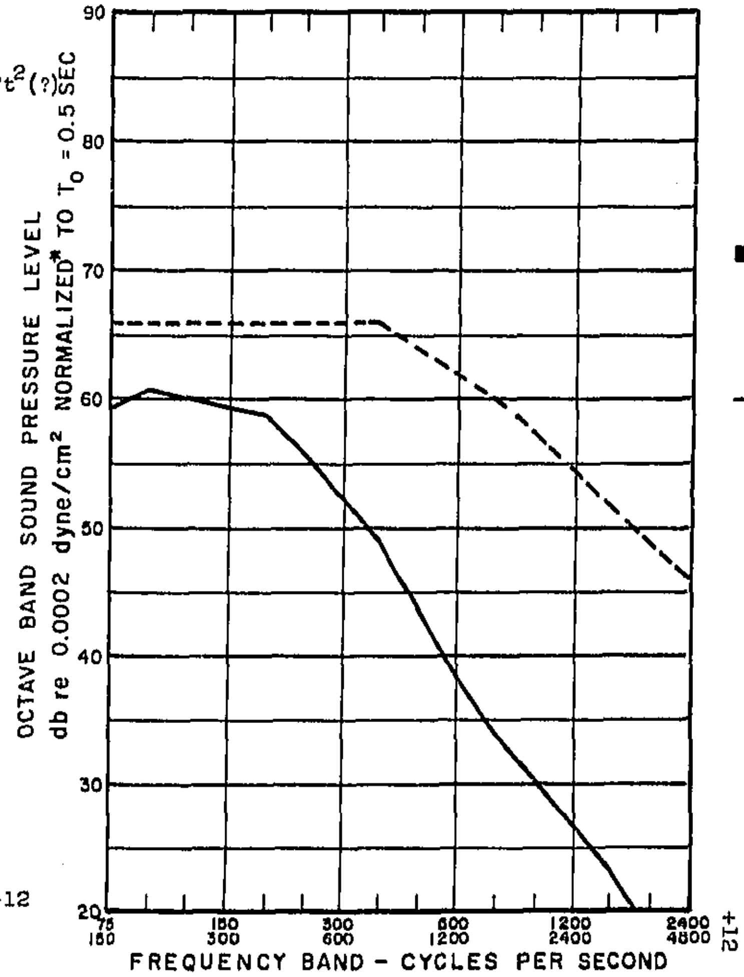
Basic Construction: Hollow tile beam, 5-1/8" thick with steel reinforcement; 3/4" plaster on upper surface.

Floor Finish: Cocomat or 3/8" carpet (no pad) loosely laid.

Ceiling: 3/8" plaster.



INR= +12



*SEE TEXT

GUIDE TO IMPACT NOISE CONTROL IN MULTI-FAMILY DWELLINGS

TEST REF: 32, #727B; (1) Laboratory measurement

SAMPLE DESCRIPTION:

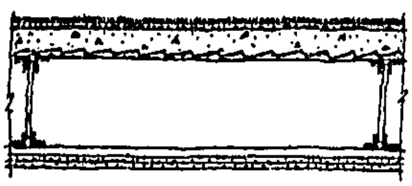
CONCRETE SLAB ON STEEL BAR JOISTS - CARPET ON FOAM PAD - SUSPENDED CEILING

Total thickness 11½", total weight 39½ lb/ft^2

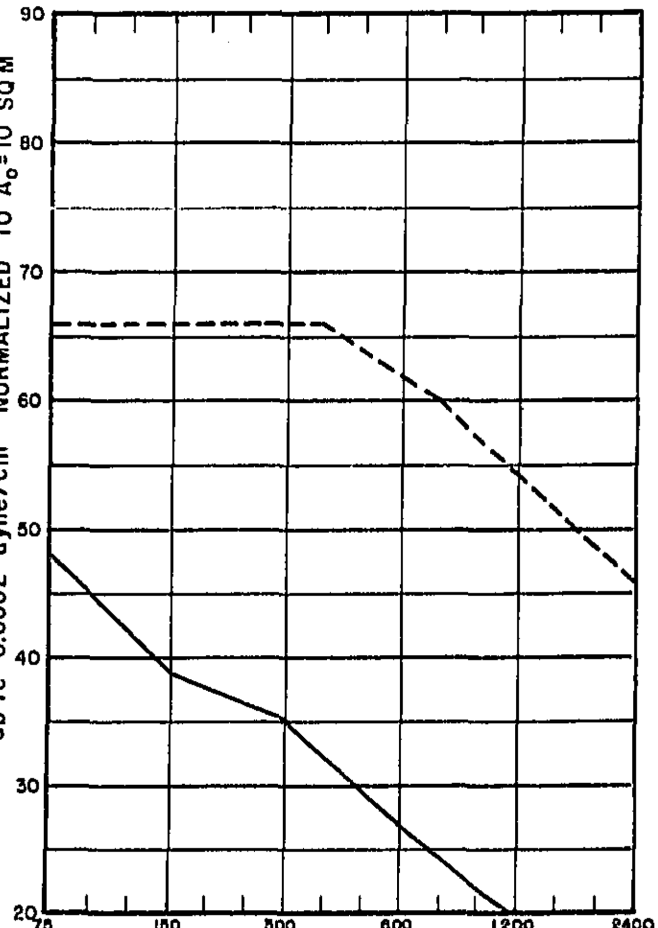
Basic Construction: 7" steel bar joists, 27" o.c.; on top of bar joists: 2" concrete floor slab on 3/8" rib lath.

Floor Finish: 3/8" nylon carpet (¼" pile) on ¼" foam rubber pad.

Ceiling: 3/4" furring channels, 16" o.c. wire tied to bottom of joists; 3/8" gypsum lath attached to furring channels by clips; 7/16" sanded plaster and 1/16" coat of lime putty finish.



INR= +26



*SEE TEXT

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SUMMARY OF DATA SHEETS

Construction	INR	Data Sheet Number
I Wood Joist Floor		
Bare - thin walls, thin ceiling	-18	4
Bare - thin walls, thick ceiling	-12	9
Bare - thick walls, thick ceiling	- 4	22
w/vinyl tile	-17	5
w/linoleum	-10	12
w/wood raft, floated on glass fiber	- 8	16
w/wood raft, floated on softboard, vinyl tile	-12	10
w/wood raft, floated on softboard, vinyl linoleum and resilient suspended ceiling	- 2	30
w/cocomat	- 3	27
w/carpet on foam rubber pad	+ 5	42
w/resilient suspended ceiling	- 5	19
II Reinforced Flat Concrete Slab		
Bare	-17	6
w/linoleum	- 4	23
w/cork tile and furred ceiling	+ 4	41
w/wood blocks or flooring	- 5	20
w/concrete screed, floated on glass fiber	+ 1	35
w/concrete screed, floated on soft-board	- 5	21
w/wood raft, floated on glass fiber	+ 7	43
w/wood raft, floated on softboard or cork	+ 3	39
w/carpet or cocomat (no pad)	+12	45
w/suspended ceiling	- 4	24

III Hollow Concrete Beams		
Bare	-22	1
w/pitch mastic screed	-20	3
w/pitch mastic on felt underlay	-21	2
w/linoleum	- 9	14
w/cork tile	- 4	25
w/cork tile and suspended ceiling	0	34
w/thin wood tiles and furred ceiling	- 3	28
w/wood flooring	- 6	18
w/wood raft	- 3	29
w/concrete screed, floated on glass fiber	- 4	26
w/concrete screed, floated on glass fiber, and suspended ceiling	+ 2	37
light, w/wood raft, floated on glass fiber	+ 1	36
heavy, w/wood raft, floated on glass fiber	+ 9	44
light, w/wood raft, floated on soft-board	- 2	31
heavy, w/wood raft, floated on soft-board	+ 3	40
w/carpet or cocomat (no pad)	+12	46
IV Ribbed Concrete Floor *		
Bare	-16	7
Bare, w/suspended ceiling	- 8	17
w/wood blocks in mastic, plaster ceiling	- 9	15
w/wood raft, floated on glass fiber with furred ceiling	+ 2	38
w/wood raft, floated on softboard	- 1	33

* Where data are lacking for ribbed concrete or bar-joist floors in combination with certain floor/ceiling finishes, an approximation can be taken from the data sheet for the same finish in combination with lightweight concrete. We do not, however, place much faith in such estimates and they should not be relied on for configurations having INR near zero. Where the INR is either very positive or very negative, the implied suitability (or not) can be trusted.

V	Bar Joist Floor *		
	Bare, w/suspended ceiling	-16	8
	w/vinyl tile and suspended ceiling	-10	13
	w/cork tile and suspended ceiling	- 2	32
	w/thin raft, floated on softboard, vinyl tile	-11	11
	w/carpet and foam rubber pad and suspended ceiling	+26	47

* See note on previous page.

C. A Check List of Precautions and Suggestions Regarding Details of Construction

It is not enough merely to choose a basically good floor/ceiling construction. Even the excellent isolation provided by a concrete "screed" floating on a glass fiber blanket over the structural floor can be nullified by careless detailing which permits conduits, ducts or plumbing to "short-circuit" the isolation at points of penetration, or by an indifferent contractor who allows his workmen to attach the floated "screed" solidly to the walls at the edges.

We have provided below, therefore, a series of warnings, precautions and suggestions in a Check List and also a collection of rough sketches of recommended architectural details. The problems discussed here must be conscientiously dealt with or the cost and effort of providing suitable basic structure will be wasted.

CHECK LIST

1. Planning: Do not locate "noisy" areas over "quiet" areas. For example: do not plan a public corridor over bedrooms or living rooms below. Do not plan living rooms or "family rooms" above bedrooms. For noise isolation as well as economy of plumbing, toilets, kitchens and laundry rooms should "stack" and should not be placed above or adjacent to quiet areas of neighboring living units.
2. Construction: The Data Sheets show that many of the floor configurations which provide adequate impact isolation involve a "floating" construction; that is, either a wooden raft or concrete "screed" supported on a resilient layer of some kind, which rests on the basic structural floor. The following points are relevant to these configurations:

a. The basic rule is that the total construction between spaces <u>must</u> be airtight. This applies to walls as well as floor/ceiling construction.

b. The next basic recommendation is that the "floating" construction must not in any way touch the surrounding construction through any rigid material.

c. Note that most resilient materials which are used are penetrable with water. Be extremely careful to seal all pipe, chase, or duct penetrations of the construction with a flexible, non-hardening material which will exclude water from the resilient material.

d. Floating concrete screeds poured over resilient materials require a waterproof membrane between the blanket and the concrete to prevent formation of "fins" or other short circuiting between joints in the resilient material. As workmen are usually not particularly careful when pouring concrete, a rigid, protective layer (e.g., 1/4" plywood) is recommended to prevent rupture of the membrane during placement of reinforcing and pouring of concrete.

e. Floating wood rafts are easily "shorted out" by nailing through the resilient material to the subfloor. Care in detailing and specification is mandatory to point out to the contractor the requirements for resilient construction.

f. Edge joints at the perimeter of a floated construction are potential trouble spots. Do not attach solid base boards to both the wall and the floor. Do not "short out" the resilient construction with toe moldings.

g. When designing floating concrete screeds, 150 sq ft is about the largest floor of 2" concrete you can pour without reinforcement to prevent edge curl. The solution for larger floors is reinforcement or thick (4") rafts of concrete.

h. Some settlement of resilient material (about 3% of initial thickness) may be expected over a long period of time. Allow for this contingency in your details.

i. Some of the "floating" ceiling constructions call for spring clip support of battens under joists. Note that nailing through the batten into the joists must be avoided in these cases.

The remaining suggestions deal with constructions other than floating floor:

j. Note that "impact noise" is not confined to floor sources. Machinery, toilets, bathtubs, showers, and piping can all produce vibration in the load-bearing structure which will be transmitted around a good floor/ceiling configuration and be radiated as noise in an adjacent space if you allow it. The basic recommendation is to isolate all such sources from the basic structure with resilient mounts or materials (see examples in the sketches which follow).

k. Remember that most of the satisfactory floor/ceiling configurations shown here also provide good isolation of airborne noise. Thus you must be careful to "match" the isolation through <u>all</u> other paths between dwelling units: the occupant won't know that you have provided an acceptable floor if he hears his overhead neighbor through the exhaust ductwork or through an open shaft between apartments.

l. A frequent source of complaint which is connected only indirectly with floor/ceiling constructions is staircase noise and door-slamming in reverberant hallways. Anti-slam devices on the doors and soft material (carpet or rubber mat) on the floors and on the treads of the stairs are recommended to reduce the noise at the source; but it is equally important to provide as much acoustical absorption as possible in these areas. This will also help reduce the annoyance from children shouting and playing in the corridors. Acoustical tile, 3/4" in thickness, on the ceiling and upper walls is suitable for this application.

m. Wall installations of door chimes, bells or buzzers must be suitably isolated --- that is, no direct, metal-to-metal contact with the building structure should be permitted: use <u>soft</u> rubber grommets at <u>all</u> attach points. This is even more the case with wall installation of telephones or ringing apparatus of telephones (the new "Princess" model is particularly annoying in this respect). Either avoid wall installations altogether or provide soft-rubber isolation, as described above.

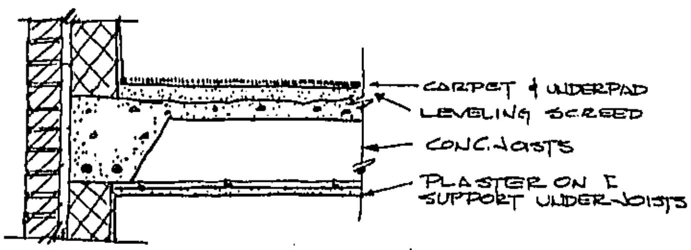
n. Door knockers should be avoided unless you are prepared to isolate the entire door.

o. Incinerator chutes are noisy nuisances and should be supported on soft-rubber, asbestos or other isolation mounts; also the outer surface should be coated with a mastic vibration damping compound similar to automobile undercoating.

3. Supervision: The results achieved in the completed building depend not only on careful planning, suitable choice of construction, and proper detailing as noted above, but also on complete and conscientious attention to the integrity of the sound-isolating construction in the field by all trades. Particular troubles are apt to arise during the period between the completion of the architectural drawings and the completion of the building due to changes in cognizant personnel; special efforts must be made to acquaint the "new men" with the reasons for unusual acoustical detailing. Continuity of acoustical understanding is essential, and for this reason it is imperative also that the contractor be made aware of the reasons for, and the importance of, the chosen construction. Due care and diligence in supervision is also required; it is important that the supervisor understand the acoustical reason for any unusual construction and the acoustical consequences of any change he may authorize.

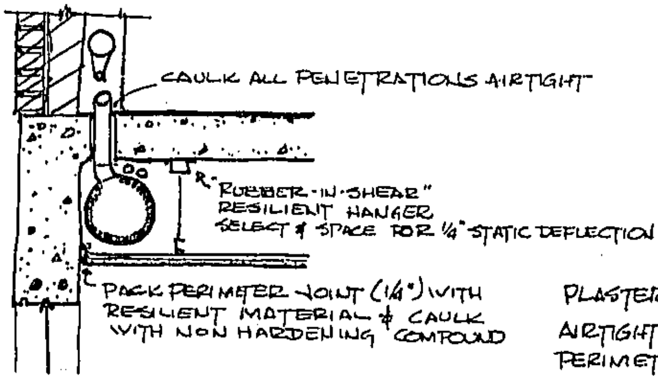
D. <u>A Collection of Rough Sketches of Acoustically Important Architectural Details</u>

The following pages give sketches which illustrate some of the points made in the Check List above. These are not the only possible solutions to the impact isolation problem, but are offered as examples of the working out of principles laid down in this Guide.



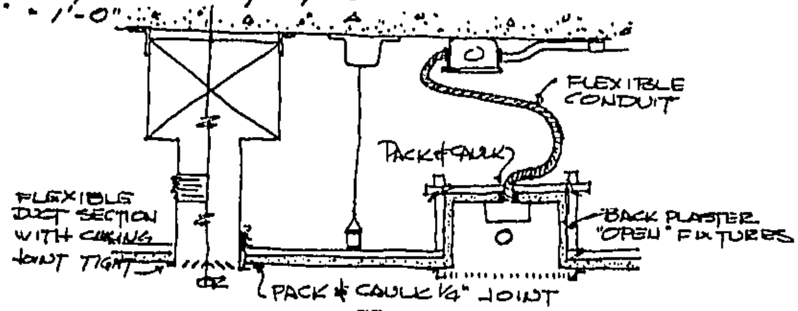
NOTE: PLASTER MUST BE AIRTIGHT
CARPET MUST EXTEND WALL to WALL
INCLUDING CORRIDORS

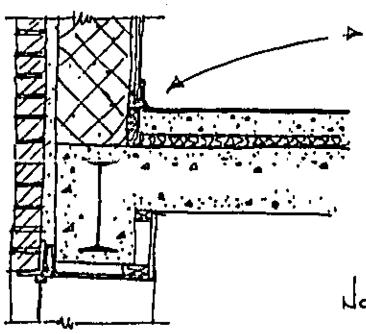
CARPET ON CONC FLOOR
WITH PLASTER CEILING
3/4" = 1'-0"



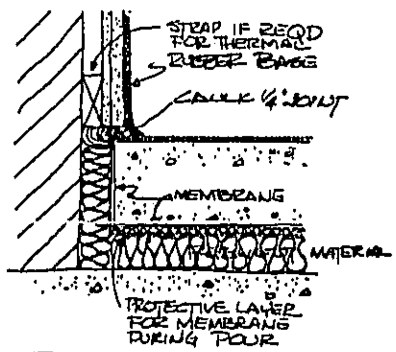
PLASTER MUST BE
AIRTIGHT & FREE OF
PERIMETER, PIPES, ETC
FLEX CONDUIT REQD
FOR ELECTRICAL CONN.

RESILIENTLY SUSPENDED
PLASTER CEILING UNDER
CONCRETE FLOOR STRUCTURE
3/4" = 1'-0"



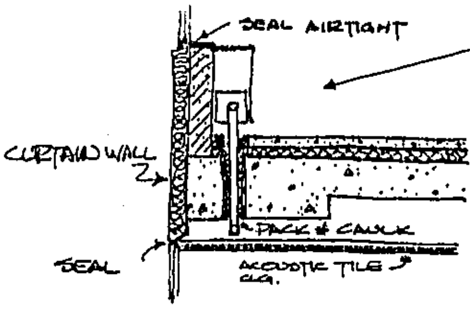


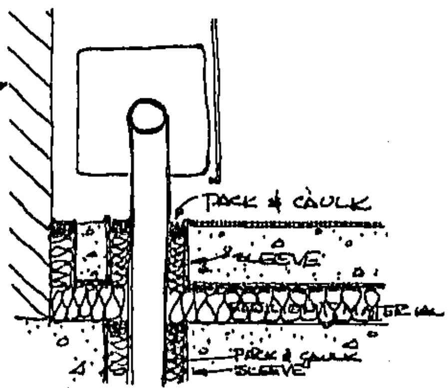
EXTERIOR WALL-
FLOATING CONC.
FLOOR INTERSECTION
3/4" = 1'-0"



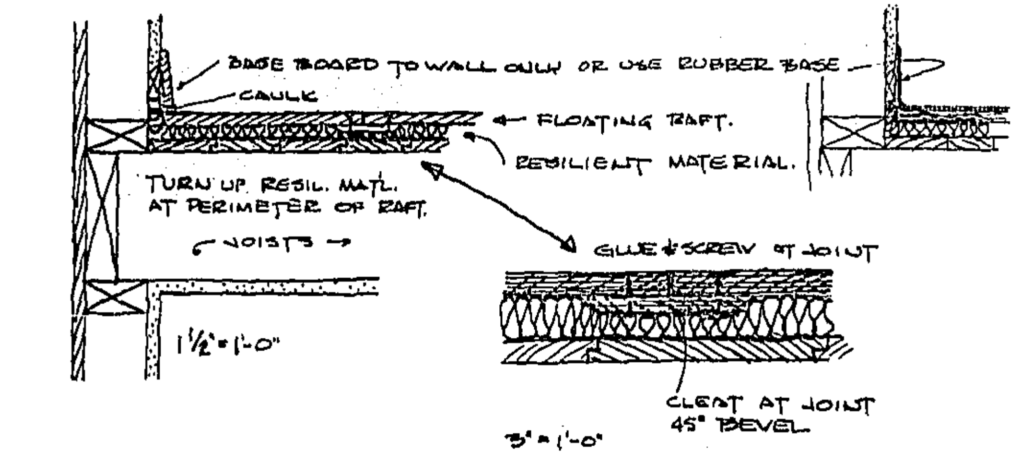
NOTE: RESILIENT MATERIAL
TURNS UP AT ALL EDGES

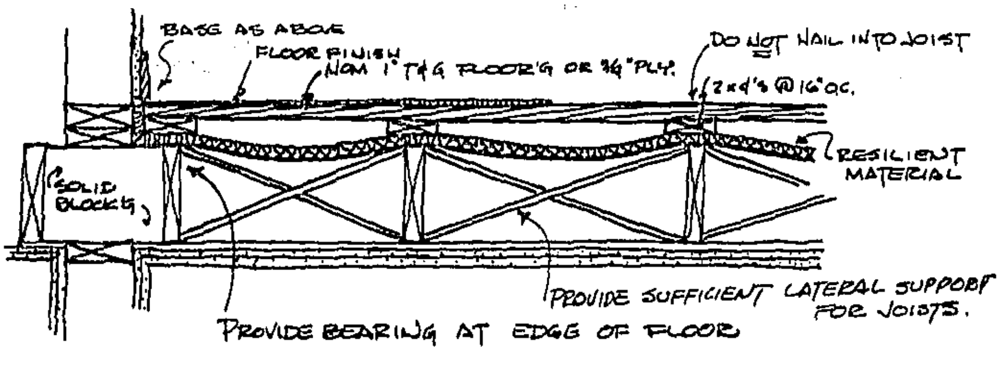
EXTERIOR OR INTERIOR
WALL - FLOOR INTERSECTION
3" = 1'-0"



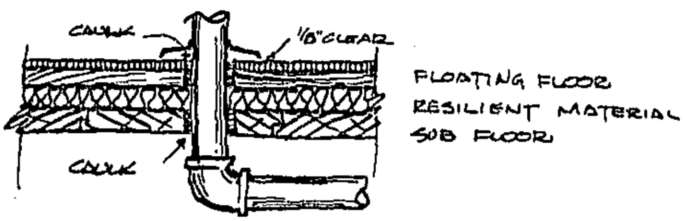


SERVICE PENETRATION
AT OR NEAR EDGE OF
FLOATING FLOOR

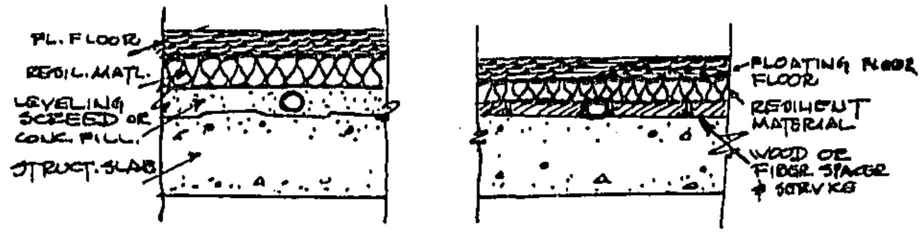




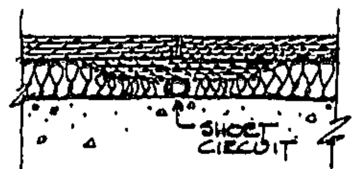
FLOATING "RAFT" FLOOR 1½"=1'-0"



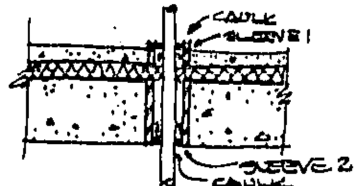
SERVICE PENETRATION OF FLOORS ABOVE



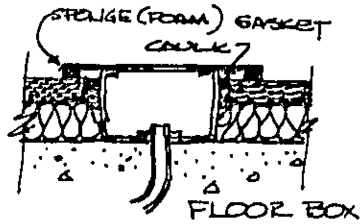
ACCEPTABLE SERVICE ARRANGEMENT UNDER FLOATING FLOORS.



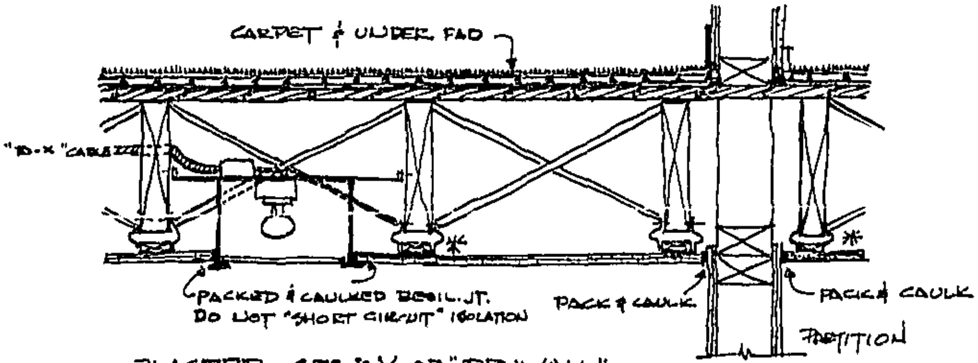
LOCATING PIPE OR CONDUIT IN THE RESILIENT LAYER UNDER THE FLOORING IS <u>NOT</u> ACCEPTABLE



2 SLEEVES ARE REQUIRED TO PASS PIPE ETC THROUGH FLOATING FLOOR



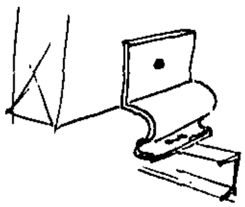
PENETRATIONS OF FLOATING FLOORS MUST NOT "SHORT OUT" THE RESILIENT LAYER.

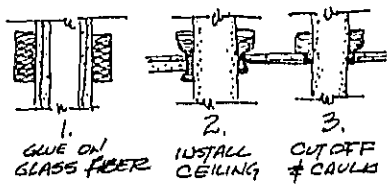


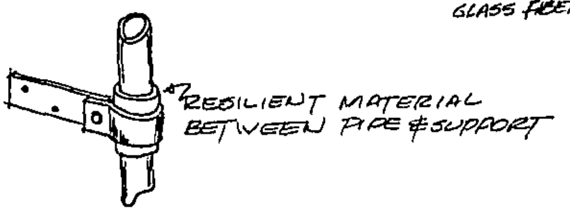
PLASTER CEILING OR "DRYWALL"
SUSPENDED ON SPRING HANGERS 1½"=1'-0"

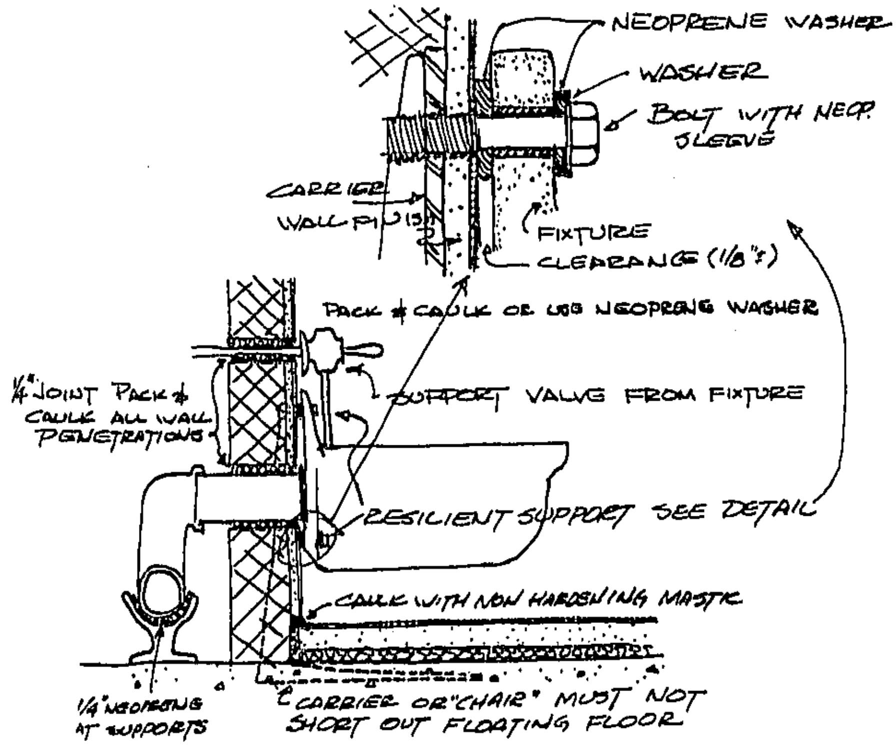
*NOTE: DO NOT NAIL THROUGH BATTENS INTO JOISTS

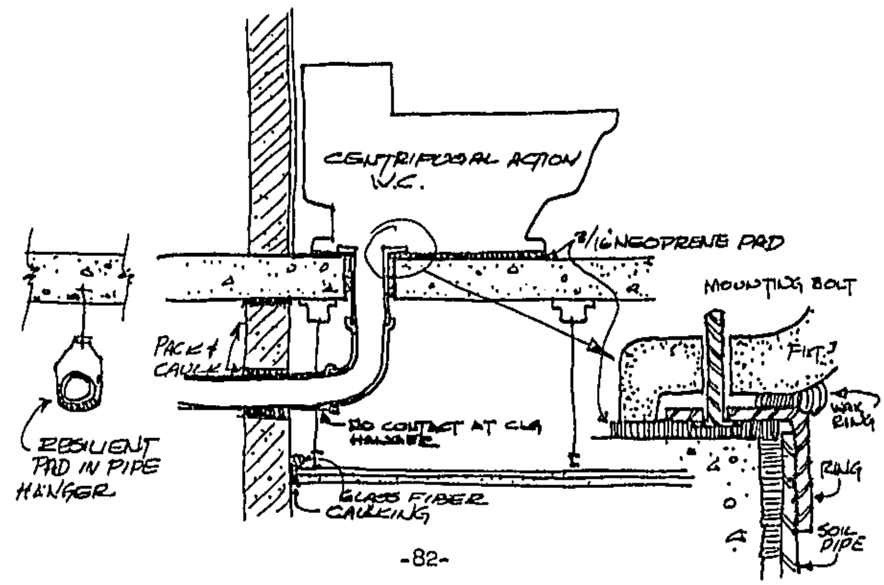
OTHER "SPRING" OR RESILIENT HANGERS
ARE AVAILABLE EG:

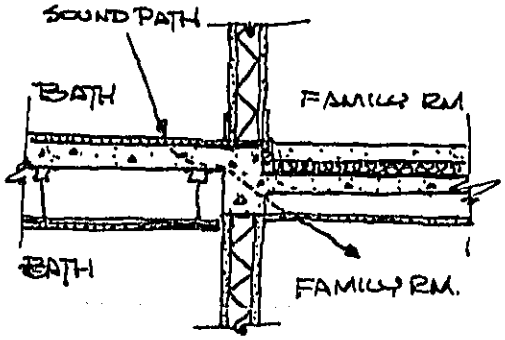







NEOPRENE WASHER
WASHER
BOLT WITH NEOP. SLEEVE
CARRIER
WALL
FIXTURE
CLEARANCE (1/8")
PACK & CAULK OR USE NEOPRENE WASHER
1/4" JOINT PACK & CAULK ALL WALL PENETRATIONS
SUPPORT VALVE FROM FIXTURE
RESILIENT SUPPORT SEE DETAIL
CAULK WITH NON HARDENING MASTIC
1/4" NEOPRENE AT SUPPORTS
CARRIER OR "CHAIR" MUST NOT SHORT OUT FLOATING FLOOR

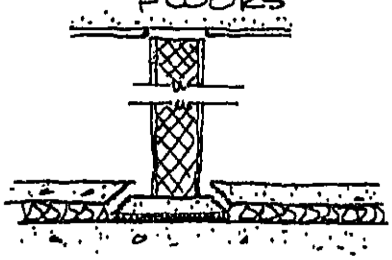

CENTRIFUGAL ACTION W.C.
3/16 NEOPRENE PAD
MOUNTING BOLT
PACK & CAULK
RESILIENT PAD IN PIPE HANGER
NO CONTACT AT CLG HANGER
GLASS FIBER CAULKING
WAX RING
RING
SOIL PIPE

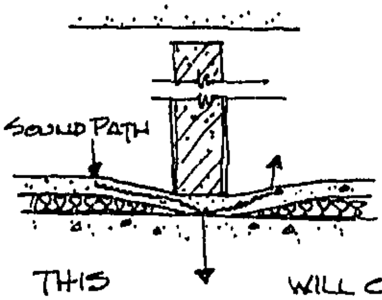


DON'T MIX CONSTRUCTION TYPES UNLESS PROVISIONS HAVE BEEN MADE TO PREVENT "FLANKING"

THESE PROVISIONS INCLUDE EXPANSION JOINTS OR BREAKS IN ALL STRUCTURAL PATHS BETWEEN EACH SPACE.

DONT SUPPORT PARTITIONS ON "FLOATING" FLOORS





THIS OR THIS WILL OCCUR

FOLLOW THE DETAILS GIVEN BEFORE AT EXAMPLES OF FLOATING FLOOR TYPES

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