UNITED STATES DEPARTMENT OF COMMERCE
ELIMINATION OF WASTE SERIES

MINIMUM LIVE LOADS ALLOWABLE FOR USE IN DESIGN OF BUILDINGS

REPORT
OF
BUILDING CODE COMMITTEE

BUREAU OF STANDARDS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

UNITED STATES DEPARTMENT OF COMMERCE
HERBERT HOOVER, SECRETARY

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REPORT OF BUILDING CODE COMMITTEE
NOVEMBER 1, 1925

Ira H. Woolson, Chairman

Edwin H. Brown
William K. Hatt
Albert Kahn
Rudolph P. Miller
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CONTENTS

PART I.—INTRODUCTION

PART II.—MINIMUM LIVE LOADS ALLOWABLE FOR USE IN DESIGN OF BUILDINGS

PART III.—APPENDIX

TABLES

ILLUSTRATION

LETTER OF SUBMITTAL

WASHINGTON, D. C.,
November 1, 1924.

Hon. HERBERT HOOVER,
Secretary of Commerce,
Washington, D. C.

DEAR SIR: In further prosecution of the program of the Building Code Committee appointed by you to simplify building code requirements, I have the honor to present its report on Minimum Live Loads Allowable for Use in Design of Buildings. This is the fourth in the series.

Existing floor-load requirements as found in building codes are in an unsettled condition. A variation of 100 per cent in allowable floor loads for the same occupancy in different cities is common, and disparities of 200 and 300 per cent are found. Such variations are without justification. Unnecessarily high requirements in respect to floor loads are a financial burden upon the builder and lead to a waste of materials.

The recommendations of Part II, while occupying but a few pages are the essence of the report. The committee believes the live loads recommended as a basis for design are conservative and safe, although frequently they are considerably lower than those in current use in many municipalities. Their general adoption will materially lessen the cost of buildings.

The appendix contains a digest of the original studies made for the committee and of all similar available information. The committee believes it to be the best and most complete accumulation of live-load data thus far published.

The report is submitted for your approval with the recommendation that it follow the usual procedure as to publication.

Yours very truly,

IRA H. WOOLSON,
Chairman, Building Code Committee,
Department of Commerce.

LETTER OF ACCEPTANCE

DEPARTMENT OF COMMERCE,
OFFICE OF THE SECRETARY,
Washington, D. C., December 19, 1924.

MR. IRA H. WOOLSON,
Chairman, Building Code Committee,
Department of Commerce, Washington, D. C.

MY DEAR MR. WOOLSON: I am most happy to receive the report of the Building Code Committee on minimum live loads allowable for use in the design of buildings. I have directed that it be published in the elimination of waste series of the Department of Commerce. These recommendations of the committee make possible, I believe, savings of millions of dollars a year for the American people, and thus contribute toward a higher standard of living.

The report is, however, significant in other ways. It demonstrates once more the willingness of American professional men to devote their time and energies to public service, and the readiness with which a well-accredited group can obtain the cooperation of hundreds of others in such an undertaking.

Another most important contribution that is being made by your committee, in addition to placing the design of buildings on a more scientific basis, is to emphasize the real saving that a thorough and efficient municipal inspection of building construction makes possible. With an inspection service of a high order, and well framed codes, the great majority of competent engineers, architects, and constructors are enabled to make the best use of their skill in design and quality of workmanship. With good inspection there is no occasion to penalize these able and honest persons by requirements for excessive use of materials that are sometimes specified as a partial measure of protection for the public from the ignorance and neglect of incompetent and irresponsible persons.

I have no hesitation in thanking you, in behalf of the American public, for your laborious efforts in the preparation of this report.

Yours faithfully,

HERBERT HOOVER

RECOMMENDED MINIMUM LIVE LOADS ALLOWABLE FOR USE IN DESIGN OF BUILDINGS

This report is divided into three general headings, as follows:

Part I.—Introduction: Describes briefly the organization of the committee and its method in preparing and presenting the recommendations.

Part II.—Minimum Live Loads Allowable for Use in Design of Buildings: These are briefly stated in the form of recommendations suitable for municipal adoption.

Part III.—Appendix: A compilation of live-load data and of material not suited for incorporation in a building law, but which is explanatory of the requirements recommended in Part II and descriptive of good practice.

PART I.—INTRODUCTION

The Department of Commerce Building Code Committee was organized early in 1921, in recognition of a general public demand for greater uniformity and economy in building code requirements. Its first work was concerned with regulations affecting construction of small dwellings, and the final report on this subject was published in January, 1923.[1]

Early in the committee's work the question was raised of code variations regarding live loads, and efforts were made to collect data on actual loads which might be used in drafting recommendations. Investigation disclosed that very little had been published on this important subject, and showed wide variation in the minimum floor, roof, and wind loads for which buildings are required to be designed by building codes. The extent of this variation, if the significance of the values be admitted, indicates either that safety is disregarded in many cases or that an unnecessary amount of building materials or labor is used because of these laws. (See Appendix, par. 4.)

It was found that live loads assumed in designing many types of buildings were largely matters of tradition and had scant scientific

[1] Recommended Minimum Requirements for Small Dwelling Construction, 15 cents. Other reports issued are: Recommended Minumum Requirements for Masonry Wall Construction; and a report on Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings, prepared by an associated committee of sanitary engineers, 35 cents. These publications are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C.

basis. The result was that accuracy in stress computations was defeated because of ignorance of the loads causing stresses. The building professions for years have busied themselves with tests of materials, but have given little attention to this complementary factor of loads.

This report presents load requirements recommended for general adoption with the object of preserving safety, stimulating uniformity of requirements, and effecting conservation of materials and labor.

Investigations

As a preliminary step the committee compiled the live-load requirements of 109 existing codes. These were referred to the building officials in the respective cities and checked to ascertain if they represented current practice. The compilation was then submitted to a number of experienced architects and their discussions of the subject were made the basis of still further inquiries. (See Appendix, par. 4.)

Through the courtesy of several technical and industrial organizations, particularly through the efforts of members of the American Institute of Architects, the National Association of Building Owners and Managers, and the American Warehousemen's Association, information has been obtained on live loads characterizing a number of typical occupancies. An extensive investigation of office floor loads was made for the committee by C. T. Coley, manager of the Equitable Office Building in New York, N. Y., and the results published in a number of journals. This stimulated others to similar efforts. C. H. Blackall, of Boston, had already reported floor loads found in a large office building in that city, thereby affording a comparison with similar investigations made by him at an earlier date.

Studies by M. W. McIntyre of office floor loads; by the Hotels Statler Co.; by the Turner Construction Co., in warehouses; and analyses by R. Fleming, of the American Bridge Co.; by C. Heller, of San Francisco; by Norman Stineman, of the Portland Cement Association; and by J. D. M. Phillips, secretary, National Association of Steel Furniture Manufacturers, have been exceedingly helpful in the preparation of this report. B. C. Kadel, of the United States Weather Bureau, assisted in preparation of the material on wind velocities and pressures.

With this information in hand, and with due reference to the structural elements involved, the committee prepared a tentative draft of recommended live load assumptions. This was submitted to over 500 carefully selected architects, engineers, building officials, and others qualified to discuss the subject with authority. About 125 letters were received from these men discussing the committee's proposals from many angles and affording a valuable basis for revision of the report into fuller agreement with the best information and practice.

Present Methods Uneconomical.

Floor live-load requirements in codes are expressed as a minimum for which buildings for each class of occupancy must be designed and built, and are intended to protect occupants and owners from loss of life or property through partial or total structural failure. In most codes these occupancy classes are few, and commercial and industrial classes in particular include under the same minimum requirement many diverse occupancies with varying characteristic loads. Inspection practice in the great majority of cities does not insure control of occupancy changes, nor does it involve periodical attention to make sure that design loads are not exceeded. It has resulted from these conditions that the minimum allowable load for all occupancies in a class approaches that which is considered safe for the heaviest occupancies in that class. A considerable increment also is attributable to the desire to provide for unreported occupancy changes and unsupervised loading conditions. Code requirements in many cases are, in fact, framed to secure buildings strong enough to endure whatever changes of use may occur, whether or not reported to the building official.

The builder who erects a structure under such drastic code requirements is directly penalized for the city's failure to provide inspection of the two types mentioned above.

It is desirable as a safety measure to regulate the live loads for which a building is designed and it is just as necessary to make sure thereafter that these loads are not exceeded. If adequate supervision of subsequent loadings is obtained, the provision of an initial surplus is unnecessary. Certain classes of buildings are distinguished by loads so light or so uniform in nature as to require no further attention after construction. Office and residence buildings fall in this class. Others, as shown by observations reported to the committee, are so often subject to overloads that a blanket requirement affecting design only, no matter how drastic in nature, is insufficient for safety unless the use of each building is watched. If floor loads and occupancy changes are controlled throughout the life of the building, it is possible to adopt the policy requiring each building merely to be strong enough for its intended use. This requires more complete information than is now current as to the floor loads which various occupancies involve, and an attempt is made in this report to present a nucleus of such data. Zoning ordinances, now generally being adopted by cities, require the reporting of occupancy

30868°—25†——2

changes to the authorities and should make the control measures described above much easier than in the past.

In drafting its recommended floor-load requirements, the Building Code Committee has given weight to all these considerations. For occupancies having a low maximum live load, or in which live loads are practically uniform, a minimum limit has been prescribed for which buildings of these specific occupancies should be designed.

Other buildings, subject to heavy floor loads or those not necessarily uniform in amount are required to be designed for loads approaching the maxima which characterize the proposed occupancy, and it is recommended that such buildings be periodically inspected after construction.

PART II.—MINIMUM LIVE LOADS ALLOWABLE FOR USE IN DESIGN OF BUILDINGS

Section 1. Definitions.

1. *Dead load.*—The dead load in a building includes the weight of walls, permanent partitions, framing, floors, roofs, and all other permanent stationary construction entering into a building. (See Appendix, par. 16, for weights of construction materials.)

2. *Live load.*—The live load includes all loads except dead loads.

Sec. 2. General.

Buildings and all parts thereof shall be of sufficient strength to support safely their imposed loads, live and dead, in addition to their own proper dead load; provided, however, that no building or part of a building shall be designed for live loads less than those specified in the following sections. (See Appendix, par. 13, for impact considerations.)

Sec. 3. Human Occupancy.

1. For rooms of private dwellings, hospital rooms and wards, guest rooms in hotels, lodging and tenement houses, and for similar occupancies, the minimum live load shall be taken as 40 pounds per square foot uniformly distributed, except that where floors of one and two family dwellings are of monolithic type or of solid or ribbed slabs the live load may be taken as 30 pounds per square foot. (See Appendix, par. 5, *1* and *2*.)

2. For floors for office purposes and for rooms with fixed seats, as in churches, school classrooms, reading rooms, museums, art galleries, and theaters, the minimum live load shall be taken as 50 pounds per square foot uniformly distributed. Provision shall be made, however, in designing office floors for a load of 2,000 pounds placed upon any space 2½ feet square wherever this load upon an otherwise unloaded floor would produce stresses greater than the 50-pound distributed load. (See Appendix, par. 5, *3*, *4*, and *5*.)

3. For aisles, corridors, lobbies, public spaces in hotels and public buildings, banquet rooms, assembly halls without fixed seats, grandstands, theater stages, gymnasiums, stairways, fire escapes or exit passageways, and other spaces where crowds of people are likely to assemble, the minimum live load shall be taken as 100 pounds per square foot uniformly distributed. This requirement shall not apply, however, to such spaces in private dwellings, for which the minimum live load shall be taken as in paragraph 1 of this section. (See Appendix, par. 5, *7*.)

Sec. 4. Industrial or Commercial Occupancy.

In designing floors used for industrial or commercial purposes, or purposes other than previously mentioned, the live load shall be assumed as the maximum caused by the use which the building or part of the building is to serve. The following loads shall be taken as the minimum live loads permissible for the occupancies listed, and loads at least equal shall be assumed for uses similar in nature to those listed in this section.

Floors used for:	Minimum live load (lb./ft.²)
Storage purposes (general)	250
Storage purposes (special)	[2] 100
Manufacturing (light)	75
Printing plants	[3] 100
Wholesale stores (light merchandise)	100
Retail salesrooms (light merchandise)	75
Stables	75
Garages—	
All types of vehicles	100
Passenger cars only	80
Sidewalks—250 or 800 pounds concentrated, which ever gives the largest moment of shear.	

(See Appendix, par. 6, for live-load data, especially divisions *3*, *4*, and *5* for discussion of considerations involved in design for light loads in commercial buildings.)

Sec. 5. Roof Loads.

Roofs having a rise of 4 inches or less per foot of horizontal projection shall be proportioned for a vertical live load of 30 pounds per square foot of horizontal projection applied to any or all slopes. With a rise of more than 4 inches and not more than 12 inches per foot a vertical live load of 20 pounds on the horizontal projection shall be assumed. If the rise exceeds 12 inches per foot no vertical live load need be assumed, but provision shall be made for a wind force acting normal to the roof surface (on one slope at a time) of 20 pounds per square foot of such surface. (See Appendix, par. 7.)

Sec. 6. Allowance for Movable Partition Loads.

Floors in office and public buildings and in other buildings subject to shifting of partitions without reference to arrangement of floor beams or girders shall be designed to support, in addition to other loads, a single partition of the type used in the building, placed in any possible position. (See Appendix, par. 8.)

[2] See Appendix, par. 5, *6*.

[3] See Table 4, item 9.

Sec. 7. Reductions in Live Loads.

Except in buildings for storage purposes the following reductions in assumed total floor live loads are permissible in designing all columns, piers or walls, foundations, trusses, and girders. (See Appendix, par. 9.)

Reduction of total live loads carried

	Per cent
Carrying one floor	0
Carrying two floors	10
Carrying three floors	20
Carrying four floors	30
Carrying five floors	40
Carrying six floors	45
Carrying seven or more floors	50

For determining the area of footings the full dead loads plus the live loads, with reductions figured as permitted above, shall be taken; except that in buildings for human occupancy, listed in section 3, a further reduction of one-half the live load as permitted above may be used.

Sec. 8. Wind Pressures.

For purposes of design the wind pressure upon all vertical plane surfaces of all buildings and structures shall be taken at not less than 10 pounds per square foot for those portions less than 40 feet above ground, and at not less than 20 pounds per square foot for those portions more than 40 feet above ground.

The wind pressure upon sprinkler tanks, sky signs, or upon similar exposed structures and their supports shall be taken at not less than 30 pounds per square foot of plane surface, acting in any direction. In calculating the wind pressure on circular tanks or stacks this pressure shall be assumed to act on six-tenths of the projected area.

Where it shall appear that a building or structure will be exposed to the full force of the wind throughout its entire height and width the pressure upon all vertical surfaces thus exposed shall be taken at not less than 20 pounds per square foot. (See Part II, section 5, roof loads. See also Appendix, par. 10.)

Sec. 9. Live Loads to be Posted.

The live loads for which each floor, or differing parts thereof, of a commercial or industrial building is designed shall be certified by the building official and shall be conspicuously posted in that part of each story where they apply, using durable metal signs. The occupant of the building shall be responsible for keeping the actual loads below the certified limits. Adequate measures shall also be taken by the building official to insure that these loadings are not exceeded. (See Appendix, par. 11.)

Sec. 10. Occupancy Permits.

Plans for other than residential buildings filed with the building official with applications for permits shall show on each drawing the live loads per square foot of area covered, for which the building is designed, and occupancy permits for buildings hereafter erected shall not be issued until the floor-load signs required by section 9 have been installed. No change in the occupancy of a building now existing or hereafter erected shall be made until a revised occupancy permit has been issued by the building official certifying that the floors are suitable for the loads characteristic of the proposed occupancy. (See Appendix, par. 12.)

PART III.—APPENDIX

Par. 1. Purpose.

The Appendix consists of explanatory matter referring to Part II and is a vital part of this report. The committee believes that every building code should be accompanied by an appendix, which should contain sufficient explanation of the code requirements to make them easily understandable, and such other information on good practice as can not be obtained elsewhere in concise form.

Par. 2. Influence of Building Inspection.

It is recognized that the requirements recommended in Part II constitute in most particulars relaxations from those in force in certain cities and parts of the country. In the committee's opinion these modifications of existing practice are justified by the facts developed through its investigations. In addition to the live-load data presented in this report, and which establishes clearly that existing requirements are too high for some occupancies, the experience is reported of several large cities which supervise live load assumptions for building design by the method recommended in Part II. This method involves three essential steps: (1) The requirement by the code of a low minimum live load for each class of occupancy, (2) the requirement by the building official of higher design loads where the prospective occupancy obviously involves such loads, and (3) the periodical inspection of buildings housing certain classes of occupancy to prevent undue overloads.

The success of this procedure in many places answers satisfactorily the objections to its adoption in localities where code requirements are now more conservative. It should be understood that the code requirements in Part II are recommended only where responsible supervision of loadings and good materials and workmanship are assured. Without such supervision mere requirements for loading will not insure safe construction.

Par. 3. Status of Recommendations.

1. It has been called to the committee's attention that some misunderstanding exists with regard to the legal status of its recommendations. It should be recognized that the committee's functions are purely advisory. The recommendations can not be considered in any sense as obligatory, but are issued to make available to those locally responsible for exercise of the police power the consensus of public opinion on this phase of building regulation.

2. The recommended code requirements are in all cases the minimum consistent with safety. The scope of the police power, upon which all such ordinances depend for authority, does not justify requirements which are merely good building practice.

Par. 4. Present Code Requirements.

Early in the committee's work on live loads an extensive investigation was made of existing floor-load requirements. The provisions of 109 building codes were carefully examined and their application in local practice checked by correspondence with building inspectors. The results of this work are summarized in Table 1. The limits commonly in force for industrial and commercial occupancies should be considered by designers in connection with the data presented in Appendix, paragraph 6. Table 1 appeared in the following journals: Buildings and Building Management, May 14, 1923; American Architect and Architectural Review, May 9, 1923; Safety Engineering, May, 1923; The Constructor, June, 1923; and Engineering News-Record, August 16, 1923.

TABLE 1.—*Minimum floor-load requirements allowed as a basis of structural design in the United States*

[Analysis of building code requirements of 109 representative cities of the United States showing number in which each of the following minimum loadings are specified for the occupancies listed. United States Department of Commerce, Building Code Committee, December, 1922]

MINIMUM LOAD IN POUNDS PER SQUARE FOOT

Occupancy	Number	Average load	20	25	30	35	40	50	60	62.5	65	70	75	80	85	90	100	105	108	110	112.5	115	120	125	130	140	145	150	160	175	180	200	250	300	350	500
Dwellings:																																				
First floor	107	52.2		1	2		28	31	38			3	1	2			1																			
Above	103	49.7		1	2		40	28	26			3		2			1																			
Tenements:																																				
First floor	109	55.8			1	1	21	32	37			4	2	8		1	2																			
Above	105	50.6			1	1	37	33	25			4	1	2			1																			
Stores, light:																																				
First floor	107	119.4												1			26						41	29				9				1				
Above	102	115.0						1					1	1		1	34						39	18				6				1				
Stores, heavy:																																				
First floor	98	162.8															12						12	6		1		31		3		21	11	1		
Above	94	136.9														1	13			1			11	7		1		29		2	1	18	9	1		
Warehouses:																																				
Heavy	98	184.2															8						4	1				28				39	16	1	1	
Light	100	137.7															22						28	14	2			16		2		12	3	1		
Factories:																																				
Heavy	97	177.0															10						8	5	1			28		1		23	20	1		
Light	103	121.8															27						37	25	1			10				2	1			
Roofs:																																				
Less than 20°	100	39.2		6	26	1	40	27																												
More than 20°	88	31.0	7	9	56		12	4																												
Assembly halls:																																				
Movable seats	102	110.3										1		1		14	38						22	20				6								
Fixed seats	102	95.9						1	1			2	8	15		33	22						3	14				3								
Drill halls	95	137.0										1				4	17		1	1			17	13				27	1	1		3	7			
Dance halls	94	115.9										1				4	18		1	1			26	14				25		1		2	1			
Schools:																																				
Corridors	96	92.5						1	3			7	13	11		26	18						7	7				3								
Assemblies	101	99.5							1			2	12	7		26	23	3				1	7	15				4								
Classrooms	96	69.9					3	10	21	1		9	41	3		5	1							1				1								
Office buildings:																																				
First floor	101	114.0					1	3	1			3		8		2	30						12	14				27								
Above	106	69.7					4	14	22			6	49	3		2	4											2								
Public buildings	80	105.8					1					1	3	1		9	37				2		6	14				5								
Garages:																																				
Public	90	126.0						1					2	5	1		24						8	11	1		1	30		2		3	1			
Private	80	73.9			1		3	4	5		2		24	7	1		18						8	3				1				2				
Hotels:																																				
Rooms	104	57.3			1	1	15	30	40		1	4	7	1		1	2											1								
Corridors	88	87.7					5	3	8			5	7	13		17	14						6	7				3								
Hospitals:																																				
Wards	96	61.0			1		13	24	35			4	7	4		1	4						1	1				1								
Corridors	84	83.6			1		5	4	10			2	4	16		20	11						5	5				1								
Sidewalks	63	272.0																										4				9	9	40		1

Par. 5. Loads Due to Human Occupancy.

1. Residential occupancies.—After investigating the floor loads in residences the Building Code Committee recommended in an earlier report (Minimum Requirements for Small Dwelling Construction) that a live load of 40 pounds be required for small dwellings with wood floors and 30 pounds for those having solid or ribbed monolithic floors. Through submission of a preliminary report on the subject opportunity was made for critical discussion of the suggestion, with the result that it received practically unanimous approval.

The heaviest furniture loads discovered by investigators were pianos, weighing up to 55 pounds per square foot, and bookcases weighing up to 170 pounds per linear foot, but in both cases the distribution was such as to bring the equivalent uniform load well below that specified above. According to information furnished by the Hotels Statler Co. the complete furniture of a typical guest room weighs 812 pounds, or about 4.1 pounds per square foot for an 11 by 18 foot room.

The reported observations of several experienced architects and builders are that the furniture loads in residential occupancies will seldom exceed 50 per cent of the minimum design load specified, but that crowds averaging 40 pounds per square foot are quite probable and should be provided for.

For the average requirements of 109 codes in respect to the occupancies mentioned above, see Appendix, paragraph 4. It will be noted that the average for hotel guest rooms is but 7.6 pounds heavier than that for corresponding parts of dwellings, and but 6.7 pounds heavier than for tenements, indicating that loads for these three occupancies are generally considered about the same.

2. Hospitals.—Through the courtesy of those in charge of the New York State hospitals for the insane at Brooklyn and Rochester, actual live-load measurements were obtained for several large wards in each institution. The data are as follows:

Live loads in crowded wards

BROOKLYN STATE HOSPITAL

Ward number	Dimensions	Total number of beds	Average weight of bed equipment and occupant	Total floor load	Load per square foot
			Pounds	*Pounds*	*Pounds*
8 and 10[1]	43 feet by 58 feet	62	275	17,050	6.9
9[1]	do	65	275	17,875	7.2
21 dormitory[1]	do	62	295	18,290	7.3
22 dormitory[1]	do	65	295	19,175	7.7
ROCHESTER STATE INSANE HOSPITAL					
9, east[2]	49 feet 6 inches by 34 feet 6 inches	46	256	11,776	6.9
9, west[2]	50 feet by 34 feet 6 inches	52	256	13,312	7.7
52[2]	48 feet by 28 feet	36	276	9,936	7.5
53, dormitory 1[2]	36 feet by 47 feet	43	276	11,868	7.0
53, dormitory 2[2]	21 feet by 36 feet	18	276	4,968	6.6
53, dormitory 3[2]	49 feet by 28 feet	45	276	12,420	9.0

[1] Wards 8, 9, and 10, females, average weight, 145 pounds; dormitories 21 and 22, males, average weight, 165 pounds. Radiators not included.

[2] Ward 9, females, average weight, 130 pounds; wards 52 and 53, males, average weight, 150 pounds. Radiators not included.

A survey of a large dormitory in the Willard, N. Y., State hospital checks the above figures very closely. The room accommodated 86 beds in a total area of 2,600 square feet. The live loads were as follows:

	Pounds
86 beds, at 85 pounds each	7, 300
86 mattresses, etc., at 45 pounds	3, 870
86 patients, at 135 pounds	11, 600
Total load	22, 770
Average load per square foot	8. 75

3. Schools.—According to investigations by Norman M. Stineman (American Architect, April 11, 1923) a standard classroom has 736 square feet area and accommodates 45 pupils. The average weight of furniture and inmates is about 7,500 pounds, or 10 pounds per square foot. He estimates the maximum possible load as 2 adults in each seat and 30 around walls, giving total live load of 28 pounds per square foot.

In the course of loading tests for schoolhouse floors made by the Milwaukee Board of Education (Engineering News-Record, May 6, 1920) a room 24 feet 5 inches by 32 feet (781.3 square feet) normally for the accommodation of a teacher and 48 pupils was crowded with 258 pupils, filling all seats double, and all aisles and open spaces. There resulted a total weight per square foot, including desks, of 41.7 pounds.

Under normal conditions with 48 pupils at an average weight of 115.6 pounds, plus weight of desks and teachers, the average floor load was 10.83 pounds per square foot. Filled under normal conditions with adults, as in the case of night school, the load amounted to 12.9 pounds per square foot.

Other investigators put the live load in school classrooms normally filled at 14 pounds per square foot, and at 22 pounds if the aisles are crowded.

4. Grandstands.—Even with due allowance for increased weight of adults the limits given in Part II, section 3, for schools, are believed to apply also for other indoor places of assembly with fixed seats. Grandstand seats are more closely spaced, the supporting structure is more open to deterioration by action of the elements, and there is greater prospect of serious impact effects from moving crowds. (See appendix, par. 13.) The minimum load for such structures was, therefore, increased considerably over that for indoor assembly places.

5. Offices.—The information available on this occupancy is much more complete than for any other. It has been carefully presented in recent technical periodicals [4] and only a résumé sufficient to support the committee's recommendations is included here.

Actual weights of furniture and occupants on three complete floors and in a number of selected heavy occupancies in the Equitable Building, New York, N. Y., are reported by C. T. Coley, manager of the building, as follows:

Maximum, minimum, and average live loads in Equitable Building

	Offices	Maximum	Minimum	Average
		Lbs./ft.²	*Lbs./ft.²*	*Lbs./ft.²*
Light-occupancy floor (twentieth)	67	55.4	0.87	10.26
Medium-occupancy floor (thirty-seventh)	64	30.73	3.27	10.67
Heavy-occupancy floor (eleventh)	62	33.84	5.00	13.96
Total and average	193			11.6
Selected heavy occupancies throughout building	14	78.3	21.4	42.4

The weights given do not include the radiators, which would add approximately 1 pound per square foot for all exterior bays.

The weight of the partitions was not included in the calculations. These, in general, are 3-inch hollow tile plastered each side, and one which was being removed was found to weigh 30 pounds per square foot, or approximately 350 pounds per linear foot.

The weight of occupants, taken at 150 pounds per person, is probably high, as most of the occupants are females, and some studies indicate that an average weight of same would not exceed 120 pounds.

Careful sketches of load arrangement prepared by Mr. Coley made it possible to throw some light on the prevailing method of assuming uniformly distributed live loads as a basis for office floor design, and help to indicate what relation such assumptions should bear to actual total loads. Examination of bays for which the live load was more than 25 pounds per square foot showed wide variation in the distribution of such loads. The larger proportion was found, as might be expected, within a zone approximately 3 feet wide around the walls, the remainder being distributed variously in the centers of the rooms. In one or two cases, however, the major portion of the load was located away from the walls and this condition must be provided for by designers. There is also the probability that practically all furniture may be collected in the central portion of a floor area when occupants are moving, or when decorating or cleaning is in progress.

The sketches show that the heavier loads, such as library shelves and double filing cabinets, are likely to be located away from walls

[4] An article on "Live loads in office buildings," based on data obtained by Mr. Coley and other investigators, appeared in the following journals: Engineering News-Record, March 29, 1923; American Architect and Architectural Review, March 28, 1923; Concrete, April, 1923; American Machinist, March 22, 1923; Distribution and Warehousing, April, 1923; Architectural Forum, April, 1923; and Buildings and Building Management, March 19, 1923.

and partitions. This is obviously for ease of access, and the same consideration demands that when total loads per square foot are high they must be quite uniformly distributed.

The heaviest loading discovered was one incidental to office purposes, being made up chiefly of card filing cases, but the stack room of a law library on one floor would have averaged 87 pounds per square foot if the shelves had been completely filled.

Only eight articles of furniture (safes) were found over 2,000 pounds in weight. A number of sectional filing cases and bookcases with contents weighed much more, but these weights were distributed over such a large area they could not be regarded as concentrated. Of 36 safes and safe cabinets, 23 weighed less than 1,000 pounds; 5 between 1,000 and 2,000 pounds; 2 weighed 2,200 pounds; 2, 2,360 pounds; 1, 2,800 pounds; 1, 3,000 pounds; 1, 3,500 pounds, and 1, 4,250 pounds.

As would naturally be expected, the live loads were found to be lighter next to the exterior walls of the building. Single-row filing cases, cabinets, safes, bookcases, and bins are usually located against blank interior walls. Whether by accident or otherwise, the heavier loads were not found where partitions cut up the floor space into small rooms, indicating that allowance may not be necessary both for movable partitions and heavy floor loads.

Several instances were found where two adjacent floor bays supported average loads of 25 pounds or more, but in no case were two adjacent bays found loaded in excess of an average of 40 pounds per square foot.

There are but two or three instances in the floor plans discussed where three or more offices or storerooms meet at the same column, and it is probable that this condition will be found but rarely in buildings designed for a sufficiency of light and ventilation.

An investigation by M. W. McIntyre of the Union Central Life Insurance Co.'s building in Cincinnati gave quite similar results. All files, desks, etc., were considered as being 100 per cent full or furnished with all necessary accessories. Following are tabulated the results of Captain McIntyre's investigations:

Office live loads in Union Central Life Insurance Building

	Number of square feet	Number of pieces of furniture	Total weight of furniture	Weight of furniture per square foot
			Pounds	*Pounds*
Section A	10,339	635	104,478	10.05
Section B	9,303	637	27,085	2.91
Section C	7,348	273	36,306	4.92
Section D	10,339	702	121,388	11.74
Average	9,332	561.5	72,314	7.405

30868°—25†——4

Weight of employees, computed at the rate of 150 pounds each, added from 0.9 to 1.75 pounds per square foot of floor area.

Several individual offices similarly surveyed by Mr. McIntyre showed an average weight of furniture of 7.66 pounds per square foot.

The chairman of the Building Code Committee has investigated the live loading in a reference room of a New York insurance company equipped with heavy steel filing cases for large Sanborn insurance map books. This was considered to represent unusually heavy occupancy. The cases were placed back to back, occupying a floor space approximately 5 by 22 feet, and were 55 inches high. It was found that the case with its aisles for access occupied a space of 247 square feet and weighed, with contents, 10,620 pounds. Observation showed it liable to use by no more than 12 men simultaneously. The total load thus occasioned amounted to 50.3 pounds per square foot.

Some interesting data on the weights per cubic foot of typical heavy office furniture resulted from this investigation. Steel filing cases filled with map books were found to weigh 21.7 pounds per cubic foot; wooden filing cases full of cards weighed 31.8 pounds per cubic foot; and steel cases similarly filled, 47 pounds. Wooden correspondence file cases, filled, weighed 21.2 pounds per cubic foot, and those of steel from 23.3 to 26.4 pounds.

C. H. Blackall, of Boston, Mass., and Arthur C. Everett, of the Boston Building Department, published in the American Architect and Building News, April 15, 1893, the results of floor load investigations in three office buildings of that city.

The buildings were examined very carefully and copious notes taken of room dimensions, occupancy, and details of contents. Average weights were assumed, based on averages for the various articles of furniture. The human occupancy was taken as the greatest known to have occurred in each of the offices investigated. The nature of occupancy was sufficiently diverse to be representative. Following is a résumé of the results obtained:

Live loads in Boston office buildings

Building	Number of offices	Total area	Total weight	Average weight per square foot
		Sq. ft.	*Pounds*	*Pounds*
Rogers	41	18, 127	294, 984	16. 8
Ames	70	32, 151	544, 419	15. 6
Adams	99	26, 183	425, 109	16. 7
Average				16. 3

The 10 heaviest loadings in each building averaged 25.9, 29.8, and 29.0 pounds per square foot, respectively. The highest load found was 40.2 pounds per square foot, and in only 12.4 per cent of the offices was the floor load in excess of 25 pounds per square foot, and in only 26 per cent did it exceed 20 pounds.

Mr. Blackall recently conducted a similar investigation of live loads in the Little Building, of Boston, which is reported in the American Architect and Architectural Review, January 3, 1923. Sixty-four offices were surveyed, the results indicating live loads even less than those discovered in the earlier investigations. The maximum floor load was 14.7 pounds per square foot, and but four offices had loadings over 10 pounds per square foot. The minimum loading discovered was 1.3 pounds per square foot.

6. *Library stack rooms.*—Investigations of library stack rooms show loads much heavier than are at all likely in reading rooms associated with them. The weight of books assembled as in library stacks is given by F. J. Ward as 35 pounds per cubic foot, which with stacks of the customary 8-foot height covering one-half the available floor space would amount to 140 pounds per square foot. The stacks, books, and equipment in the library of the New York Law Institute, weighed by C. T. Coley, were found to average 77.3 pounds per square foot of floor area. The Department of Commerce library, Washington, D. C., weighed 87 pounds per square foot. Records bound in leather and stored in heavy oaken racks 8 feet high were found by Frank Burton, commissioner of buildings, Detroit, Mich., to weigh 85 pounds per square foot of floor area. The average floor load was 125 pounds, due to the fact that additional records had been piled to considerable heights on top of the racks.

The committee would consider this occupancy a form of special storage, coming under item 2 of the list in Part II, section 4.

7. *Crowded rooms.*—Densely crowded groups have been shown by several investigators to weigh at least 140 pounds per square foot, but those results were obtained by strenuous methods, and it is held unlikely that they will occur under ordinary conditions. Observations of the loading obtained under normal conditions in the elevators at the Grand Central Terminal in New York showed a maximum of 73 persons on 92 square feet of floor area. With an estimated weight of 130 pounds each this gives a load of 100 pounds per square foot. Crowds of students at Iowa State University, packed for the purpose of testing balcony construction under dynamic loads, weighed 116 pounds per square foot. The floor load for spaces subject to crowding, therefore, has been placed at 100 pounds rather than 140 pounds per square foot. Crowds may occur in places such as listed in section 3, *3*, but need not be provided for in rooms with fixed seats. The average of present code requirements for assembly places is shown in Appendix, paragraph 4.

Par. 6. Floor Loads in Industrial and Commercial Buildings.

It will at once be noticed that the minimum loads prescribed in Part II, section 4, for industrial and commercial occupancies are much less than the average of such requirements now in force. (See Appendix, par. 4). This results from a number of factors which were carefully considered by the committee.

1. It has been strongly urged by a number of those who participated in the preliminary work on this subject that present code requirements work an injustice to those conscientiously designing buildings for certain light commercial and industrial occupancies. In the effort to secure safety in structures subject to unexpected and possibly unregulated change of use the tendency has been to choose the minima which were believed safe under all circumstances. These minima, applied indiscriminately, have occasioned unnecessary expense in many cases for the construction of floors heavier than needed. Comparison of the observed floor loads in Tables 3 and 4 and the average requirements shown in Appendix, paragraph 4, will illustrate this point.

2. It also has been shown that in many cases the enforcement of a high minimum for design purposes is ineffectual to secure safe conditions unless buildings are periodically inspected for overloads and changes of use carefully regulated by municipal authorities. Data received by the committee show many cases of serious overloads in manufacturing and storage buildings, sometimes as high as 300 and 400 per cent. Attention is called to the observed floor loads in Table 3 and to the fact that many of the commodities listed in this table, if piled to moderate story heights, would cause loads far greater than the minima now generally prescribed for storage occupancies.

_3._ In view of the foregoing, the committee has recommended minimum floor load requirements which will permit design of buildings in each case for the purposes intended, and has provided in succeeding sections of Part II for a system of control after erection, which, if consistently applied, will eliminate dangers due to overloading.

_4._ It should be emphasized that the loads prescribed in Part II as the basis of design are in all cases the minimum loads and must be increased where the type of occupancy makes this necessary. Special allowance must be made for special loadings, as, for example, laboratories in school buildings, file rooms in office buildings, or library stack rooms. The committee, therefore, has made its requirements apply to portions of buildings rather than whole buildings, specifying the purpose for which such portions will be used.

_5._ Those designing buildings for the minimum loads allowed should bear in mind that the future adaptability of the structure may thus be seriously impaired, its serviceability limited, and its sale or rental value reduced. The minimum loads permit a builder having in mind a

specific occupancy involving light loads to build with maximum economy, but he should look ahead to the possibility that he may wish to use or sell the building for some purpose involving greater loads, and that this will not be permitted without expensive changes. The additional cost of a heavier floor and supporting members may be returned many times over in superior adaptability of the building. It is recommended that in designing plants for commercial or industrial purposes, at least some buildings or parts of buildings be made stronger than may at the time appear necessary. Future changes in the purpose or process involving increased loads can then be provided for by utilizing these heavier bays or buildings.

It has been found good economy in many cases to design flat roofs of commercial or industrial buildings for loads equal to those assumed for floors below. It often is desirable to use such roof spaces for purposes unforseen when the structure was built, as, for example, temporary storage of materials, recreation purposes, or additional light equipment, roof signs, small tanks, etc. By making the roof structure strong enough for such service a small initial outlay at the time the building is built may avoid much greater expense later.

6. Where a building is designed for a particular purpose, as, for example, a chemical or gas plant where loads are inconsiderable except for those of tanks and other heavy apparatus built into the structure, and where extensive alteration would have to be made before the building could be used for other purposes, it is assumed by the committee that floors will be adequate at all points for at least 75 pounds per square foot, and that the necessary provision will be made for special or concentrated loads exceeding that amount.

7. It is well established by information made available to the committee that storage buildings for certain special purposes may never be loaded to more than 100 pounds per square foot. It is also well proved that space for general storage purposes may be loaded over large areas to a much greater amount than this. Two minimum limits are, therefore, specified in Part II, section 4, the first to apply to buildings for general storage purposes, and the second only when the special commodity which the structure is to shelter will obviously not entail loads greater than 100 pounds per square foot. It must be clearly understood that the larger figure is a minimum also and that it should not be used where there is a possibility of the building being used for materials weighing more than 250 pounds per square foot.

8. For the guidance of those designing buildings and of building inspectors in checking applications for building and occupancy permits there follow tables of floor load data for storage and factory buildings.

The data of Table 2 were furnished by C. H. Heller, consulting engineer of San Francisco, Calif., as a result of requests in the tentative draft of this report. Properly interpreted, this information should materially assist in determining the probable live loads in storage buildings for special purposes. Together with data given in Table 3, it indicates that live loads in buildings for general storage purposes may and do frequently exceed greatly those commonly assumed for such structures.

TABLE 2.—*Weights of Merchandise in Warehouse of wholesale hardware company*

[Compiled by C. Heller, consulting engineer, San Francisco, Calif.]

Article	Size [1] (in inches)	Weight of article	Number of tiers [2]	Load per square foot of floor area covered [3]
		Pounds		
Ammunition	8½ by 8½ by 14	50	6	600 if on end; if flat, 370.
Ash cans	20 diameter by 26	30	6	64-90
Auto bumpers	6 by 72 by 7	54	20	360
Auto lenses	22 by 13 by 13	47	9	211
	11½ by 17 by 5	13	23	225
Auto wheels	25 by 25 by 17	45	5	52
Barbed wire	14 diameter	110	5	400
Batteries (dry cells)	11 by 18 by 18	105	5	375
Bicycles	5 by 74 by ?	61	3	71
Bolts, in barrels	12 by 12 by 22	195	3	585
Bowls, mixing (barrels)	24 by 24 by 29	200	4	200
Brace bits	16 by 42 by 9	63	11	148
Brass pipe and bars rack	11 by 4½ by 7 (ft.)	11 (racks)	(Ave.)	100
Clothes hangers	17½ by 19 by 19	38	8	132
Clothes pins	19 by 17 by 10	48	8	170
Cocoa mat., bundles	27 by 31 by 15	107	7	266
Concrete buckets	24 by 30	173	2	75
Copper wire (barrel)	18 diameter	300	2	270
Crow bars, 55-inch, bin	2 by 5	15 (bins)	7	577
Drip cans	17 by 15 by 10	50	9	254
Electric washing machines.	35 by 26 by ?	370	2	119
Electric wire	13 by 13 by 16	80	6	420
	14 diameter by 3	28	24	500
Enamel ware	17½ by 28 by 27	62	8	146
Fishing tackle, etc	24 by 24 by 6	600		150
Fittings, in barrels	18 diameter	450-600	1 or 2	250-500
Flywheels	24 diameter by 8½	236	1	170
Glassware	15 by 22½ by 11	18	6	99
Grindstones	24 diameter	110	10	275
Handles (axe), 126 bundles in area (31 by 31).	31 by 5 by 5	16 (pile)	126	300
Handles	25 by 22 by 7	37	12	117
Hoe handles, 162 bundles, packed.	5 diameter by 60; 60 by 60	13	18	84
Hoes, in barrels	20 diameter	485	2	350
Iron wheelbarrow frames	24 by 66 by 6	53	24	116
Iron wheelbarrow trays	27 by 32 by 6	24	100	400
Lamp chimneys	20 by 20 by 17	25	9	81
Lanterns	15 by 21 by 13	25	8	91
Lawn mowers	13 by 20 by 9½	37	11	225
Mason jars	12 by 15 by 6	13	20	208
Mops	42 by 28 by 15	158	3	58

[1] First two dimensions determine area on floor. Third dimension is height of article.
[2] Number of tiers exact, found at time of investigation.
[3] This load is based upon number of tiers in previous column and not upon weight of one package.

TABLE 2.—*Weights of Merchandise in Warehouse of wholesale hardware company*—Continued

Article	Size (in inches)	Weight of article	Number of tiers	Load per square foot of floor area covered
Mop sticks	18 by 57 by 22	181	6	153
Mop wringers	24 by 20 by 32	199	3	180
Nails	1 foot diameter	210	4	840
Oil cans	12 by 36 by 15	21	10	70
Oil heaters	12 by 12 by 23	13	9	117
Oil stoves	20 by 36 by 18½	65	10	130
Pails (6 are 11 inches high)	2 feet diameter	50	72 inches	150
Paint	15 by 22 by 9	110	8	390
Paper			3–4½	158
Paper (for print department).	3½ feet by 2 feet 2 inches by 1 foot 9 inches.	650	3⅓	290
Pipe fittings bins 30 by 30 by 24 by 3 bins barrel fittings weight 500:				
1 barrel fitting per bin.		500	3	240
2 barrel fittings, per bin.				500
Pump	9 diameter	26		
Pump cylinders	30 by 30 by 72	20	77	246
Pump equipment	17 by 21 by 16½	84	5	170
Pump jacks	14½ by 27	350	1	130
Pump packing	8½ by 27 by 2	6 (3 wide, 3 long)	16	64
Pumps	24 by 22 by 51	396	1	100
Do	1 foot diameter	56	1	56
Do	29 by 33	800	1	121
Rakes 100 bundles in pile	6 feet square	40		110
Roasters (2 deep)	24 by 19 by 13	30 (2 deep)	13	123
Rolls (wrapping paper)	9 diameter, 15 high	30	6	325–475
Roofing paper	6 diameter	40	2	320
Rope	21 diameter	125	5	200
Rope	4 feet 0 inches by 3 feet 0 inches	2,162	1	180
Rope	14 diameter	41	8	242
Shells (ammunition)	24 by 36 by 6	4,000 pounds per bin.	6	250
Shovels, 30 pounds per bundle, 96 bundles to pile (pile is 5 by 5 feet).		30		115
Sledges in barrels	1 foot diameter	315	3	945
Soap	19½ by 20½ by 10½	112	5	200
Spark plugs	14 by 23 by 15	120	4	212
Steel mats	32 by 28 by ?	320	4	206
Tacks	8 by 12	25	12	450
Tees	6	30	3	90
Toilet paper	23 by 18 by 23	56	6	112
Tools (bins 2 feet by 4 feet) 6 high; 270 in bin 2 equal.	2 by 4 by 8	7	(½ load)	710
Toys	25 by 35 by 22	84	5	56
Trucks (hand)	12–24 wide; 48 long	90	12	180
Varnish	16 by 24	105	8	315
Waste cotton	24 by 34 by 15	100	7	125
Weed chains (barrel)	1 foot 6 inches diameter	530	28 inches high	240–300
Weed chains (barrel)	8 by 8	16	12	430
Wheelbarrow trays (bundle of 6).	26 by 32	117 (9 in row)	10	195
Window weights (bin) (10 per bundle).	2 feet 9 inches by 4 feet 0 inches	5 (63 bundles)	4	1,145
Wire	18 by 17 by 10	50	10	220
Wire	26 diameter	180	12	460
Wire cloth	10 diameter, 3 feet high	87	3	375–500

TABLE 3.—*Floor loads in storage buildings*

[See explanatory note for method of compiling data]

Class of commodity	Maximum probable weight per cubic foot of storage space	Maximum probable weight per square foot of storage space	Observed loads per square foot of floor space in storage buildings
Acids	55	440	
Agricultural machinery	55	440	
Asbestos	50	400	200
Automobiles, crated	13	104	
Automobile parts	40	320	50, 58, 60, 75, 80, 90, 110, 140, 150, 165, 200, 225, 235, 345, 700
Automobile tires	30	240	90, 100, 171
Automobiles, uncrated	8	64	
Baggage:			
Empty	6	48	
Packed	20	160	
Beverages	40	320	
Books (solidly packed)	65	520	330
Bricks:			
Building	45	360	
Fire clay	75	600	
Cable and wire	75	600	220
Carpets and rugs	30	240	
Cement	65	520	
Cereals	45	360	256, 200
Chain	100	800	1,200
Chemicals	50	400	370, 600, 450
Clocks and watches	40	320	
Cocoa	35	280	210, 450
Cotton:			
American ..... bales	30	240	
Foreign ..... do	40	320	180
Cotton goods	45	360	
Cutlery	45	360	
Electrical goods and machinery	40	320	
Extracts	60	480	
Flour and meal	45	360	200, 300–400, 350
Fruits, dried or canned	50	400	350, 450, 340, 315, 300–400, 400
Fruits, fresh	35	280	250
Furniture	20	160	250, 60–85, 100
Guns and ammunition	65	520	
Gypsum	50	400	
Hardware, small	110	880	250, 650
Hides, green	55	440	
Hemp, jute, and other fibers	35	280	220
Leather and leather goods	40	320	175, 210, 260, 85–300
Machinery, light	20	160	150
Meat and meat products	45	360	410, 370, 340
Milk, condensed	50	400	370, 305, 365, 360, 385
Nonferrous metals, bulk	250	2,000	
Oils and greases	45	360	240
Paints	90	720	
Paper and books	50	400	270, 395, 340, 300, 275, 500, 200
Photographic supplies	40	320	
Plumbing:			
Fixtures	30	240	
Supplies	55	440	75
Potash	55	440	300, 330
Rope, fiber	30	240	
Rubber, crude	50	400	250, 310, 400
Shafting steel	125	1,000	435, 650
Silk and silk goods	45	360	
Soaps	50	400	
Steel, bulk	225	1,800	
Sugars, sirups, and candies	50	400	200, 350, 325, 350, 300–400
Tiles	50	400	
Tobacco ..... bales	35	280	180
Tobacco ..... hogsheads and barrels	28	224	
Toilet articles, miscellaneous	35	280	
Tools, small, metal	75	600	100
Trucks	22	176	250
Varnishes	55	440	

TABLE 3.—*Floor loads in storage buildings*—Continued

Class of commodity	Maximum probable weight per cubic foot of storage space	Maximum probable weight per square foot of storage space	Observed loads per square foot of floor space in storage buildings
Vegetables, canned or dried	45	360	285, 250, 300–400, 400
Woods, bulk	45	360	
Wool and woolen goods	50	400	150, 245, 250, 330

NOTE.—The "maximum probable weight per cubic foot of storage space" shown in Table 3 is based on careful study of data compiled by the United States Shipping Board for use of the American Expeditionary Force and published in "Stowage Factors for Ship Cargoes." Reference also was had to data presented in Report No. V, Slow Burning or Mill Construction, prepared by the Boston Manufacturers Mutual Fire Insurance Co. (The former publication is obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 35 cents per copy, and the latter from the organization named, at 31 Milk Street, Boston, Mass., for 25 cents per copy.) Data also were obtained from various private sources as to floor loads actually obtaining in different warehouses. They are given in the column to the right. The "maximum probable weight per cubic foot" is computed from figures obtained by the United States Shipping Board on the weights per cubic foot of commodities crated or prepared for shipment and stored in a ship's hold. It represents, in other words, the weights of the customary packages or units divided by the storage space they occupy and is believed the most suitable unit for estimating the probable loads on storage floors.

The United States Shipping Board, in practically every case, gives figures for a number of different packages or units or containers, customarily used in different localities, or for different types or weights of the commodity in question. These usually vary through a range of 100 per cent or more above the minimum figure. In selecting the maximum probable weight per cubic foot of storage space it was assumed as unlikely in most cases that the heaviest type of load would obtain over a whole bay to the greatest possible depth. The maximum probable load was selected with reference to the range of data for that class of commodities and is as a rule from 10 to 25 per cent less than the maximum figure given in the bulletin.

Having in mind the use of modern elevating machinery for piling packages to full-story height in warehouses, the necessary clearance for handling goods, or for effective sprinkler action, it is suggested that an 8-foot depth of stored material is a conservative basis for estimating probable warehouse floor loads. Column 3 of Table 3 has been computed on this basis, and though the results in some cases are rather improbable the reported loads (column 4) indicate that for most commodities the assumption is not far wrong

TABLE 4.—*Floor loads in manufacturing buildings*

Occupancy	Observed loads per square foot of floor space [1]
1. Automobile plants:	
Machine shop floors	60, 75, 80, 95, 100, 110, 115, 120, 125, 200.
Body building	14, 35.
Motor assembly	110.
Car assembly	60.
Ovens	150.
Furnaces	300.
Storage of parts	60, 65, 70, 75, 80, 85, 90, 110, 140, 145, 165, 195, 225, 235, 345.
Storage of bodies	14, 27, 32, 33, 41, 50.
2. Automobile tire plants:	
Vulcanizers	175.
Dryers	75.
3. Furniture factories (domestic):	
Woodworking and assembly of pieces	100–300.[2]
Finishing departments	25.
Storage and shipping	50.
4. Furniture factories (steel furniture):	
Fabricating departments	200.
Machine shops	250.
Warehouses, factory	250.
Warehouses, distributors	300.[3]

[1] The "observed loads per square foot of floor space" are from many sources, and are understood to represent in each case the results of careful observations or actual weighings by those reporting them. The greater number of observations on machine shops, perfumery, and automobile factories were furnished by Albert Kahn; those on textile mills by Charles T. Main; and those on furniture factories by the Grand Rapids Chapter of the American Institute of Architects and by the National Association of Steel Furniture Manufacturers. The data are regrettably scant in view of the need for such information. They are all that were obtained from an earnest appeal to the architectural and engineering professions.

[2] Typical unit loading uniform on all bays at once was judged to be 150 pounds per square foot.

[3] Much material shipped in knock-down condition.

TABLE 4—*Floor loads in manufacturing buildings*—Continued

Occupancy	Observed loads per square foot of floor space
5. Textile mills:	
Cardrooms	80.
Other departments	50, 75.
6. Machine shops:	
Light work	7 bays at 30 pounds, 2 at 35, 4 at 40, 3 at 45, 9 at 50, 4 at 55, 5 at 60, 2 at 70, 5 at 75, 2 at 85, 3 at 90, 1 at 95, 2 at 100.
Heavy work	150–175.
7. Garment factories	100.
8. Perfumery works	40, 65, 75, 85, 105, 120, 150.
9. Printing and binding:	
Heavy pressrooms	250–400.
Light presses	175.
Composing rooms	75–85.
Linotype rooms	75–85.
Type cases, closely packed	250.
Stereotype rooms	200–250.
10. Silk mills	30.

The following information on floor loads in packing plants is given by John G. Hormel, of Austin, Minn. The figures for storage floors are based on story heights of 11 feet or less and should be interpreted accordingly when heights are greater. The data are given in round numbers, but are stated to approximate closely the actual loading in different departments of the packing plant.

	Pounds per square foot
Beef cooler floors	100.
Beef cooler ceilings	250 per linear foot of rail (beef in sides).
Do	150 per linear foot of rail (beef in quarters).
Casing storage	200.
Cattle pens	100.
Curing coolers	250 (meat in tierces laid flat and piled 3 high).
Do	200 (dry salt meat).
Cutting rooms	150.
Cooper shop	150.
Fertilizer storage	300.
Freezer storage:	
Beef piled loose on floors	200.
Sheep piled loose on floors	175.
Offal freezer	250.
Sharp freezer with racks	200.
Storage freezer	250 to 300.
Hair drying and storage	200.
Hide storage	250 (usually in cellars).
Hog coolers—floor	100.
Hog coolers—ceilings	200 per linear foot of rail.
Hogpen	100.
Hog dressing room	150.
Killing floors	150.
Lard refinery	150.
Lard storage coolers	200.
Smokehouse	100.

In spite of repeated efforts no information has been obtained on the floor loads characterizing retail salesrooms. It is obvious that many of these are very light, and that the maximum load frequently is due to human occupancy. Such maximum loads approach, but do not equal those in assembly places not equipped with fixed seats.

Robert D. Kohn, architect, New York, N. Y., reports loads of from 40 to 600 pounds per square foot in a large department store building. Floors in this building were used for office and school purposes, light and heavy storage, retail sales, and in some cases were traversed by loaded delivery trucks.

The National Association of Steel Furniture Manufacturers, on invitation of the Building Code Committee, has completed a very thorough investigation of live loads resulting from the use of steel furniture with various conditions of loading.

The equipment investigated included four general types, namely, vertical and horizontal filing cases, safes, office desks, and shelving, such as used for factory storage or library purposes. The weights of several representative types in each class were obtained for three conditions. First, empty; second, filled with materials, such as commonly used in offices and representing an average condition; and, third, with the load produced by the heaviest material likely to be stored in the type of equipment under consideration.

The overall dimensions of the furniture were used in computing the weights per cubic foot and the square feet of floor occupied. Allowance was made in the case of library shelving for human occupancy. It is reported that the storage and library shelving is rarely moved in the ordinary course of office use, but that the other types of equipment are all of a portable nature.

The following table summarizes the information supplied by the association:

TABLE 5.—*Data on live loads resulting with use of steel furniture*

Equipment: Type	Equipment: Style	Height	Filing	Weight empty	Material with which filled	Type of load	Weight of load	Total weight	Number of cubic feet	Weight per cubic foot	Number of square feet	Weight per square foot
		Inches	*Inches*	*Pounds*			*Pounds*	*Pounds*		*Pounds*		*Pounds*
Verticals:												
Office	Letter	53	95	148		Light		148	11	14	2	61
Do	do	53	95	148	Manila folders	Medium	331	479	11	45	2	198
Do	do	53	95	148	Pressboard guides	Heavy	473	621	11	58	2	256
Do	Large card	53	322	190		Light		190	14	14	3	59
Do	do	53	322	190	Record cards	Medium	403	593	14	42	3	185
Do	do	53	322	190	Pressboard guides	Heavy	564	754	14	54	3	235
Counter	Letter	42	86	139		Light		139	10	14	3	48
Do	do	42	86	139	Manila folders	Medium	300	439	10	43	3	151
Do	do	42	86	139	Pressboard guides	Heavy	429	568	10	56	3	196
Do	Large card	42	280	205		Light		205	13	15	4	53
Do	do	42	280	205	Record cards	Medium	350	555	13	41	4	146
Do	do	42	280	205	Pressboard guides	Heavy	490	695	13	52	4	181
Horizontals:												
Full	Letter Large card	74	451	523		Light		523	30	18	4	127
Do.[1]	Letter Large card	74	451	523	Manila folders Record cards	Medium	634	1,157	30	39	4	282
Do.[1]	Letter Large card	74	451	523	Pressboard guides do	Heavy	891	1,414	30	48	4	344
Do	Letter Large card	63	451	500		Light		500	26	19	4	122
Do.[1]	Letter Large card	63	451	500	Manila folders Record cards	Medium	634	1,134	26	44	4	276
Do.[1]	Letter Large card	63	451	500	Pressboard guides do	Heavy	891	1,391	26	54	4	339
Safes:												
Labeled	High and wide	80		1,929		Light		1,929	64	30	10	201
Do.[2]	do	80		1,929	Court books	Medium	718	2,647	64	42	10	276
Do	do	80	480	2,225		Light		2,225	64	36	10	232
Do	do	80	480	2,225	Record cards	Medium	600	2,825	64	44	10	294
Do	do	80	480	2,225	Pressboard guides	Heavy	840	3,065	64	48	10	319
Furniture:												
Desks	Flat top	31		253		Light		253	36	7	20	13
Do	do	31		253	Manila folders	Medium	220	473	36	13	20	23
Do	do	31		253	Pressboard guides	Heavy	315	568	36	16	20	28
Shelving:												
Storage	Inclosed	72		397		Light		397	54	7	9	44
Do.[3]	do	72		397	Steel	Heavy	16,208	16,605	54	307	9	1,845
Do.[4]	Slotted	630		7,285		Light		7,285	709	10	14	520
Do.[4]	do	630		7,285	Library books	Heavy	5,880	13,165	709	19	14	940
Do	do	90		1,155		Light		1,155	150	8	14	82
Do	do	90		1,155	Library books	Heavy	840	1,995	150	13	14	143

[1] Two sizes of records—31-inch letter and 420-inch large card.
[2] Two court books on each shelf, which produces a weight of 26 books for test material.
[3] Each shelf of the specimen contained 1,351 pounds, which totaled 16,208 in the test.
[4] Includes for each stack 150 pounds, and for the floor construction 205 pounds per column.

The minimum live load for sidewalk design was taken at 250 pounds per square foot, in view of the possibility that paving materials or coal may be piled on walks, or that delivered goods may be placed on them temporarily to an extent approximating conditions in general storage warehouses.

Recommended live loads for garage floors are based principally on the standard weights of trucks with pay load; data compiled by E. L. Verveer, of New York. (Engineering News-Record, Feb. 9, 1922.) The following is a partial presentation of this information:

TABLE 6.—*Dimensions and weights of typical trucks*

Capacity (tons)	Over-all length	Over-all width	Front tread	Rear tread	Wheel base	Rear tire	Chassis and body weights combined			Chassis, body, and pay load combined		
							Front axle	Rear axle	Total	Front axle	Rear axle	Total
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	16 7	5 11	4 10	4 10	11 5	5	1,942	2,428	4,370	2,102	4,268	6,370
	16 2	5 8½	4 8	4 10	10 8	4	1,700	3,100	4,800	2,095	4,705	6,800
2	17 10	5 9½	4 9	4 11½	11 11	6	2,020	3,000	5,020	2,240	6,780	9.020
	18 1	6 1	4 10½	4 10½	12 0	7	2,600	3,800	6,400	3,000	7,400	10,400
3	17 11	5 10	4 8	4 8	10 4	6	2,700	4,122	6,822	5,460	7,362	12,822
	20 2	7 0	5 4	5 4	13 6	9	3,000	4,700	7,700	3,600	10,100	13,700
4	19 7	7 4	5 7	5 7	13 0	10	3,550	5,910	9,460	4,430	13,030	17,460
	23 7	7 4	5 7	5 7	15 6	12	3,550	6,020	9,570	4,430	13,140	17,570
5	20 6½	7 5½	5 6	6 2½	13 4	12	3,616	5,684	9,300	4,818	14,482	19,300
	26 9	7 7¾	5 8	5 4	17 0	13½	4,110	7,590	11,700	4,550	17,150	21,700
6	18 1½	7 5½	5 7½	6 1	10 8	14	4,025	7,225	11,250	5,630	17,620	23,250
	23 7	7 4½	5 9¾	5 9¾	15 6	14	3,950	7,605	11,555	5,505	18,050	23,555

Mr. Verveer compiled, also, the figures for the distances separating wheel loads when trucks are parked in a garage as closely as is reasonably to be expected in practice. These data are given below.

Distance between wheel centers

Truck capacity (tons)	Trucks parked side by side	Trucks parked front to back	Trucks parked back to back
	Ft. in.	*Ft. in.*	*Ft. in.*
1	1 6	6 0	8 0
2	1 6	6 6	8 0
3	2 0	6 6	8 6
4	2 0	6 6	8 6
5	2 0	6 6	8 6
6	2 0	6 6	8 6

It is very probable that loaded trucks will be driven into garages from time to time for shelter or repair, and provision should be made for the heavy wheel concentrations thus imposed, taking into account the possibility that such trucks may be overloaded. It is not at all probable, except, perhaps, in special cases, that there will be several loaded trucks closely adjacent and code requirements providing for such contingencies or for loaded trucks above the entrance floor are believed unnecessary.

Par. 7. Roof Loads.

The minimum roof loads specified in Part II, section 5, apply only in localities where snow loads are not an important consideration. Roofs having a slope of less than 4 inches per foot are always liable to accidental loading, such as groups of moving people, storage of material, etc. Hence the necessity of moderate unit loads even where snow is not to be expected. Where large snow loads are to be anticipated, the loadings prescribed should be increased in accordance with local experience.

Par. 8. Partition Loads.

There is slight chance that the shifting of partitions will be an important matter except in particular occupancies. Residential buildings in which the floor loads, due to furnishings, approach the minima prescribed for design are usually not those in which a rearrangement of plan is likely. Apartment buildings, especially those of recent years, do not admit of much further subdivision, and the shifting of partitions, once located, is improbable. Construction plans indicate the position of partitions with respect to floor spans, and unusual loading conditions may readily be checked up. The weight of wood stud and plaster partitions varies from 80 to 150 pounds per linear foot, depending on height and thickness of plaster, gypsum block from 100 to 150, and hollow-tile partitions from 150 to 300 pounds per linear foot for partitions 10 feet high. The weight of an additional partition in a building designed for storage or heavy manufacture purposes therefore is not an important matter.

Relocation of partitions is a frequent practice in office and public buildings and must be provided for. A study of the 193 floor plan sketches made in the course of Mr. Coley's investigation (see Appendix, par. 5, *5*) shows that 33 per cent had partitions additional to those originally located over floor beams. These varied in total length from 12 or 14 feet inclosing a corner of the original office space, to 38 feet dividing the room into four parts. The average length was 28 feet in a floor bay about 21 feet long by 16 feet 6 inches wide. In a number of cases the length exceeded 33 feet and consisted of partitions running each way of the floor slab and centered on it. With the type of partitions used in the Equitable building, the weight thus added amounted in the most extreme case to 13,300 pounds, or 38.4 pounds per square foot uniformly distributed. The fact must also be considered that these weights are not thus distributed.

So far as the offices in the Equitable building were concerned, there were no cases in which a furniture load of over 30 pounds occurred in conjunction with extra partitions, and it appears that the type of occupancy which causes heavy loads does not usually require partitions.

Par. 9. Reduction of Live Loads.

The usual building code requirement is the following:

Every column, post, or other vertical support shall be of sufficient strength to bear safely the combined live and dead loads of such portions of each and every floor as depend upon it for support, except that in buildings more than five stories high the live load on the floor next below the top floor may be assumed at 95 per cent of the allowable live load, on the next lower floor at 90 per cent, and on each succeeding lower floor at correspondingly decreasing percentages, provided that in no case shall less than 50 per cent of the allowable live load be assumed.

The committee, however, in the light of evidence received, considers this too conservative.

According to statements by a number of authorities, the actual floor loads in a dwelling or apartment may reach 40 pounds per square foot in one room, but do not average over 15 pounds over the whole living space and may be much less. Data on hotel rooms given by the Hotels Statler Co. indicate even lighter loads, and there seems no reason to believe that the contents of asylums, hospitals, and other residential institutions are any heavier than those of dwellings. (See Appendix, par. 5, *2*, *3*.) There is the consideration, moreover, that in residential occupancies only a few interior columns have all quarters of the adjacent floor slab loaded. At least one quarter will usually be corridor space, thereby reducing the probable total load on the column, and it is most unlikely that more than one quarter at a time will be called upon to support the full floor load assumed for the occupancy.

There was very little difference between the average loads on the floors selected as representing light, medium, and heavy occupancy in the Equitable Building, and no case occurred where more than three offices or filing rooms came together at one column.

In view of this and the remarkable uniformity of average floor loads in office buildings, as disclosed by several other investigations, it seems fully justifiable to reduce assumed loads for column design far below those for floor slabs.

Consideration was given to reduction of assumed loads for design of beams and girders supporting considerable floor areas. Data on overloading obtained by the committee show that reductions can not safely be applied to floors for storage or manufacturing purposes and most codes exclude these occupancies from reduction clauses. In view of the moderate floor-load requirements recommended in Part II for other occupancies, the committee believes reductions on beams and girders carrying one floor only is unwise. Study of the floor-load sketches made in the Equitable Building shows a general tendency for loads to accumulate along partitions and, therefore, over beams. The same also is true to a certain extent in residence buildings, and indicates that reductions for design of beams may be unadvisable as well as unnecessary.

Current code provisions on this point are extremely diverse and often complicated. Their omission would not appreciably increase construction costs, and would assist greatly in simplifying code requirements.

Par. 10. Wind Pressures.

Some experiments made by the Weather Bureau several years ago gave for the relation between wind velocity and pressure the formula:

$$P = 0.004 \frac{B}{30} S V^2$$

in which P is the pressure in pounds due to positive and negative wind effects upon a small rectangular plate, B is the barometric pressure in inches of mercury, S is the surface of the plate in square feet, and V is the actual velocity of the wind in miles per hour. The factor $\frac{B}{30}$ is generally neglected.

More recently M. Eiffel, of Paris, determined for the numerical factor in the above formula the value 0.0033. It seems quite likely that with the more accurate appliances used by M. Eiffel, his value is the better one.

Records of wind velocities have been maintained for many years by the Weather Bureau at its stations located in the principal cities of the country, and the maximum recorded velocities for an average of five minutes may be found in the publications of the Weather Bureau, or at any of its offices. These five-minute averages require correction before they can be used in the formula given above, because of known departures of the records of the Robinson anemometer from actual wind velocity, and also because individual gusts greatly exceed the average for a five-minute period. The relation of gust to five-minute average is not well worked out. From a few actual records up to 48 miles per hour, it appears that a 50 per cent increase may be expected, but it is not established that such a large increase occurs at velocities beyond 50. Inasmuch, however, as the maximum actual velocities shown in Table 7, following this discussion, seldom exceed by any considerable amount a velocity of 50 miles per hour, it would seem safe and not unduly drastic to apply the same allowance of 50 per cent for gusts in cities where higher actual velocities may be expected.

Practical considerations have led to important differences in the exposures of anemometers of the Weather Bureau in different cities. Furthermore, because of removal from one building to another, the erection of neighboring buildings, or the gradual increase in height of surrounding buildings, the records from the same city are not strictly comparable year upon year. Hence the use of Weather Bureau records of wind velocity for engineering purposes involves specific inquiry in each instance as to local surroundings, and a general code requirement that does not take these conditions into account is likely to lead either to unsafe construction or to needless expense.

TABLE 7.—*Recorded wind velocities in various American cities*

City and State	Period of observations (in years)	Maximum indicated velocity recorded in five-minute periods	Equivalent actual velocity in miles per hour	Building code requirements for heights of approximately 50 to 100 feet
Boston, Mass	45	72	55.8	20
Columbus, Ohio	20	70	54.4	30
New Haven, Conn	35	62	48.6	30
New York, N. Y	23	96	73.6	30
Pittsburgh, Pa	17	69	53.7	25
Salt Lake City, Utah	24	68	52.9	20
St. Paul, Minn	19	102	78.0	30
St. Joseph, Mo	10	60	47.0	------------
Spokane, Wash	41	52	41.3	30
Richmond, Va	18	61	47.8	20
Washington, D. C	46	68	52.9	15–30

The velocities shown in the table may or may not be the maximum reasonably to be expected in the life of a building. Certainly no pains should be spared to insure against the wrecking of high buildings or structures by wind pressure. It is recommended therefore that in all cities the assumed pressure should be at least 20 pounds per square foot and that in cities where indicated maximum velocities have exceeded 70 miles per hour, this assumption be increased accordingly.

Except in localities where unusually high winds prevail, it is probable that the ordinary structural requirements will afford sufficient wind bracing for most small buildings. The protective effect of natural objects and of other buildings is also in favor of the small structure. High buildings are not often built in an exposed location with regard to other buildings.

The requirements suggested in Part II, section 8, are predicated on the assumption that an unretarded wind pressure will not occur on low buildings nor the lower parts of high buildings. Where this may occur, as, for example, on Michigan Avenue, Chicago, Ill., provision for greater wind pressures should be demanded.

The requirements for wind loads take into account the custom of using lower factors of safety for wind stresses and the impact effect which gusts of wind may produce.

When buildings are exposed to unusually high winds the structural design should provide for the effects of the wind's negative pressure component on the leeward side of the building, and for the interior pressures which occur when the wind finds access on the windward side of the building. These may be fully as great as the direct pressures on exterior surfaces. The factor of safety against overturning, in structures or parts of structures, the stability of which against wind force depends wholly upon the force of gravity, should be increased rather than reduced. For such structures safety may be assured by increasing the assumed wind pressure to 40 pounds per square foot, or, in localities subject to tornadoes, to 60 pounds per square foot.

Par. 11. Floor-Load Placards.

The practice recommended in Part II, section 4, allows greater latitude than is now generally customary in the choice of floor loads for which commercial and industrial buildings are designed. The owner may take advantage of low floor loads characteristic of the particular need of his building, but it should be kept in mind that it is always possible that he or some subsequent owner may wish to put the building to a use involving heavier loads. The building official should be required to issue, and the owner to display prominently in each story of a building, permanent notices giving the safe load. The occupant should be held strictly responsible for overloading, but it is also the duty of the building official so far as practicable, to prevent this. If the actual loads are checked occasionally by the inspection force, as should be done, it is believed that failures due to overloading will for the most part be prevented and the responsibility for such failures as do occur will be more readily established.

It is suggested that metal placards similar to automobile number plates will be most suitable for such purposes, and it is recommended that issue of an occupancy permit for a building be made conditional on the display of an adequate number of such notices.

A suggested form of notice is shown in Figure 1. In this notice the figure will, of course, vary with the conditions. The date in the lower left-hand corner should correspond with the time when the posted floor capacity was approved. It serves merely to find the record of approval readily, when that may be necessary or desirable. It might be replaced by an official record number if there is such. In the lower right-hand corner should appear the name and title of the official who issued the placard. A suitable size for the placard would be 8½ by 11 inches. This would make the figure (the outstanding feature) 1¾ inches high, the lettering of the three principal lines one-half inch high, and that of the lower (secondary) lines one-fourth inch high.

The design of different portions of a floor and its supporting members for varying uniform live loads should be permitted only when the portions in question are separated by a permanent partition or wall so that the higher loading may not carelessly be extended over a floor space not designed to support it.

THIS FLOOR WILL SAFELY SUSTAIN
150
POUNDS PER SQUARE FOOT
UNIFORMLY DISTRIBUTED

IT IS UNLAWFUL TO PLACE ANY
GREATER LOAD ON THIS FLOOR
OFFENDERS ARE SUBJECT TO PROSECUTION

OCTOBER
1924

JOHN DOE
BUILDING INSPECTOR

Fig. 1.—*Recommended form of floor-load placard*

Par. 12. Occupancy Permits.

When the design load for which each part of a building is designed is shown on the plans it facilitates checking by the building official and helps to prevent misunderstandings. It is also easier to ascertain the allowable floor loads if the building occupancy changes at some later date.

Recommendations as to the use of occupancy permits in code enforcement work are somewhat outside the scope of this report. The committee is unanimous in considering them essential to effective control of building construction, and has called attention in Part II to their usefulness in floor load regulation.

Where municipal inspection is effective, the owner is required to report changes in character of occupancy, and occasional inspections are made to detect overloading. There is much evidence that this is necessary if public safety is to be assured. Data from numerous sources indicate that overloads are common in manufacturing and storage buildings and show that requirements governing original construction must be supplemented by periodical inspection and the checking of occupancy changes if dangerous conditions are to be prevented.

Par. 13. Impact Allowances.

Tests of the impact blows produced by trucks moving at various speeds were made by the United States Bureau of Public Roads and are reported in "Public Roads," March, 1921. These tests showed that up to 10 miles an hour on a level surface the load is practically static. When a solid-tired truck passes over a one-half inch obstacle, no increased load due to impact need be considered up to a speed of 5 miles per hour. A review of available information leads to the conclusion that no impact allowance is necessary in the design of garage floors.

The live loads specified in Part II are intended to include a sufficient allowance to cover the effect of impact. In the case of special occupancies involving unusual impacts a provision for this may well be made by increasing the loads herein specified.

Several of those reviewing the tentative draft of this report have expressed the view that buildings designed for low live loads will be too flexible and that vibration due to dynamic loads, particularly in theater balconies and similar places, may seriously alarm the occupants. Several cases are reported of buildings which have required alterations for this reason. There is no evidence, however, that vibration indicates dangerous conditions. A well-built structure may be flexible; and the absence of vibration does not necessarily prove that a building is safe. Two structures may be equal in strength, but may differ in stiffness, particularly if one is of cantilever type.

When it is desirable for any reason to avoid vibration or undue deflection, care should be taken to that end by designing for greater live loads or by using more braces. Safety considerations, however, on which code requirements are based, do not justify live-load assumptions greater than those given in Part II.

1. Experiments were made at Iowa State College in 1921 and 1922, under supervision of Almon H. Fuller, professor of civil engineering, to determine the stress increases caused by crowds in rhythmic concerted motion such as may characterize the cheering sections at university games or in fact any crowd under general stimulus of excitement or alarm.

Thirteen different investigations were made with groups of men on a balcony framed on steel beams, supported at one end on a masonry wall and at the other end by tension rods suspended from roof trusses. Extensometer measurements on the floor beams and the suspension rods showing increased stresses due to dynamic loading are given in Table 8.

TABLE 8.—*Extensometer investigation of live load and impact stresses due to crowded loadings on balcony of the gymnasium of Iowa State College* [1]

Experiment number	Nature of dynamic load	Number of observations	Number of men	Total weight	Floor area occupied	Weight per square foot	Stress in suspension rod: Due to static load	Stress in suspension rod: Total static and dynamic effect	Stress in suspension rod: Stress due to dynamic effect	Stress in floor beam: Due to static load	Stress in floor beam: Total static and dynamic effect	Stress in floor beam: Stress due to dynamic effect
				Pounds	*Sq. ft.*	*Pounds*	*Kips*	*Kips*	*Per cent*	*Kips*	*Kips*	*Per cent*
1	Crowd rising on toes and dropping on heels at 2-second intervals	10	23	3,637	[2] 40	[2] 90				2.75	3.45	25
2	Crowd starts by rising on heels and ends by jumping at 1-second intervals	10	23	3,637	[2] 40	[2] 90	4.5	6.0	35	2.85	5.65	100
3	Crowd rising on toes and dropping on heels at 1-second intervals	10	23	3,637	[2] 40	[2] 90	2.25	3.2	40	2.75	4.8	75
4	Crowd swaying in standing position at 5-second intervals	10	23	3,637	[2] 40	[2] 90	1.1	1.8	70	3.7	5.2	40
5	Crowd teetering on toes, at 5-second intervals	10	41	6,300	54	116	2.1	5.6	165	5.6	14.2	155
6	Crowd rises from chairs. Floor space entirely filled with chairs	2	41	6,300	163	39	1.9	3.0	50	5.2	7.5	45
7	Crowd teetering on toes, 1-second intervals	9	81	12,100	132	92	3.8	5.3	40	9.7	13.2	35
8	Crowd teetering on toes, followed by jumping	5	81	12,100	132	92	3.8	7.5	100	9.7	21.7	125
9	Similar to 8	10	81	12,100	132	92	3.6	6.6	80	9.1	16.2	80
10	Crowd swaying from side to side	10	81	12,100	130	93	3.5	3.8	10	8.4	10.0	20
11	Crowd giving college yell, standing position	10	81	12,100			3.5	4.8	40	8.4	12.0	45
12	do	10	81	12,100			3.1	4.3	40	8.2	12.3	50
13	Crowd sitting on chairs rising suddenly together	2	70	10,500	235	45	2.9	4.5	55	6.8	9.2	35
14	Crowd teetering on toes						2.2	3.0	35			
15	do	Crowd gradually collecting					2.7	4.2	55	6.0	9.4	55
16	Crowd jumping mildly						3.0	7.5	150	7.5	15.7	110
17	Crowd teetering on toes	11	95	14,250	161	89	3.9	5.1	30	9.9	13.2	35
18	do	8	95	14,250	161	89	3.9	7.0	80	9.5	21.7	130
19	Crowd cheering	8	95	14,250	161	89	4.2	4.8	15	9.0	11.2	20
20	Crowd cheering (mildly)	8	95	14,250	161	89	4.8	5.4	10	9.5	11.0	15
21	Crowd cheering (vigorously)	8	95	14,250	161	89	4.8	7.5	55	9.5	14.0	50
22	Crowd cheering (pantomine)	8	95	14,250	161	89	3.9	5.3	35	9.0	10.8	20

[1] Made by 1921 and 1922 senior classes in civil engineering under supervision of faculty.
[2] About.

2. R. Moreland, in London Engineering, recounts that in the course of an experiment about 1900, 90 men were crowded into a space of 112 square feet on a large scale platform. The average weight was 100 pounds per square foot. They were asked to jump up and down, and the scale beam registered 150 pounds per square foot due to impact. The men then ran four abreast across the platform, but registered no increase over the 150 reading.

3. In the experiments by C. J. Tilden, of Yale University,[5] men of varying weight were placed on scale platforms, the scales were balanced and they were then asked to rise quickly from a crouching to a standing posture. The increased weight registered by the scale beam averaged 66 per cent of the static weight, with variations from 45 to 80 per cent. The men were then asked to rise from a sitting to a standing posture. The average weight increase registered was 79 per cent, with variations from 61 to 122 per cent.

Individuals were then asked to stand on the scale platforms and jump up and down in such manner as to produce the greatest possible effects. The average increase thus caused over static weight was 174 per cent. Mr. Tilden points out that while this last effect was much more than the others, it is extremely unlikely that the movements of a number of individuals would occur coincidently. Investigations of the horizontal impulse exerted by persons rising suddenly from their seats showed that they might exert a backward horizontal push, about equal to one-half their weights, for a very brief period of time. Similarly, the horizontal force exerted by a man in walking will be approximately one-half his weight exerted for a small fraction of the time during which he passes over a given space.

4. Tests were made on three different bridges of the lateral forces exerted by men running from one side to another as might occur in watching a boat race beneath. The bridges were of different widths varying from 17 feet to 68 feet. The average velocity of movement in feet per second was from 10.8 to 13.7 and kinetic energy amounted to an average of 360 foot-pounds for a man of 144 pounds weight. The acceleration and deceleration were accomplished within a space of from one-quarter to one-fifth of a second and a horizontal force was exerted during that period of about 150 pounds. If deceleration were accomplished in a much shorter space of time, the lateral force might amount to several hundred pounds.

Where vibration is pronounced, the ratio of dead to live load should be increased as much as possible, and particularly good workmanship should be required for masonry walls and piers.

The relation between the mass of the live load and the mass of the structure must be considered in judging the application of impact tests to design.

[1] Transactions of A. S. C. E., Vol. LXXVI, p. 2107 (1913).

Par. 14. Effects of Lighter Load Assumptions on General Stability

Consideration was given to the possibility that design for less than customary loads might result in structures too light and flimsy from the viewpoint of general construction requirements, such as stability and fire resistance. It was decided that the changes proposed do not affect the safety of buildings. The relation of dead load stress to live load stress in fire-resistive construction is great enough so that no considerable decrease in stability, as conferred by weight of materials or rigidity of framing, will occur. The protection of structural members from fire effects is entirely independent of load and stress considerations. If a building is adequate under normal conditions to carry its assumed live loads with a reasonable factor of safety for stresses, and if its structural members are well protected, it will endure a fire successfully. Wooden joists subject to fire will not be seriously decreased in cross section during the period ordinarily necessary to vacate the building.

Par. 15. Load Assumptions Unrelated to Stress Requirements.

Code requirements for live load assumptions frequently are increased above what may ordinarily be expected, to offset the effects of unusually liberal working stress requirements elsewhere in such ordinances. In other cases the situation is reversed, and stress requirements are rigid to prevent dangerous conditions in structures designed for less than actual loads. The committee takes the stand that these are independent considerations and should be so treated. Live load requirements should be adopted with reference only to the probable actual conditions of use. Stress limits should be based on the known ultimate strength of materials with due reference to workmanship and use conditions affecting uniformity and durability of the material.

Par. 16. Weight of Construction Materials.

An understanding between designer and building official as to the weights of construction materials is necessary and desirable for purposes of code enforcement. Provision for this does not come within the scope of the report. It is suggested, however, that a section somewhat as follows should be included in a building code.

In the absence of definite information establishing the weights of construction materials which are to be used the following unit weights shall be assumed.

	Pounds per cubic foot
Brickwork, solid	120
Concrete, plain or reinforced	150
Cinder concrete	84
Douglas fir, cypress	36
Oak, yellow pine, maple, birch	48
Spruce, hemlock	30
Hollow gypsum partition block	48
Hollow tile partition block	60
Plaster and mortar	96

Other materials and equipment entering into the dead load of the building shall be taken at their unit weights as given by the manufacturer.

DEPARTMENT OF COMMERCE

WASHINGTON

PUBLICATIONS IN RELATION TO HOUSING AND MUNICIPAL REGULATION

[These publications may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., payments to be made by money order or New York draft; currency at sender's risk. Postage or foreign money not accepted.]

Recommended Minimum Requirements for Small Dwelling Construction.
By the Building Code Committee: Ira H. Woolson, chairman; Edwin H. Brown, William K. Hatt, Rudolph P. Miller, J. A. Newlin, Ernest J. Russell, and Joseph R. Worcester. 30 illustrations. 108 pages. Government Printing Office, Washington. Price, 15 cents.

Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings.
By the Subcommittee on Plumbing: George C. Whipple, chairman; Harry Y. Carson, William C. Groeniger, Thomas F. Hanley, and A. E. Hansen. 100 illustrations. 250 pages. Government Printing Office, Washington. Price, 35 cents.

Recommended Minimum Requirements for Masonry Wall Construction.
By the Building Code Committee: Ira H. Woolson, chairman; Edwin H. Brown, William K. Hatt, Albert Kahn, Rudolph P. Miller, J. A. Newlin, and Joseph R. Worcester. 4 illustrations. 57 pages. Government Printing Office, Washington.

A Zoning Primer.
By the Advisory Committee on Zoning: Edward M. Bassett, Irving B. Hiett, John Ihlder, Morris Knowles, Nelson P. Lewis, J. Horace McFarland, Frederick Law Olmsted, and Lawrence Veiller. 12 pages. Government Printing Office, Washington. Price, 5 cents.

A Standard State Zoning Enabling Act, under which Municipalities may Adopt Zoning Regulations.
By the Advisory Committee on Zoning. 12 pages, Government Printing Office, Washington. Price, 5 cents.

How to Own Your Home.
By John M. Gries and James S. Taylor, with a foreword by Herbert Hoover, viii plus 28 pages. Government Printing Office, Washington. Price, 5 cents.

MIMEOGRAPHED MATERIAL

A list of zoned municipalities and references to State laws relating to zoning is kept by the Division of Building and Housing, Department of Commerce, Washington, and copies may be obtained on application.