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CANADA

DIVISION OF BUILDING RESEARCH

FLOORING DAMAGE BY HEELS

BY

ANALYZED

H. J. THORBURN

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Flooring Damage by Heels*

By H. J. THORBURN

THE SHAPE OF women's shoes has undergone distinct changes during the past few years: the toe has evolved into a form approaching a weapon, and the heel has become so tall and thin that the term "stiletto heel" is almost as accurate as it is descriptive.

The technical significance of the slimming of heels lies in the sharp reduction in the contact area of the heel on the ground or floor surface. Since presumably the weight to be carried by the heel is a variable only within fashionable limits, a reduction in the bearing area must be accompanied by a corresponding increase in the contact pressure. Signs and reports of the effects of stiletto heel pressures are by no means rare. Asphalt walkways and fillers between flagstones frequently reveal tell-tale effects. Such relatively soft materials are not the only victims, however, for many common flooring materials have suffered extensive damage. The Boeing Aircraft Co. has reported that the aluminum floor panels in its jet liners are beginning "to look like waffle irons" from the repeated impact of stiletto heels.

Probably the most widespread stiletto heel damage is to various types of floors in buildings. In the Building Research Centre, which houses the Division of Building Research of the National Research Council in Ottawa, Canada, some floor areas have been indented and some have had to be replaced. The Division decided the problem warranted the attention of a wider audience and initiated an investigation into (1) the nature and magnitude of the heel pressures applied to the flooring and (2) a comparison of these with the allowable pressures on various flooring materials and with the pressures applied in some standard test methods. The main purpose of this report is to stimulate discussion of the problem; the fact that this paper reports on damage caused to linoleum tile should not be interpreted as an indication of absence of damage

Extensive damage to flooring caused by the stiletto heels of women's shoes can be traced to the high pressures produced by heel diameters as small as $\frac{1}{4}$ in. These pressures, which reach 2000 to 3000 psi, are compared with other pressures. Some suggestions are made to those responsible for selecting flooring materials.



Fig. 1.—Perpendicular indentations.

in other flooring materials. The damage reported is merely an example of the type of problem currently encountered in practically all organic floorings.

Nature of the Load

Examination of damaged floors indicates two general types of indentation: (1) those made with the heel perpendicular to the floor (Fig. 1), and (2) those made with the heel at an angle to the floor and in contact only along one edge (Fig. 2). Although only static or quasi-static loads have been considered in this paper, dynamic or impact loads

can undoubtedly cause damage also. This has not been the case, however, in the Building Research Centre in Ottawa, where the corridors and stairs are covered with hard materials such as terrazzo.

Types of Heels

Aside from the magnitude of the load, any damage that occurs depends on the type and condition of the bearing surface of the heel. Two damaging types of heel surfaces have been common: (1) cylindrical metal tips fastened to the body of the heel with a screw or other device (Fig. 3), and (2) a thin metal shaft extending from the body of the heel and enclosed in a washer-shaped piece of compressible material (Fig. 4), which, when new, extends slightly

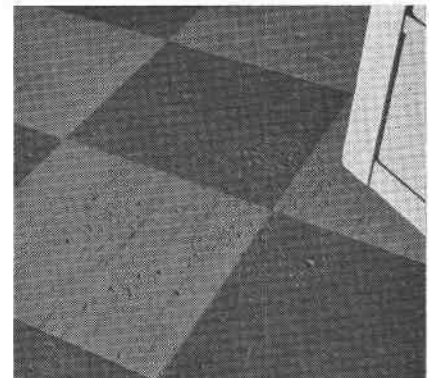


Fig. 2.—Angular indentations.

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* This paper is a contribution from the Division of Building Research, National Research Council, Canada, and is published with the approval of the director of the Division.

HERBERT J. THORBURN was graduated from the University of British Columbia in 1958 with a B.A.Sc. degree in civil engineering and subsequently joined the Building Structures Section of the Division of Building Research of the National Research Council of Canada. His work consisted of studies of snow loads on roofs of buildings and investigations of strength and deformation characteristics of wood-frame roof constructions. In his studies of the loads acting on building structures, he came across the problem of the loads produced by women's shoe heels. In 1961 he left the National Research Council to accept an Athlone Fellowship for postgraduate studies at the University of Bristol in England.

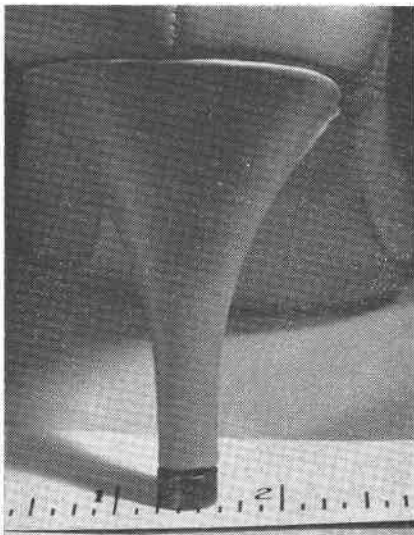


Fig. 3.—Metal-tipped heel (scale in inches).

beyond the end of the shaft. Since both these types can be considered in either a new or worn condition in reviewing the damage, there are four possible heel-bearing surfaces which can exert either perpendicular or angular pressure.

The most damaging combination of these variables is a new metal tip applying the load at an angle to the floor. Although the total load transferred by the heel at an angle is not large, the exposure of the sharp edge of the tip to the floor has a knife-like effect. Frequently such an exposure is accompanied by a rocking motion that adds substantially to the cutting action and leaves marks that are usually crescent-shaped, fairly deep, and very noticeable (Fig. 2). Well-worn metal tips with rounded edges have a similar but less damaging effect.

Another damaging combination is a worn shaft-and-washer heel applying a load perpendicular to the floor. Since the compressible washer wears away more rapidly than the metal shaft, the exposed shaft on the bearing surface of the heel exerts very high unit pressures on the floor (Fig. 5).

Probably the least damaging stiletto heel is a new shaft-and-washer heel. Unlike the same heel in a well-worn con-

dition, it transfers much of the load through the compressible washer when perpendicular to the floor. An even larger part of the load is carried by the washer when this heel is at an angle to the floor, thus making it relatively harmless.

Magnitude of Pressures

For the heel perpendicular to the floor two means of determining the pressures were used. In the first, it was assumed possible for a large part of the weight, say 80 per cent, of a 120-lb girl, to be transferred through one heel.

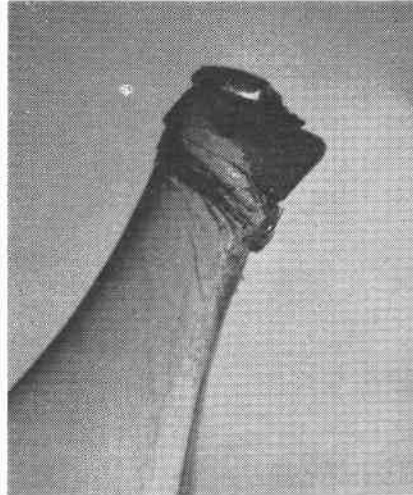


Fig. 4.—Shaft-and-washer heel (worn).

Thus, if the heel is a well-worn shaft-and-washer type with a shaft diameter of $\frac{3}{16}$ in., or an area of 0.0276 sq. in., the initial bearing pressure is 3500 psi. Thinner shafts, larger weights, and higher pressures are quite possible. A pressure of 3500 psi might be compared with a pressure of 20 to 30 psi exerted by the tire of an automobile, or with the pressure of 50 to 100 psi developed under an elephant's foot, or with the allowable bearing stress on concrete, approximately 1500 psi.

The calculated pressure of 3500 psi is initial, because as soon as some indentation occurs, the worn part of the heel comes into contact with the floor, the bearing area increases, and the bearing pressure decreases to a value approaching that for a new or slightly worn shaft-

and-washer or metal-tipped heel. On the basis of the same weights being transferred by a $\frac{3}{8}$ in. diam heel surface (Fig. 3), the bearing pressure would be 900 psi. Diameters down to $\frac{1}{4}$ in. (2000 psi), however, are not uncommon.

A second method of approximating the pressure involves duplication of the actual indentations by an apparatus applying a known force through a known area (Fig. 6). For a bearing area of 0.20-in. diam, a force of 30 to 40 lb, or a bearing pressure of 1000 to 1200 psi, was required to produce an indentation similar to the actual heel indentation.

Calculation of the pressures applied by a heel at an angle to the floor is difficult because of the wide variability of load and area. The load transferred to the floor can be any value up to the full weight, or more, with impact, while the bearing area can be as little as a knife-edge.

Comparison of Pressures

A comparison between the pressures applied to flooring by stiletto heels

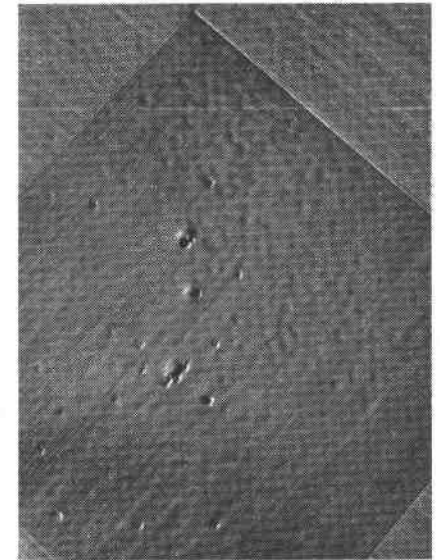


Fig. 5.—Indentations due to worn shaft-and-washer heels.

TABLE II.—MAXIMUM SAFE LOADS FOR DETERMINING THE PROPER SIZE OF FURNITURE RESTS.^a

Type of Flooring	Allowable Pressure, psi		
	25 ^b	25 ^c	25 ^d
Asphalt tile.....	25	25	25
Vinyl asbestos tile.....	25	25	25
Vinyl tile, regular backed... 75	75	75	75
Vinyl tile, homogeneous... 200	200	200	200
Rubber tile.....	200	200	200
Linoleum tile.....	75	75	75
Cork tile.....	75	75	75

^a Based on recommendations by manufacturers of resilient floorings.

^b "Installation and Maintenance of Resilient Smooth Surface Flooring," *Publication No. 597*, Building Research Inst., Nat. Acad. Science—Nat. Research Council, Washington, D. C. (1958)

^c "Which Floor... Where?," *Institutions Magazine*, Vol. 48, No. 3, March, 1961, p. 116.

^d D. E. Smalley, "Floor Maintenance Manual," 4th edition, Milwaukee Trade Press Publishing Co., 1959.

TABLE I.—STILETTO HEEL PRESSURES OF TWELVE WEARERS.^a

Size of Heel, mm	Area of Heel, sq in.	Material of Heel	Weight of Person, lb	Unit Pressure on One Heel, psi
11 by 12	0.161	leather	150	930
11 by 11	0.148	leather	115	780
9 by 8	0.038	steel	122	1390
10 by 10	0.122	leather	115	940
10 by 10	0.122	leather	123	1010
10 by 10	0.122	steel	130	1070
7 by 7	0.0597	steel	135	2260
9 by 11	0.122	leather	110	900
8 by 9	0.0878	steel	120	1370
14 by 15	0.255	leather	139	550
9 by 9	0.0986	steel	106	1070
11 by 13	0.175	leather	112	640

^a "Random" sample taken from the staff of the Division of Building Research.

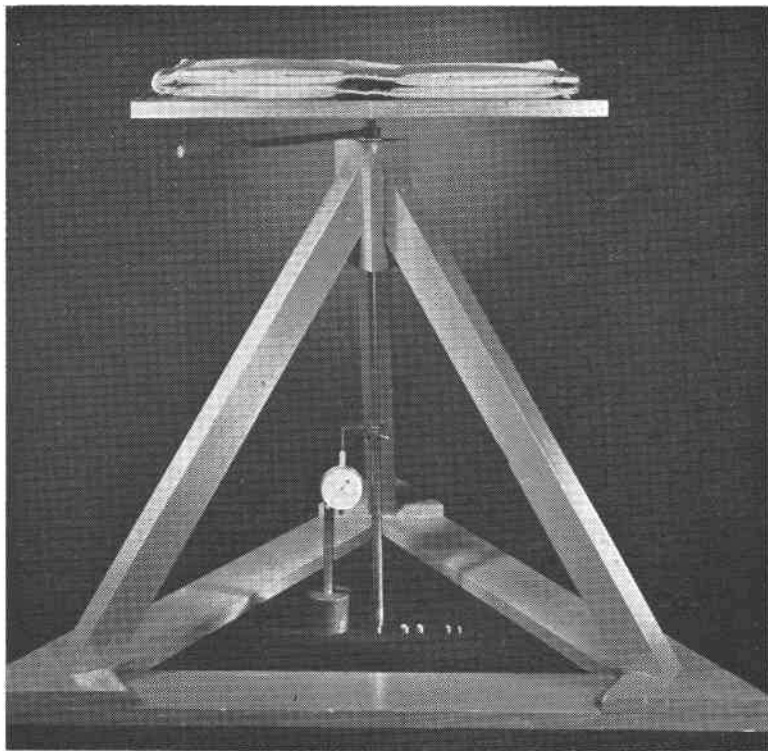


Fig. 6.—Heel load simulator.

(Table I) and the recommended allowable indentation pressures for various flooring materials (Table II) reveals a wide discrepancy. Values in Table II are based on static, long-time pressures recommended by flooring manufacturers, and are applicable to flooring materials at normal temperatures. Higher floor temperatures resulting from direct sunlight or other heat sources would probably call for a reduction of the allowable

pressures of some materials. The flooring in Fig. 1 was subjected to these conditions.

Another comparison can be made with the pressures ranging from 1300 to 3200 psi used in the indentation tests recommended in Canadian standard methods for testing flooring. These indentation tests, however, are expected to indent or damage flooring and are not related to the stiletto heel pres-

ures encountered in service; the pressures are used to measure initial hardness of the material, to measure its resilience, and to determine whether it is properly cured.

Discussion

Although banning or capping heels could be considered a solution to the problem of damage to flooring, the choice of floor materials that can resist the loads would seem to be a better solution, since, without policing, the former method offers uncertain success. The choice of acceptable materials with good indentation resistance is limited, however, because other factors such as cost, comfort, noise, location, and use must be considered.

The problem of damage to flooring by stiletto heels is primarily of concern to the building owner, but, since a solution to the problem involves the choice of a flooring material, it must also be appreciated by architects and others who select flooring. It is suggested that flooring manufacturers should (1) recommend the type of flooring that offers the best recovery from indentation, (2) help the customer select patterns or colors which hide or subdue marks that remain after being exposed to stiletto heels, and (3) suggest materials that possess low-gloss surfaces.

Acknowledgment:

This paper has been prepared with the assistance of G. K. Garden of the Construction Section and W. R. Schriever and W. A. Dalgliesh of the Building Structures Section.

Discussion

MR. PAUL KLIENER.¹—Mr. Thorburn and the Division of Building Research, National Research Council, Canada, are to be commended for their thorough analysis of a problem that has been plaguing architects and building maintenance engineers in recent years.

Mr. Thorburn, in discussing heel pressures and the ability of various surfaces, to resist these pressures, states that “. . . the allowable bearing stress on concrete [is] approximately 1500 psi.” Concrete floors can be and are built to withstand considerably greater than 1500 psi bearing stress. Detailed

information on this subject is available in “Concrete Information,” American Institute of Architects A. I. A. File No. 4-E-6, contained in Sweet’s Catalog. Since Mr. Thorburn’s major conclusion is that the problem of damage by heel pressure can best be solved by the proper selection of flooring material, the information relative to terrazzo and concrete contained in that file should be of value to architects and building owners.

MR. F. M. GAVAN.²—Mr. Thorburn is calling attention once again to a problem that was rather serious from our standpoint but has become less acute with time because of (1) changes to the very style that brought it about, and (2) the good sense of the public in realizing that this was primarily a matter of style

and shoe design and not the intrinsic quality of the affected floorings.

When reports of damage by pencil or stiletto heels first reached us several years ago, we immediately launched an investigation to determine if our flooring materials were at fault. The same action was probably taken by other producers in this industry. It did not take too much effort to learn that the damage was real but that it applied to almost every type of flooring.

Our laboratory tests plus reports from the field indicated that stiletto heels have been known to damage all types of floorings, that wood flooring is affected critically, and that carpeting as well as marble floors have come in for a fair share of the complaints. In addition to the indentations caused by static

¹ Manager, Field Research Section, Portland Cement Assn., Research and Development Laboratories, Skokie, Ill.

² Manager, Physical Test Dept., Research and Development Center, Armstrong Cork Co., Lancaster, Pa.

stresses, considerable marking has resulted from the dynamic loads developed in the mere act of walking on these heels. Examples of these markings have been noted in the halls and corridors of buildings where large numbers of female secretaries, typists, and clerks are employed.

The dynamic marking is particularly noticeable when made by the three protruding nail heads visible on a heel when the leather or rubber lift has been worn away. The pressure exerted by one of these nail heads can be as great as 12,000 to 60,000 psi.

Aside from recommending that these heels not be worn when walking over sensitive floorings, our principal action has been to recommend a selection of floors which would not show these indentations so readily. This information has been regularly published in the *Armstrong Technical Data Book* for the last several years, and the reader is referred to page 22 of the 1961-1962 issue (AIA File No. 23G) for the latest word on the subject. It is gratifying to note that Mr. Thorburn's recommendations agree with our statements in that document.

We feel that it should be made quite clear that the static load pressures published by the various manufacturers are not related directly or indirectly to the question of marking by stiletto heels. As Mr. Thorburn has intimated, they are made primarily for the purpose of selecting the proper furniture rests, and in our company they are based on a combination of tests used to arrive at broad recommendations. The effect of temperature is recognized, but this is controlled by statements on the limiting floor temperature (85 F) such as is given on page 28 of our manual.

Since the Canadian standard methods mentioned by Mr. Thorburn were not cited, it is not possible to say exactly what they contain. In our own Federal specifications the standard methods for indentation testing of floorings are absolutely not related to the damage due to spike heels. Indentation tests in the Federal specifications are required for three purposes:

1. To measure the initial hardness of the material.
2. To get a measure of its resilience.
3. To determine whether it is properly cured or consolidated.

Therefore, a variety of pressures and indentation tips are used for these several purposes across the whole line of resilient floorings. In these tests the unit pressure is not translatable since it is rheological. The pressure is a function of the test made for a particular purpose and has no relation to the pressures encountered in service.

³ Engineer, U. S. Forest Products Laboratory, Madison, Wis.

Nevertheless, it is with pleasure and some relief that we note that these extreme heels are going out of fashion, and the trend is to much larger heels and more comfortable shoes.

MR. J. A. LISKA.³—There are few moderate-cost flooring materials that are not affected by women's stiletto heels. However, the density and hardness of modern hardwood floors are important factors in resisting these impacts. The following values, taken from the *Wood Handbook*, indicate the properties at 12 per cent moisture content of species commonly used in flooring manufacture:

Species	Specific gravity	Hardness (load required to embed a 0.444-in. steel ball to one half its diameter), lb
White ash	0.60	1320
Beech	0.64	1300
Yellow birch	0.62	1260
Pecan hickory	0.66	1820
Sugar maple	0.63	1450
Red oak	0.63	1290
White oak	0.68	1360
Black walnut	0.55	1010

While hardwood floors are not entirely free from damage caused by women's heels, they are more resistant to indentation than many other materials and have certain advantages which should be considered in comparing the performance of various floor coverings. Temperature changes, for example, have little or no effect on the hardness of these hardwood species. Most types of wood floors can be resurfaced and refinished under extreme damage conditions. The new polyurethane finishes are well adapted for floor finishes and have the capacity to resist surface scuffs.

SPIKE HEELS are causing so much damage in various office buildings and plant offices that drastic measures are being taken by some establishments. It seems that rubber or plastic caps that fit over the heels offer insufficient protection to floors. A ban has been placed by a number of business concerns on the wearing of spike heels. Women who show up for work in spikes are required to change to other shoes before entering, or are sent home and docked a day's pay. The maintenance man just can't cope with harm to floors by indentations that cannot be removed by any known method."

From *Consumer Bulletin*, January, 1962, p. 3

Modified woods, such as resin-treated Impreg or resin-treated compressed wood (Compreg), have higher specific gravities than normal woods. Furthermore, their hardness is greatly increased—Compreg from 10 to 20 times that of normal wood. While these treatments are costly at the present time and produce a slippery surface, continued research will aid in the development of other resistant surfaces for wood flooring. In line with these developments, the lobby of the Forest Products Laboratory is surfaced with wood floor tiles made of plywood faced with resin-impregnated paper. For nearly a decade, this experimental floor has taken the stabs and scuffs of many types of footwear with little or no surface marking. This may be one answer to floors that can resist the stiletto heels of the fair sex.

SELECTED BIBLIOGRAPHY

- (1) Aeroweb Metal Honeycomb CIBA (A.R.L.) Limited (Advertisement), *The New Scientist*, Vol. 9, No. 221, Feb. 9, 1961.
- (2) D. M. J. Davidson, *Floors and Flooring* (2nd edition), Crosby Lockwood, London, 1958.
- (3) H. Elftman, "The Measurement of the External Force in Walking," *Science*, Vol. 88, No. 2276, 1938, pp. 152-153.
- (4) F. C. Harper, "Floor Finishes," *Journal*, Royal Institute of British Architects, Vol. 58, No. 5, March, 1951, pp. 182-186.
- (5) F. C. Harper, W. J. Warlow, and B. L. Clarke, "The Forces Applied to the Floor by the Foot in Walking—Part I, Walking on a Level Surface," National Building Studies, *Research Paper 32*, Her Majesty's Stationery Office, London, 1961.
- (6) T. S. Holden and R. W. Muncey, "Pressure on the Human Foot During Walking," *Australian Journal of Applied Science*, Vol. 3, 1953, pp. 405-417.
- (7) H. M. Llewellyn and F. C. Harper, "Floor Finishes for Houses and Other Nonindustrial Buildings," National Building Studies, *Bulletin No. 11*, London, 1950.
- (8) P. A. Sigler and M. B. Woodward, "Indentation and Recovery of Low-Cost Floor Coverings," Building Materials and Structures, *Report BMS 14*, National Bureau of Standards, Washington, D. C., 1939.
- (9) P. A. Sigler and M. B. Woodward, "Indentation Characteristics of Floor Coverings," *BMS 73*, National Bureau of Standards, Washington, D. C., 1941.
- (10) B. R. Stewart, O. R. Kunze, and P. Hobgood, "Indentation and Recovery Tests of Common Resilient Floor Coverings," *Bulletin No. 961*, Texas Agricultural Experiment Station, College Station, Tex., August, 1960.