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FIRE DAMAGE TO BUILDINGS - SOME STATISTICS

by

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SUMMARY

A random sample of about 5000 fires confined to the room of origin has been examined to establish the amount of fire damage to the building fabric. Overall, only 30 per cent of the fires caused damage to the building but this figure varies with the occupancy of the building. The distribution of damage to the various building elements (floor, wall, ceiling and roof) is studied.

Key word: Fire Damage

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INTRODUCTION

Building regulations and other building controls rely on passive fire protection to provide an adequate degree of safety in buildings against fire by protecting the structure, providing compartmentation, protection of escape routes, etc. This fire-resisting protection is only required for fires which would otherwise cause damage to the protected element, corresponding roughly to those fires which have become fully developed.

Baldwin and Allen[1] in a pilot survey have analysed a small sample of brigade reports in order to obtain estimates of the proportion of fires in which damage occurred to the building fabric and of the severity of damage. The sample was too small to obtain other than indicative estimates or to examine the differences between occupancies, but the results were sufficiently encouraging to justify a more extensive survey. This is the subject of the present paper.

DATA

From the fires reported to the brigades during 1967, only those which were confined to the room of origin were considered for the present work, since this provided a more homogeneous sample. This restriction must, however, be kept in mind throughout this note, since it materially affects the distribution of the data. A random sample of the original reports from England and Wales was studied to extract details of damage done to the building by fire and heat; smoke and water damage being ignored. This damage was then coded and a computer analysis of the data performed. Thus, our data involves a subjective element: first, in the fireman's account of the actual damage and, second, in our interpretation and codifying of this account, reflected in the system of classification described below. These errors have been minimized by the use of a large number of reports and will not seriously affect the results.

Only damage to the fabric of the building was considered for this exercise but 'structural damage' has been taken to include such minor effects as damage to wall plaster and does not necessarily imply any threat to the stability or integrity of the building, i.e. it is all fire and heat damage other than that occurring to the contents and fittings. This damage was sub-divided according to the building 'element' affected; these elements being walls, floors, ceilings and roofs. For each element, ideally there was specified an area of damage and a severity of damage over this area. The severity, where stated, will fall into one of five classes, these being:

i) No damage to the element

ii) Surface damage. This includes serious damage which is confined to the covering of an element, e.g. plaster, wall/ceiling/roof linings, etc.

iii) Slight damage to the element

iv) Severe damage to the element

v) Destruction or collapse of the element.

The severity of the damage was a subjective estimate based, usually, on the fireman's original estimate. Otherwise, the destruction of some parts of an element has been considered 'severe' damage. The classification is necessarily imprecise but does provide some additional information.

For some fires, less information was available. Out of the 5312 fires considered, 433 reports gave only the severity of damage, 59 reports gave the extent of damage as a percentage and, in 116 cases, it proved impossible to classify the damage.

ANALYSIS

It is possible to subdivide the fires by the occupancy of the building, which is allocated to the groups shown in Table 1. The number of fires in the sample falling into each group and the proportion suffering structural damage are given in Table 2. Between one-half and three-quarters of the sampled fires did not cause structural damage, with most groups lying between 65 and 75 per cent.

The maximum severity of damage to any building element in each building was examined and the results given in Table 3 as a proportion of all fires in that occupancy group (excluding fires which caused no damage). The maximum severity of damage in a given fire was defined as the highest severity rating amongst the elements reported as damaged, and is relevant because failure is most likely to occur where damage is most severe.

The proportions were broadly similar for all groups, with the exception of the industrial group, where the proportion of destroyed elements was greater, and the storage group, where a low proportion of surface damage was allied to a high proportion of severely damaged elements. In general terms, it may be said that, of those fires which caused some structural damage, about 40 per cent caused slight damage; surface damage and severe damage each occurred in about 25 per cent of fires, and the destruction of some part of the element occurred in about 10 per cent of cases.

The distribution of the total area of damage to all elements in each building is given in Table 4. It will be seen that there are wide variations in the mean area of damage between the different occupancy groups; three groups having means of about 5 ft^2 (0.5 m^2); another three, values between 20 and 30 ft^2 (1.9 to 2.7 m^2); one with a mean of about 60 ft^2 (5.5 m^2) and the last with about 160 ft^2 (15 m^2). Offices have a low fire-load and are usually considered not to cause much damage to the structure: however, the present data appear to show an area of damage of about five times the average value, but this difference is due largely to the single fire which damaged more than 1000 ft^2; if this had been excluded from the sample, the mean area of damage for offices would have been 11.8 ft^2 (1.1 m^2), an average figure.

The 'total' column of Table 4 can be fitted by the probability distribution function:

$$q\ (A) = A^{-0.26 - 0.15 \log A}$$

where q (A) is the proportion of fires which cause A ft^2, or more, of damage (fires with zero damage being excluded). This distribution is of the same form as that used for fire losses[2] and for the number of sprinkler heads opening in fires[3]. It might be expected that fire damage would be related to these other features, since all of them will be affected to some extent by the size of the fire.

The severity of damage to individual building elements is given in Table 5 and these figures are expressed in a proportional form in Table 6. It can be seen from the former that about 5 per cent of fires led to damage of the walls, ceiling or roof; while 12 per cent damaged a floor. In houses, which form about two-thirds of the sample, the items in which a fire may start will be mainly on, near or under the floor, which is often constructed of timber. Although convection will remove heat from the fire without affecting the floor, the other forms of heat transfer will affect the floor at short range. Thus, it might be expected that a comparatively high proportion of fires will affect the floor, while its construction and coverings are fairly flammable and liable to fire damage. The walls will be somewhat less frequently close to the initial fire and their construction makes them unlikely to be seriously damaged by a small fire. This is indicated in Table 6, where the proportion of walls suffering only surface damage is seen to be large. Ceilings are still further from the fire and so less affected by flames. They have a plaster surface which may be affected by heat but offers some protection to the timber behind it. This is shown by the high proportion of surface damage (Table 6), although other severities of damage are higher than for the incombustible walls. A fire in a house which is confined to the room of origin and damages the roof must, of course, have started in the roof, where it is surrounded by timber framework and is thus able to easily damage the roof timbers. This is reflected in the figures for severity of damage (Table 6), where the proportions of damage to roofs and floors are similar. We can thus divide the building elements into two classes on the basis of damage: the first class consisting of floors and roofs, in which the damage is more severe on average, and the second of walls and ceilings, which normally suffer less serious damage.

Table 7 shows the areas of each element damaged. The damage has a mean area of about 2 ft^2 (0.2 m^2) for floors, walls and ceilings, although different proportions of these elements are damaged (Table 5). This indicates that, for these elements, a high proportion damaged is roughly balanced by a high proportion with a small area of damage and that the area of damage has a continuous distribution, i.e. there is no abrupt transition between absence and presence of damage. With a mean damaged agrea of about 6 ft^2 (0.6 m^2), roofs have by far the highest mean area of damage but this is combined with the lowest probability of any damage occurring.

CONCLUSIONS

Cnly fires which did not spread beyond the room of origin are considered in this note and, of these, 70 per cent were reported as causing no damage to the building fabric. Of the remainder, some 40 per cent caused only slight damage and 10 per cent caused destruction of some part of the fabric; the other fires were divided equally between those causing surface damage and those causing severe damage. The amount of damage varied with different building occupancies.

It was found that about 12 per cent of the fires damaged a floor, while the wall, ceiling or roof was affected in only 5 per cent of cases. The damage to floors and roofs was generally more severe than that to walls and ceilings, although floors, walls and ceilings all have a mean area of damage of about

2 ft^2 (0.2 m^2) and roofs of about 6 ft^2 (0.6 m^2).

REFERENCES

1. BALDWIN, R. and ALLEN, G. Some statistics of damage to buildings in fires. Joint Fire Research Organization. F.R. Note No. 805, 1970.

2. RAMACHANDRAN, G. Frequency distribution of fire loss. Joint Fire Research Organization. F.R. Note No. 664, 1967.

3. BALDWIN, R. and NORTH, M. A. The number of sprinkler heads opening in fires. Joint Fire Research Organization. F.R. Note No. 886, 1971.

Table 1

Specification of occupancy groups

Name	Contents
HFM	Private houses, flats and maisonettes
Residential	Residential clubs, colleges, schools and ecclesiastical buildings. Hotels, motels, boarding houses, lodging houses and hostels. Public houses with residential accommodation attached. Hospitals, private nursing homes, sanatoria, children's homes, old people's homes.
Offices	Offices and blocks of offices attached to other establishments
Shops	Shop premises, television, radio and film studios. Laboratories.
Assembly	Non-residential clubs, colleges, schools and ecclesiastical buildings. Meeting houses, clinics and public houses. Theatres, cinemas, radio and television studios to which the public are admitted. Concert halls, dance halls, exhibition halls, restaurants and cafes.
Industrial	As laid down in building regulations
Storage	Both hazardous and non-hazardous
Other	Occupancies not specified elsewhere

Table 2

Proportion of fire buildings suffering structural damage

Building:	Occupancy group								Total
	HFM	Residential	Offices	Shops	Assembly	Industrial	Storage	Other	
Damaged	1012	74	30	116	106	132	28	86	1584
Undamaged	2398	135	33	300	186	386	65	109	3612
Unknown	88	4	1	6	1	10	3	3	116
TOTAL	3498	213	64	422	293	528	96	198	5312
Proportion undamaged	0.70	0.65	0.52	0.72	0.64	0.75	0.70	0.56	0.70

Table 3

The maximum severity of damage as a proportion of all fires with known severities

Maximum* severity	Occupancy group						
	HFM	Residential	Offices	Shops	Assembly	Industrial	Storage
Surface damage	0.24	0.29	0.24	0.23	0.30	0.24	0.11
Slight damage	0.39	0.41	0.45	0.35	0.35	0.30	0.29
Severe damage	0.29	0.25	0.21	0.29	0.24	0.26	0.54
Destruction of element	0.07	0.06	0.10	0.13	0.10	0.20	0.07
No. of fires included	983	69	29	111	99	127	28

*Those fires in which no structural damage was reported are excluded

Table 4

Distribution of the
total area of damage by occupancy group

Area of damage		Occupancy group								Total
m^2	ft^2	HFM	Residen-tial	Offices	Shops	Assembly	Indus-trial	Storage	Other	
0	0	2399	135	33	297	186	384	65	109	3608
0.1–	1–	442	26	11	42	40	33	4	28	626
0.9–	10–	103	8	3	13	11	17	4	14	173
1.9–	20–	92	10	2	12	10	21	1	8	156
4.6–	50–	35	3	1	1	7	5	2	3	57
9.3–	100–	24	1	2	6	10	20	1	5	69
46.5–	500–	0	0	0	0	0	6	1	0	7
92.9	1000–	0	0	1	0	1	1	2	2	8
557.4	6000									
Unknown		403	30	11	51	28	41	15	29	608
Total		3498	213	64	422	293	528	96	198	5312
mean (ft^2)		4.7	5.2	58.8	5.7	20.0	26.6	163	29.0	12.1
mean (m^2)		0.44	0.48	5.5	0.53	1.9	2.5	15.1	2.7	1.12

Table 5

The severity of damage to individual building elements

Severity of damage	Element			
	Floor	Wall	Ceiling	Roof
None	4558	4868	4905	4970
Surface	133	177	122	49
Slight	220	86	83	72
Severe	188	47	60	74
Destruction	64	8	17	22
Not stated	149	126	125	125
Total	5312	5312	5312	5312
Proportion undamaged	0.88	0.94	0.95	0.96

Table 6

The proportional distribution of those fires causing structural damage*

Severity of damage	Element			
	Floor	Wall	Ceiling	Roof
Surface	0.22	0.56	0.43	0.23
Slight	0.36	0.27	0.29	0.33
Severe	0.31	0.15	0.21	0.34
Destruction	0.11	0.03	0.06	0.10
No. of fires included	605	318	282	217

*Excluding those fires which caused no structural damage or for which the damage could not be classified.

Table 7

Distribution of the area of damage
by building element

Area of damage		Element			
m^2	ft^2	Floor	Wall	Ceiling	Roof
0	0	4148	4469	4512	4547
0.1–	1–	397	101	102	52
0.9–	10–	72	46	34	23
1.9–	20–	59	55	29	24
4.6–	50–	19	11	15	15
9.3–	100–	7	20	10	32
46.5–	500–	1	1	0	5
92.9–	1000–	1	1	1	6
557.4	6000				
Unknown		608	608	608	608
Total		5312	5312	5312	5312
mean (ft^2)		2.1	2.1	1.5	6.2
mean (m^2)		0.20	0.20	0.14	0.58