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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

THE BEHAVIOUR OF ROOFS DURING FIRES

by

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Summary

A study has been made of the behaviour of roofs of buildings in which large fires occurred. Owing to the small numbers involved no firm conclusions can be drawn but certain indications can be discerned.

In approximately one fifth of the number of large fires occurring during one year the roof played an important role in the development of the fires, and one third of these originated within the roof. Supposed causes of fire were unknown in about one half the cases considered.

Fires involving wooden roof structures were noted on 22 occasions and metal on 14, half of the latter were covered with bituminised metal sheeting and the fire was often aggravated by drops of burning bitumen falling on the contents below. Wooden framed roofs may not be easily ignited but fire spreads rapidly once it has obtained a hold.

Most of the fires were said to have spread rapidly in the roofs and most of the roofs covered compartments of large area. Smaller compartments with walls taken through the roof could prevent fire spread. Maximum roof damage was not necessarily associated with the maximum damage to the building.

Felt and fibreboard roof linings tended to assist the growth of fire in the few cases in which they were reported.

Venting of the fire can in certain circumstances reduce the rate of spread but there may be conditions in which the opposite effect occurs.

Mansard and Belfast roofs can from the nature of their construction assist in spreading the fire.

Combustible material adhering to roof members enables easy spread of fire, regular cleaning of the roof structures would minimise fire spread by this means.

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THE BEHAVIOUR OF ROOFS DURING FIRES

by

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A study has been made of the behaviour of the roofs of buildings in which "large fires" occurred during the year ending August, 1954. For the purpose of this study a "large fire" (1) has been defined as one in which a direct loss of £10,000 or more was incurred at the prices prevailing at the time. Particulars of such fires were taken from the monthly lists published in "The Times" and these were used because detailed research reports on them had already been collected for other purposes.

In 51, some 22 per cent of the 226 large fires occurring in this period, the roof played an important role in the development of the fires, and detailed examination of the reports on these fires forms the basis of this investigation. In 133 (or some 59 per cent) the roof was completely destroyed as a result of a severe fire within the building, i.e. the fire was so fierce as to destroy the roof completely over the entire building or that portion of building which was also destroyed, but it was impossible to assess the part played by the roofs owing to the destruction caused. The fire had spread upwards from below in these cases. In the remaining 41 fires, the roof did not become involved, either because of its fire resistant construction, or because fire broke out on a lower storey of a multi-storied building and the fire brigade succeeded in preventing it from reaching the roof.

CAUSES OF FIRES IN WHICH THE ROOF PLAYED AN IMPORTANT ROLE

In Table 1 the cause of fire is related to the point of origin of the outbreak. It will be noted that 18 of the fires originated in the roof or roof space and in four of these fires the roof had become ignited by spread from a neighbouring hazard. Three fires due to short circuits in electrical installations originated in the roof space. In almost one half the occurrences the supposed cause of fire was returned as unknown but of these only approximately one fifth broke out in the roof. "Smoking material" was the greatest single defined cause of the fires which did not originate within the roof or roof space.

CONSTRUCTION OF ROOFS

In Table 2 the type of material used in the construction of the roofs concerned is shown together with the rapidity of fire spread as reported by fire brigades. Wooden roof structures covered with slates or tiles with or without glazing, which is probably the commonest form of construction in the United Kingdom, were involved in 22 fires. Metal roof structures were involved on 14 occasions; in one half of these the roof covering was of sheet metal protected by a layer of bituminous surfacing which became ignited easily and flames spread rapidly over it. The material melts readily and four reports referred to blazing drops falling on to the contents and aggravating the fire. This trouble was also encountered with another similarly covered roof in which the framework consisted of wood and metal members. It was interesting to note that fire spread was halted on one bituminised metal roof when the flames reached a section whose surface had been burned off in a previous fire.

In incidents in which the roof played a part in spreading the fire, spread was rapid and wood was the principal constructional material used. Wooden framed roofs may not be easily ignited but fire spread in them may be rapid once the fire has gained a hold.

There were five reports of fires in which roofs of the "Belfast" type were involved. In these the relatively thin timber members appear to have burned through rapidly, causing collapse of the whole roof which increased damage to the contents beneath and made extinction difficult.

Three fires were reported in which Mansard roofs of timber construction were involved. In one of these a cavity running the length of the roof had a timber lining supported on studding and this construction, together with the fact that rubbish had lodged in the cavity, contributed to the growth of fire.

According to the information reported from fire brigades, at 32 outbreaks, the roof failed at an early stage in the fire and of these, 23 buildings had roof structures of wood, 15 of them covered with slates or tiles. Six of the early roof failures were metal structures and two of these roofs were covered with bituminised metal sheeting.

FIRES ORIGINATING IN THE ROOF

The fire spread through the roof or roof space after originating there on 18 occasions and only five of these were confined to within the roof, three of these latter were the result of spread from a neighbouring hazard. It is possible that roof fires breaking out as a result of spread from neighbouring hazards are not likely to involve the building below if the primary fire is well established, since the fire brigade would then be present enabling prompt action to be taken.

PERSON DISCOVERING FIRE

The discovery of the fire was made by a person on the premises on 29 occasions and outside on 22 occasions. From these figures it cannot be concluded that fires involving roofs are particularly likely to be noticed from outside the premises involved.

AREA OF DAMAGE

Manufacturing and commercial premises were involved in 35 of the 51 fires considered; these were occupancies of the type which require buildings with large floor areas and often compartments within buildings were of large area. In Table 3 the proportions of roof damage, expressed as percentages, are related to roof areas. From the reports received it was noted that dividing buildings of large floor area into compartments with fire resisting walls was ineffective in preventing spread unless such walls were carried through the roof; fire spread in a number of cases because the compartment walls were built only to eaves level or the roof members rested on top of the wall.

In Table 3A the proportion of roof damage is related to the proportion of building damage estimated from the reports. It is seen that the maximum roof damage tends to be associated with the maximum building damage. In approximately 20 per cent of the fires, however, the roof damage was larger than the corresponding building damage; in such cases fire had spread by rising in a well or other natural "chimney" in the building and "mushrooming" outwards at roof level, or by spreading over the tops of compartment walls built to the eaves. This type of spread occurred both with the roof open to the building below and also when it was enclosed by a ceiling.

EFFECT OF CEILINGS AND ROOF LININGS

In 22 of the buildings involved it was known that no ceiling existed below the roof and mainly these roofs were glazed. Otherwise little information was available about the materials used in ceilings and their effect on fire. In over 80 per cent of the reports examined there was no information about roof linings and the part they played in the fire, but there were eight fires in which roof linings were mentioned and the types of material are shown in the Table below.

Roof lining material	No.
Felt	3
Fibreboard	2
Hardboard	1
Compressed wood wool	1
Aluminium foil	1
	8

With the exception of the wood wool and hardboard linings fire spread readily over these materials. The compressed wood wool lining, which withstood the heat well, was part of the construction of a constant temperature enclosure at a biscuit factory; the roof failed owing to distortion of the metal frame by heat. The aluminium foil tended to spread fire readily if loose edges were hanging vertically, but laboratory tests showed that flame would not spread if this material were laid horizontally and intact; it is interesting to note that this roof was ignited by spread from another hazard. Felt might be expected to spread fire owing to its bitumen content. Fireboard is also likely to extend fire; at one of the two fires involving this material the fire brigade had previously recommended removal of the fireboard roof lining, but at the time of the fire this had not been done and the severe damage that ensued was considered to be partly due to this fact.

GLAZING AND VENTING

Fires involving roofs incorporating glazing were noted on twelve occasions, but only four of these were reported to have failed at an early stage in the fire. Glazing fails readily and enables the fire to "vent" itself and it is thought that, in certain circumstances, "venting" tends to prevent extensive damage by allowing the accumulated heat to escape. There were three cases where "venting" was thought to have minimised fire damage but in three cases fire damage was thought to have been worsened by fire breaking through the roof. It was interesting to note that after one fire where damage had been minimised by "venting", the proprietors of the firm had renewed the glazing with the wire-reinforced type; the fire brigade on a subsequent routine visit had noted this and pointed out that more serious damage might ensue should fire break out in the future.

In fires where failure of the roof tended to aggravate the fire some other factor had been associated with this failure such as outer openings of the building being open to the air, explosions or the presence of highly flammable contents. There were two fires in which the flashover occurred as the Fire Brigade broke in to fight the fire which then spread upwards and involved the roof.

EFFECT OF MATERIAL IN ROOF SPACE

Combustible material lying in the roof space or adhering to roof members was noted on ten occasions, the presence of such material was not recorded in the remaining reports. There were three fires in textile processing establishments where cotton was being used, three in agricultural premises and the remaining four in premises of various types including an hotel which had a Mansard roof.

In the textile works cotton fluff thrown up in the processing adhered to roof members and it was noted that, once it was ignited, flame flashed readily along a fluff encrusted beam. Similar effects were observed in

agricultural premises dealing with the processing of provender. At one such establishment flames had spread up dust encrusted walls to similarly coated roof members; the fire brigade stated that if the walls etc. had been regularly swept down the damage would have been greatly reduced. In the other fires dust, sometimes oil-impregnated, had assisted fire spread, and at one fire the beams had been coated with varnish.

CONCLUSIONS

In approximately one-fifth of the "large fires" occurring during a period of one year the roof played a part in spreading the fire; owing to the small numbers of detailed reports examined little statistical evidence of the behaviour of roofs was obtained, but some indications of the contribution of roofs to fire spread were discernable. In the 51 reports studied approximately one-third of the outbreaks originated in the roof (4 by spread from other hazards) and the remainder elsewhere. The chief points arising from this examination of fire reports are:

(1) Light timber-framed roofs fail at an early stage once fire has taken hold.

(2) Bituminised metal sheeting when used as covering can spread fire readily both over the surface and by flaming particles of molten bitumen dropping on the contents below.

(3) While fire spread over roofs covering large-area compartments of buildings might be prevented by dividing the building into smaller compartments with fire resisting walls, it is essential that such walls be carried above the roof.

(4) Incomplete fire resisting walls and common roof voids permit fire spread through the roof space.

(5) Roof linings of the bituminised felt and fibreboard types tend to assist the growth of fire.

(6) The failure of glazing can vent a fire and in some circumstances this reduces the rate of spread although there were indication that there may be conditions under which venting has the opposite effect.

(7) Roofs of the Mansard and Belfast types can, from the nature of their constructions, assist in spreading fire.

(8) Combustible material adhering to roof members enables easy spread of fire, regular cleaning of roof structures in premises where the roof members are likely to become encrusted with flammable material is helpful in minimising fire spread by this means.

REFERENCE

(1) MILLAR, D. W. and FRY, J. F. Fires causing a large monetary loss.

F.R. Note No. 222/1955.

TABLE 1

The supposed cause of fire related to its point of origin

Supposed cause of fire	Fires starting in roof or roof space	Fires starting other than in the roof	Total
Spread from other hazard ignited roof	4	-	4
Radiated or conducted heat from fluepipe	2	-	2
Sparks from defective flue	1	-	1
Dropped light or smoking materials	-	5	5
Blowlamps	2	1	3
Defective electrical installations	3	-	3
(fixed)			
" " " (in vehicle)	-	1	1
Mechanical heat	-	2	2
Defective oil burning appliance	-	1	1
Spontaneous combustion	-	1	1
Miscellaneous	1	3	4
Unknown	5	19	24
	18	33	51

TABLE 2

Reported speed of fire spread in roof related to roof construction

							Glazing with			Other combinations				
Material of covering Structural material	Tiles or slates	Metal	Bituminised metal	Felt on wood	Wood	Asbestos	Tiles or slates	Asbestos	Bitumetal	Slates and flat sheet metal	Slates and concrete	Felt and asbestos	Thatch and metal	Total
Rapid spread														
Wood	13	-	-	4	1	-	5	-	-	2	-	1	1	27
Metal	2	-	3	1	-	1	2	-	3	-	-	-	-	12
Wood and metal	-	1	1	-	1	-	-	-	-	-	-	-	-	3
Total	15	1	4	5	2	1	7	-	3	2	-	1	1	42
Slow spread														
Wood	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Metal	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wood and metal	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Spread not stated														
Wood	2	1	-	1	-	-	1	-	-	-	1	-	-	6
Metal	-	-	1	-	-	-	-	1	-	-	-	-	-	2
Wood and metal	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	2	1	1	1	-	-	1	1	-	-	1	-	-	8
All spread speeds														
Wood	16	1	-	5	1	-	6	-	-	2	1	1	1	34
Metal	2	-	4	1	-	1	2	1	3	-	-	-	-	14
Wood and metal	-	1	1	-	1	-	-	-	-	-	-	-	-	3
Total	18	2	5	6	2	1	8	1	3	2	1	1	1	51

TABLE 3

Estimated proportion of roof damaged related to area of roof

Area of roof sq. ft	Proportion damaged %	1-25%	26-50%	51-75%	76-100%	Total
0-500	-	-	-	-	-	-
501-1000	-	-	-	1	1	2
1001-2000	-	-	1	2	6	9
2001-5000	-	1	3	1	7	11
5001-10000	-	3	4	2	4	10
10001-20000	-	4	6	-	6	13
Over 20000	1	6	-	1	4	5
Not stated	-	-	-	1	4	5
		1	14	7	29	51

TABLE 3A

Estimated proportion of roof damage related to building damage

Proportion of building damaged %	Proportion of roof damaged %	1-25%	26-50%	51-75%	76-100%	Not stated	Total
1-25%	-	1	4	1	-	-	6
26-50%	-	-	7	1	7	-	15
51-75%	-	-	-	4	4	-	8
76-100%	-	-	-	1	18	-	19
Not stated	-	-	3	-	-	-	3
		1	14	7	29	-	51