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THE SPREAD OF FIRE IN BUILDINGS -
THE EFFECT OF THE TYPE OF CONSTRUCTION

by

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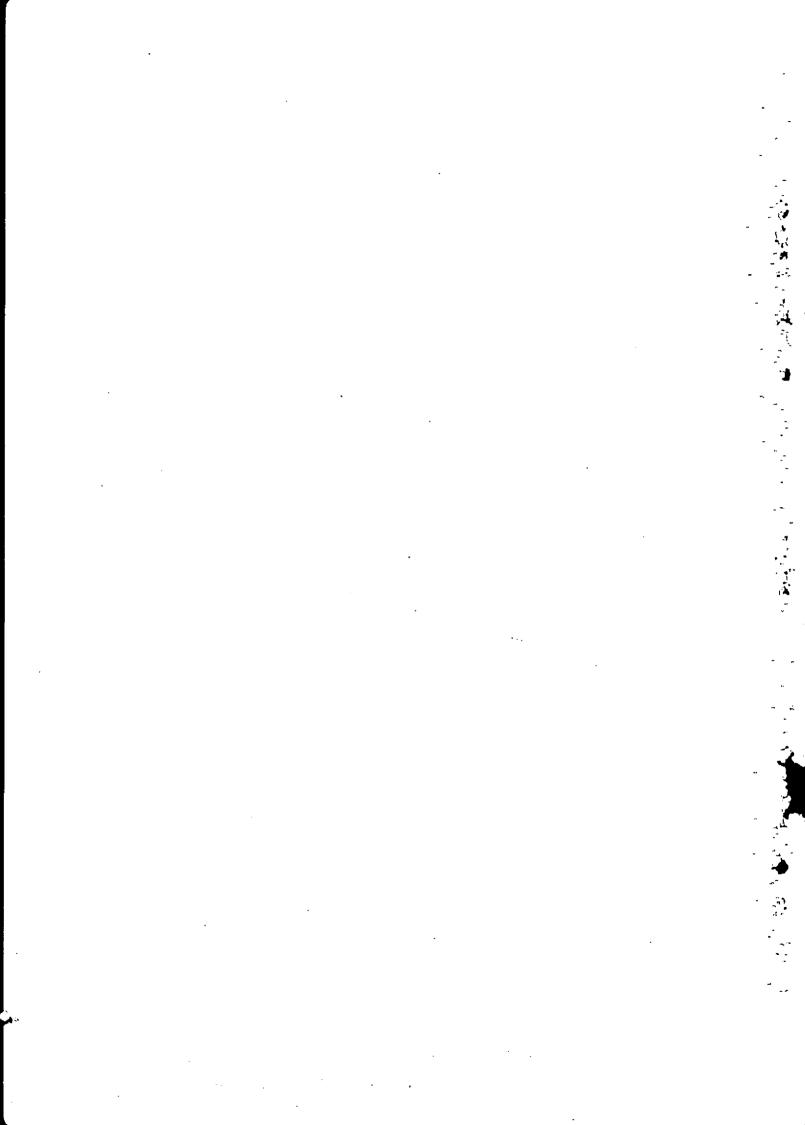
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SUMMARY

The statistics of fires attended by the fire brigades are examined to investigate the influence of certain structural features on the chance of a fire spreading beyond the room of origin. A statistical analysis shows that there is no significant variation from year to year (1963 and 1964) and that the chance of spread in buildings with timber framed walls is about twice as large as in those with other types of wall. The role of internal columns is not clear and those variations which have been found to be significant may be the result of other features associated with the type of column.

KEY WORDS: Building, columns, walls, fire spread, fire statistics, probability.

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Previous papers[1,2] have used the U.K. Fire Statistics to investigate the influence of various factors on the spread of fire in buildings. This technique is based on the calculation of the chance, or proportion, of fires attended by the fire brigades which spread beyond the room of origin, and it is used in the present paper to investigate the effect of certain structural features on the spread of fire.

In 1963 and 1964 buildings were classified by the Fire Brigade in their reports according to the following structural features.

Type No.	Structural features
1	Timber framed walls, no internal columns
2	" " " unprotected int. columns
3	" " " protected int. columns
4	Loadbearing walls, no internal columns
5	" " unprotected internal columns
6	" " protected internal columns
7	Framed, unloaded walls, no internal columns
8	" " " unprotected int. columns
9	" " " protected int. columns

In this table each type of column appears in combination with each type of wall so the 9 construction types may be arranged in a 3 x 3 table as follows.

		Internal columns		
		None	Unprotected	Protected
Walls	Timber framed	Type 1	Type 2	Type 3
	Load bearing	Type 4	Type 5	Type 6
	Framed unloaded	Type 7	Type 8	Type 9

From the statistics of fires attended by the fire brigades, coded at the Fire Research Station, it is possible to calculate a value of p, the proportion of fires spreading beyond the room of origin, each value of p being associated with one of the nine construction types. The values of p entered in a 3 x 3 table as described above are amenable to statistical analysis, by means of which any trends may be detected and their significance tested. Details will be given below.

Whatever defects there may be in this classification, which has recently been altered, it is the only systematic one for which data are currently available, and its two way symmetry allows the data to be very effectively analysed.

CALCULATION OF THE CHANCE OF FIRE SPREAD

The values of the spread parameter p for the different construction types are shown in Tables 1a, 2a, 3a and 4a, the upper one in each cell being for 1963 and the lower one for 1964. This analysis excludes fires confined to a single item, in which the integrity of the structure is not affected, the small number of fires spreading to other buildings, fires occurring in single compartment buildings in which there is no measure of spread, and fires confined to exterior components or service areas. The data have also been broken down into different occupancies and into single and multi-storey buildings, since these factors are known to influence the spread of fire[1,2].

Tables 1b, 2b, 3b, 4b show the frequencies of fires occurring in Tables 1a - 4a. It will be noticed that the frequencies are very unbalanced and in some cells there were no fires at all. This probably reflects the numbers of buildings of each construction type at risk: type 3 in particular is very rare.

		Internal columns		
		None	Unprotected	Protected
Walls	Timber framed	0.667 0.667	– 0.667	– 0.500
	Load bearing	0.355 0.328	0.313 0.290	0.296 0.182
	Framed unloaded	0.484 0.370	0.333 0.385	0.294 0.159

Table 1a. Proportion of fires spreading beyond the room of origin in the year 1963-1964 for different construction types in the Manufacturing Industries (multi-storey buildings)

		Internal columns		
		None	Unprotected	Protected
Walls	Timber framed	3 6	– 3	– 2
	Load bearing	476 433	265 321	27 33
	Framed unloaded	31 38	32 52	34 44

Table 1b. Numbers of fires occurring in the years 1963 and 1964 in different types of construction in the Manufacturing Industries (multi-storey buildings)

		Internal columns		
		None	Unprotected	Protected
Walls	Timber framed	0.527 0.460	0.300 0.500	– –
	Load bearing	0.211 0.266	0.153 0.170	0 0.176
	Framed unloaded	0.202 0.230	0.124 0.148	0.333 0.111

Table 2a. Proportion of fires spreading beyond the room of origin in the years 1963 and 1964 for different construction types in the Manufacturing Industries (single-storey buildings)

		Internal columns		
		None	Unprotected	Protected
Walls	Timber framed	55 65	10 10	–
	Load bearing	261 341	190 224	6 17
	Framed unloaded	84 117	145 210	6 9

Table 2b. Numbers of fires occurring in the years 1963 and 1964 in different types of construction in the Manufacturing Industries (single-storey buildings)

		Internal columns		
		None	Unprotected	Protected
Walls	Timber framed	0.600 0.143	– 0.333	– –
	Load bearing	0.231 0.220	0.417 0.390	0.368 0.212
	Framed unloaded	0.167 0.182	0.333 0.200	0.219 0.206

Table 3a. Proportion of fires spreading beyond the room of origin in the years 1963 and 1964 for different construction types in the Distributive Trades (multi-storey buildings)

		Internal columns		
		None	Unprotected	Protected
Walls	Timber framed	5 7	– 3	– –
	Load bearing	822 823	72 59	19 33
	Framed unloaded	12 11	3 5	32 34

Table 3b. Numbers of fires occurring in the years 1963 and 1964 in different types of construction in the Distributive Trades (multi-storey buildings)

		Internal columns		
		None	Unprotected	Protected
Walls	Timber framed	0.371 0.548	0.667 –	– –
	Load bearing	0.254 0.313	0.286 0.222	– –
	Framed unloaded	0.100 0.462	0.572 0.125	– –

Table 4a. Proportion of fires spreading beyond the
room of origin in the years 1963 and 1964
for different construction types in the
Distributive Trades (single-storey buildings)

		Internal columns		
		None	Unprotected	Protected
Walls	Timber framed	35 31	6 –	– –
	Load bearing	130 163	14 27	– –
	Framed unloaded	10 13	7 8	– –

Table 4b. Numbers of fires occurring in the years
1963 and 1964 in different types of
construction in the Distributive Trades
(single-storey buildings)

STATISTICAL ANALYSIS

A statistical analysis of the data has been performed on a computer, using a program described by Lewis[3]. First, the data were transformed using the logit transformation, so that if p is the observed proportion in each cell and $q = 1 - p$ the logit z of p is given by $z = \frac{1}{2} \log_e (p/q)$. This transformation is used because it may be expected to give approximately additive effects under many conditions. Thus we assume an additive model, so that if $z_{i,j}$ is the logit of the proportion in cell i, j, (with wall i, column j) then

$$z_{i,j} = \mu + \alpha_i + \beta_j + e_{i,j}$$

where μ is a mean value, α_i is the effect of the ith wall, β_j is the effect of the jth column and $e_{i,j}$ is the error term. The constants μ, α_i, β_j are fitted by the computer by the method of maximum likelihood.

RESULTS OF STATISTICAL ANALYSIS

Table 5 gives the residual χ^2 resulting from fitting the above model. It is clear that the differences between observed and fitted values are not significant so we accept the additive model of the transformed proportions as an adequate representation of the data.

Table 6 gives the estimated constants of the additive model together with the standard errors. Combination of these leads to the value of the logit for a particular construction. A clearer overall picture is given by Table 7, the expected marginal proportions for each construction element. These are simply the expected probabilities of spread for all fires in buildings with a particular type of structural element. The expected marginal proportions for the two different years have not been included since the difference is very small and not significant.

Other quantities were derived by the computer, such as an analysis of variance, the standard errors of differences within walls, columns and years, and the expected cell percentages, but these will not be tabulated here.

	Residual χ^2	Degrees of freedom
Manufacturing industries - multi-storey	4.02	10
Manufacturing industries - single-storey	6.30	10
Distributive trades - multi-storey	4.41	9
Distributive trades - single-storey	10.54	6

Table 5. Values of the residual χ^2

	WALLS						INTERNAL COLUMNS						YEAR			
	Timber framed		Load-bearing		Framed unloaded		None		Unprotected		Protected		1963		1964	
	Parameter values	Standard error	Parameter values	Standard error	Parameter values	Standard error	Parameter values	Standard error	Parameter values	Standard error	Parameter values	Standard error	Parameter values	Standard error	Parameter values	Standard error
Manufacturing Industries - multi-storey	0.70	0.281	-0.02	0.011	0.11	0.071	0.06	0.024	-0.03	0.033	-0.30	0.103	0.04	0.026	-0.04	0.025
Manufacturing Industries - single-storey	0.55	0.085	-0.02	0.025	-0.10	0.046	0.12	0.030	-0.13	0.035	-0.13	0.220	-0.05	0.034	0.04	0.026
Distributive Trades - multi-storey	0.20	0.277	0.01	0.008	-0.18	0.150	-0.04	0.011	0.37	0.084	0.10	0.129	0.03	0.027	-0.03	0.027
Distributive Trades - single-storey	0.36	0.111	-0.08	0.029	0.01	0.172	0.00	0.021	0.00	0.132			-0.07	0.057	0.06	0.048

Table 6. Estimates of the constants of the additive model

	Walls			Internal columns		
	Timber framed	Load-bearing	Framed unloaded	None	Unprotected	Protected
Manufacturing Industries - multi-storey	0.66	0.32	0.37	0.35	0.31	0.21
Manufacturing Industries - single-storey	0.44	0.21	0.18	0.26	0.17	0.17
Distributive Trades - multi-storey	0.33	0.24	0.18	0.22	0.39	0.27
Distributive Trades - single-storey	0.48	0.28	0.32	0.32	0.31	-

Table 7. Expected marginal proportions

DISCUSSION

The analysis shows that there are no significant differences in the proportion of fires spreading in the two years, and such differences that do occur could well be by chance. In all Tables (1b, 2b, 3b and 4b) the totals for 1964 exceed those for 1963. This is consistent with the view that increasing fire loss is the result of an increase in the number of fires, or their value, not their severity.

Table 7, indicates clear differences between timber-framed walls and other walls. A t-test based on the standard errors of differences (not tabulated here) shows that these differences are significant except in the case of Distributive Trades (multi-storey), where only a few fires are involved. Thus from the tabulated chance of spread it appears that, by and large, fires in buildings with timber framed walls are twice as likely to spread beyond the room of origin as other fires. It is well-known that timber framed walls are less likely to withstand fire than other types of wall, but this technique has enabled a quantitative estimate of their hazard to be made.

The influence of columns is not so clear and varies between occupancies. For manufacturing industries the chance of spread in multi-storey buildings with protected internal columns is significantly less than with other columns, but in

single-storey buildings fires spread more often in the absence of internal columns, with no difference between protected and unprotected columns. For Distributive Trades the position is different, spread being most frequent with unprotected internal columns.

The reason for the varying merits of columns is probably that the presence and type of internal columns is associated with other features: this requires further investigation. For example buildings of different construction types may have different uses, and contents, and may be of completely different size.

Unfortunately, the data in this paper is inadequate for a study of the effect of Building Regulations on fire spread and this is a deficiency which needs correcting. The basic philosophy of such regulations is the inhibition of fire spread by specifying structural elements of suitable fire resistance, and although these regulations have been in force for some years now, there is at present no data collected specifically to measure their effectiveness. This paper is not an appropriate place to discuss the nature of such data, but, it would not be difficult to design a scheme similar to the 3 x 3 table of this paper, or to collect data, answering some important questions about the effect of some features of building regulations.

CONCLUSIONS

A statistical analysis of the chances of spread for different construction types shows that there is no significant variation between the two consecutive years 1963 and 1964. Fires in buildings with timber-framed walls are about twice as likely to spread beyond the room of origin as in other buildings. The role of internal columns varies with occupancy and is probably associated with other features. An interesting result is that in multi-storey manufacturing industry buildings, protected internal columns are significantly better than unprotected columns or no internal columns. The significance of this result - and whether it is really associated with the type of column or with some other feature of the building which is associated with the type of column has still to be studied.

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ACKNOWLEDGEMENTS