Fire Spread along Roofs—Some Experimental Studies

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ABSTRACT

In the paper is described a number of test series where the influence of the wind velocity on the fire spread along the external surface of a roof has been studied. Different types of roof coverings and insulating materials within a wide range of combustibility properties have been studied. The results show that the spread of flame is fairly independent of these properties if the covering material is glued to the roof over its entire surface. For point-wise (mechanically) fixed roof covering materials, however, the fire spread is rapid and the damages extensive. The reason seems to be that the fire can take place and spread also in the space under the covering material.

Key words: fire spread, roofing materials, heat insulating materials, wind effects.

INTRODUCTION

During the last years the Swedish Fire Protection Association has been carrying out investigations with the aim to demonstrate the fire technical properties of light weight roof structures in different respects and to give the base for testing and judging these components from the points of view of the fire insurers. As a result of these studies a proposal for a fire testing and classification procedure has been presented by the author /Ödeen, 1985/. This procedure is at present implemented in the routine activities of the Swedish fire insurance companies.

Concerning the total fire technical behaviour of a roof structure the spread of a fire along the external surface creates an important phenomenon which has turned out to be subject to very few studies. In this paper some Swedish experimental tests are presented and the results are briefly discussed.

HISTORY

The fire technical properties of the light weight roof structures in general have been subject to discussions and investigations since they were introduced in the fifties. Due to the famous Livonis fire Factory Mutual in the USA an extensive research work was started resulting in a half-scale test method "Construction Materials Calorimeter" /Factory Mutual Research Corporation, 1980/. This method is at present used for insurance classification purposes in the USA (in combination with the "tunnel test"). The method was essentially new and reflected when it was introduced in many respect a new way of thinking in fire testing. Especially its ability to measure the fuel contribution of the test specimen is of great value. The method was based on comparisons with about 50 "full scale tests" in a test building with the horizontal measures 100 x 20 ft.

As this type of roof structures were introduced in Scandinavia the fire authorities as well as the fire insurance companies were faced to a number of intricate questions concerning the fire technical behaviour of the roofs. To find some answers the Norwegian and Swedish national testing institutes performed some test series in the early sixties. The aim of these tests was to give the base for regulations and guidelines in the national building codes. A comprehensive description of these tests is given in a report from the Swedish National Testing Institute /Statens provningsanstalt, 1966/.

In practice the problem of external spread of flame along roofs with combustible thermal insulation or combustible surface material is tackled in different ways. In e.g. Norway and the FRG a roof insulation of this type is divided into fields of a certain maximum area by strips of non-combustible material, in most cases mineral wool. Some preliminary tests in the sixties indicated this to be a useful method to prevent the ignition of larger roof areas. However, it must be emphasized that these tests were performed without taking into account the effect of a wind along the roof surface.

Experimental investigations of the mechanism at external fire spread along the roof surface in combination with wind have previously been carried out in Sweden. Of special interest are some studies in 1966 by the National Swedish Testing Institute in cooperation with some industries where the influence on the fire spread of the wind velocity was studied. This test series was later followed up by similar tests in 1973 /Bengtson 1973/.

The 1966- tests were carried out in a specially designed test rig with test specimens 70 x 500 cm, slightly inclined and with a fan arrangement which could be controlled up to a wind velocity along the surface of maximum 5 meters per sec. In total 8 tests were performed. 7 test specimens were built up of steel tin profiles and heat insulation of polystyrene-foam and cork and one as a conventional wood panel roof. In all cases the roofs were covered with normal bitumenous roofing felt.

Even if these tests must be regarded as preliminary some general conclusions can be drawn from the observations. One is that the speed of the fire spread along the roof seems to increase with increasing wind velocity, however, only up to a maximum value. At further increase of the wind velocity a tendency to decrease of the fire spread can be observed. The results are not very clear but in any case it can be stated that the speed of the fire spread does not increase over a certain wind velocity (cf figure 1).

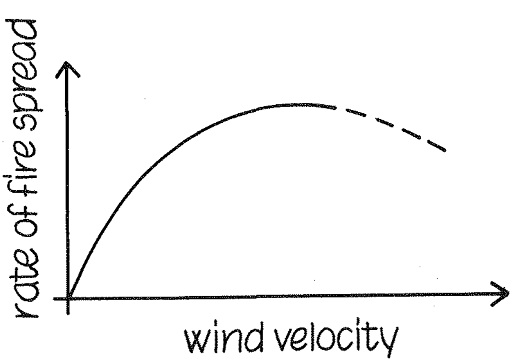

FIGURE 1. Rate of fire spread vs wind velocity.

The 1973-tests were performed with larger test specimens but following the same concept. The test specimens had the width 100 cm and the length 500 cm (or in some cases 1000 cm). The fan arrangement could give a wind velocity of up to 10 meters per sec.

At the tests was clearly demonstrated that the method of separating a combustible roof insulation with non-combustible mineral wool strips gave an almost neglectable effect as soon as the influence of wind was taken into account. A separation of this type did only give considerable effect if it was combined with other arrangements e.g. a non-combustible screen on the roof and the tests gave some indications to how this should be designed. The very small effect of the traditional separation metod turned out to depend on the fact that the fire spread took place essentially in the roofing felt and its adhesive and that the combustible insulation material (polystyrene foam) contributed only to a minor degree to the fire development.

Later on complementary tests have been performed with entirely non-combustible heat insulation as well as with light-weight concrete and all the results indicate that the spread of flame is almost unaffected by the combustibility and thermal inertia of the underlaying material. However, this preliminary statement has certain important exceptions which are further commented later on /Ahlen - Ödeen, 1982/.

In the following sections are described some tests series with modern industrial roof structures with different types of insulating and covering material.

TEST ARRANGEMENT

The tests were performed in a surplus industrial building mainly built of light weight and normal concrete. The test arrangement was similar to that of the previous tests and is shown in figure 2. The test specimens were 2 x 8 meters. In total 6 tests were carried out (A - F).

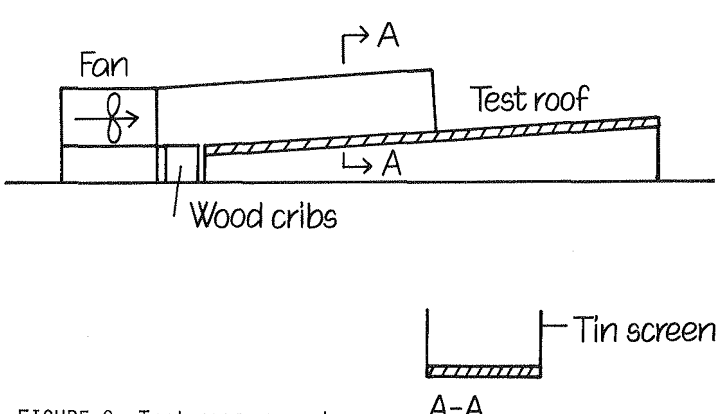

FIGURE 2. Test arrangement.

The test roofs were of a conventional steel-tin type (tests A - E) or light-weight concrete (test F). The details are shown in figure 3.

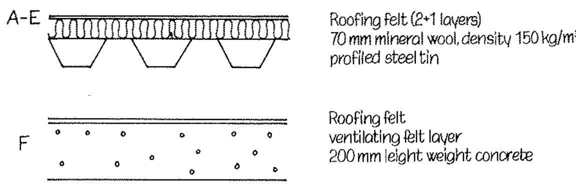

FIGURE 3. Test specimens

The roofing felt was glued to the underlaying material with a bitumenous glue. The amounts of glue were determined to 4.5 - 6.1 kg per sq meter (test A - E) and 2.6 kg per sq meter (test F). These figures do not include the bitumen in the roofing felt itself. The source of ignition was in the two first tests (A and B) two wooden cribs with a total weight of 150 kg. Observations at these tests raised doubts whether this gave a realistic picture of a fire attack. Therefore three cribs with a total weight of 225 kg were used as ignition source in the rest of the test series. The net calorimetric heat value can be estimated to appr. 2500 MJ for two cribs and 3700 MJ for three cribs. The cribs were built up of sawn pieces 50 x 50 x 500 mm. On a first layer of 4 pieces another 12 layers with 6 pieces each were laid cross-wise. The very upper layer with 4 pieces was kept at the same level as the nearest short edge of the test specimen (cf figure 1). The cribs were ignited simultaneously with 2 liters of alcohol in small tin containers under each crib.

At two preliminary tests (A and B) the wind velocity was chosen 2 and 5 meters per sec. At these tests no significant fire spread took place and the damages were restricted to the area immediately adjacent to the ignition source. Therefore these low wind velocities were judged to be too small and of no relevance for the rest of the test series.

After extensive discussions test C was performed with widely varying wind in order to give guidance as far as possible for chosing a proper profile for a test procedure. Observations at this test indicated that maximum impact and fire spread could be achieved at a velocity profile increasing step-wise from 0 during the first 3 minutes to 5 meters per sec during the following 5 minutes and then up to a final value of 7 meters per sec (cf figure 4).

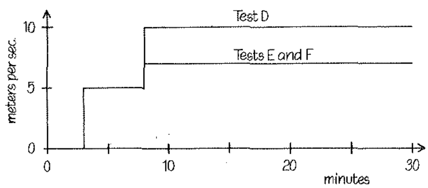

FIGURE 4. Wind velocity profiles.

The tests started with the ignition of the cribs. After about 3 minutes they were entirely ignited and the flames were 1.5 to 2 meters high. At this time the fan was started and the fire in cribs and roof was allowed to develop freely. The tests were terminated after about 30 minutes when the cribs had almost burnt down.

The fire courses were basically the same in all tests with only minor damages to the test roofs. It should be observed that these two types of roofs at present are classified in the best class according to Swedish insurance rules.

INFLUENCE OF INSULATION MATERIAL AND OF METHOD FOR FIXING THE COVERING MATERIAL

The testing method described above has been applied to a number of roof structures manufactured by Swedish manufacturers. The scope of this test series was primarily to show the influence of the thermal and combustibility properties of the insulating material and furthermore to demonstrate the difference - if any - of different methods of fixing the covering material (roofing felt or similar) to the roof. Tests were performed with the following insulating materials.

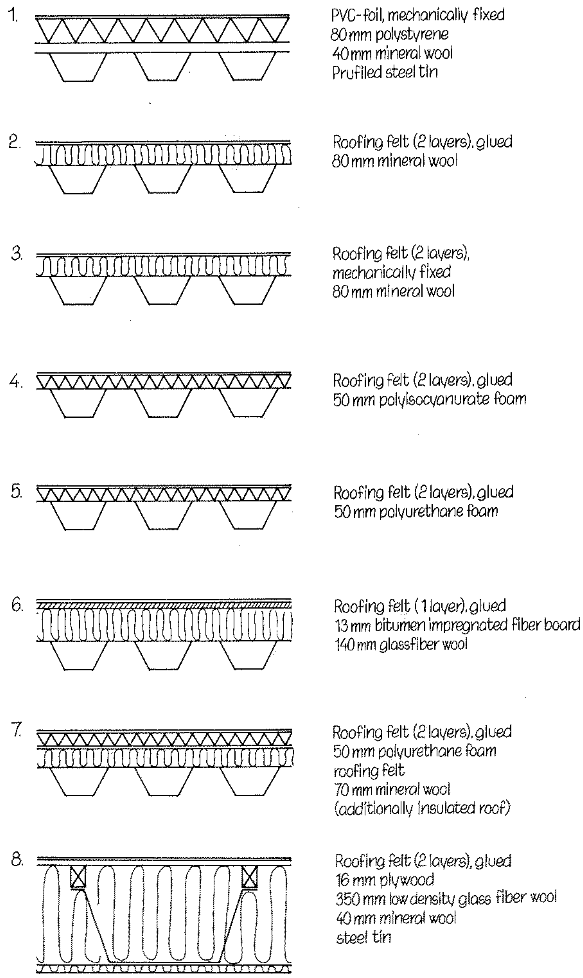

Figure 5. Compositions of the test specimens.

- Polystyrene foam
- Mineral wool
- Polyisocyanurate foam (PIR)
- Polyurethane foam (PUR)
- Bitumen impregnated fiber board
- Wood (plywood)

Covering materials glued over the entire area as well as fixed point-wise with mechanical devices were included in the test series. A brief description of the test specimens is given in figure 5.

TESTS RESULTS AND DISCUSSION

The fire developments were in most cases fairly similar and were - for the roofing felt covered roofs - characterized by an initially rapid spread of flames along the upper surface of the felt. However, this spread decreased after some time and the damages were limited even in those cases were the insulating material was more or less combustible. It is important to state that this did only hold for the surface layers glued to the insulation over its entire surface. For the layers which were mechanically, point-wise attached to the roof the spread of flames was rapid and the damages extensive. The reason is obviously that in these cases the combustion takes place not only along the upper surface of the layer but also in the space between the surface layer and the insulating material. This type of fire behaviour is essentially the same as has previously been clearly observed for e.g. internal wall coverings tested in the American Tunnel test, the Scandinavian Box test or in full scale room tests.

A conclusion of all test results seems to be that the fire spread in a combustible roofing layer is fairly independent of the combustibility properties of the under-laying material. However, this conclusion must be restricted to surface layers which are glued to the roof over its entire area whereas roofing systems with mechanically fixed surface layers increase the risk of rapid spread of fire over the roof surface. One consequence of this conclusion - drawn by Swedish insurance companies - is that the latter type of roof cannot be approved in the highest (best) class without further testing proving acceptable fire behaviour of the roof.

Finally it can be noted that there has been developed a small scale test based on the test results described above. This test is a modification of the test method for external roof surfaces referred to in the Scandinavian building codes (NORD-TEST, Test Method NT Fire 006).

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