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Structural Fire Testing in the 18th Century

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A digitisation project to archive early fire test reports (with both structural fire engineering and fire dynamics considered) is underway at the University of Edinburgh and the digitised documents will in time be publicly accessible. This collection of historical documents forms the basis of our current understanding in fire science and engineering and provides context for many current research questions. Summarised below is one fascinating example of the records that will be preserved in the archive. The following accounts illustrate some of the issues with using fire test results obtained in small compartments to design fire protection for large compartments in real buildings. Today, 200 years later, fire scientists and engineers still wrestle with how real fires influence real structures.

Charles Mahon can be considered as one of the first scientists to test and attempt to rationally understand the behaviour of a building exposed to fire. In 1777, at the age of 25, Mahon developed principles and a system for fire protection of timber buildings. His hypothesis was that a plaster made of water, sand, lime, and hay could be applied to timber elements to provide fire protection. Given that party walls had begun to show good ability at stopping horizontal fire spread, Mahon concerned himself with the ability to stop vertical fire spread in a building by compartmentalising rooms. Given the damage caused by conflagrations at the time, Mahon aimed to halt the progress of fires without reliance on water. In his words [1]:

> *"… to show how effectually even a wooden building, if secured according to my new method would stop the progress of the flames on that side, without any assistance from fire-engines." – C. Mahon*

Mahon constructed a two-storey structure (compartments of approx. 8m x 5m), and tested it under exposure to fire. The lower room of the building was filled with wood shavings and furniture pieces then set alight. Neither pyrometers nor thermocouples were available at the time to measure temperatures – Mahon also never reported the duration of the fires. There was therefore no quantitative way to measure heat transmission through the floors or walls. Mahon instead attempted to demonstrate the 'lack' of heat transmission through the floor in what must be considered a very peculiar manner. During the test, and incredibly, Mahon entertained guests on the floor above the fire compartment. Delegates included William Pitt (previously Prime Minister of the United Kingdom), the President of the Royal Society, the Lord Mayor of London, and several foreign ministers – each guest was given ice cream to enjoy as the fire raged below them [2]. The fire was sufficiently hot to melt the windows on the lower room. The floor boards of the lower room remained intact, but were charred – however more importantly to Mahon and his guests, no discomfort was experienced as they socialized and ate ice cream directly above the inferno. Indeed, it was alleged that some of the guests decided to walk around the room barefoot during the experiment to test whether they could feel heat from the fire. Little science in this experiment existed outside qualitative observation; no quantitative analysis of the fire or the structural reactions were made.

Mahon's fireproofing plaster was not patented – probably owing to its similarity to other common plasters used at the time. However, applying plaster for the purpose of fire protection (and indeed considering the need for fire protection) was deemed novel during the Georgian era. The plaster was advocated for use in construction by the Associated Architects Committee in 1793 [3] based upon the results of repeated fire tests conducted by a group of researchers headed by Henry Holland. However, Mahon's test conditions were not replicated identically in these tests. Holland's research group changed the composition of the plaster by adding plaster of Paris, screened rubbish, brick debris, coal ashes and other materials in order to make strong cement. They also procured a Georgian town house (dimensions unavailable) and subjected each room to compartment fires. Holland varied the fuel load in each room by using charcoal, tar and wood. The ventilation conditions were also varied to control flaming during these 'repeat' tests. No measurements were made to assess the severity of the test fires; however the duration of each test was recorded and ranged between 1 and nearly 4 hours. Some observations suggested issues with the plaster's ability to withstand fire (the plaster was found to dry out and crumble), but it was felt that, since the fires did not propagate to adjacent rooms, the

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performance of the plaster was satisfactory. Holland concluded, without attempting to experiment and giving no justification, that the amount of fire protection should be doubled in buildings requiring more security from fire. Quoting the report:

> *"In buildings that require a more than ordinary degree of security,… [Any] means of prevention, must be doubled; in which case, the committee are warranted to say, that it will effectually resist the strongest fire." – H. Holland*

In 1794, Mahon`s plaster (as well as several other fireproofing technologies of the time) was used in the construction of floors and stairs in the mostly timber-framed Drury Lane Theatre (Theatre Royal) in London. Henry Holland, who was responsible for the 1793 fire tests, was retained as the architect of the theatre [4]. The Drury Lane Theatre was considered the most advanced fire-proofed building of the time. Four water reservoirs were installed on the roof in order to quell any fire that could occur. However, during theatrical performances, these reservoirs served another purpose: the tanks were used to produce real waterfalls and lakes on stage – at the expense of fire fighting. An iron curtain was also installed to separate the stage from the audience, but after 15 years it was said to be rusted and non-functional. In 1809, the theatre caught fire while its water tanks were empty [5] and the fireproofing was insufficient to protect the building. The building collapsed within 30 minutes – there was no reported life loss (Figure 1).

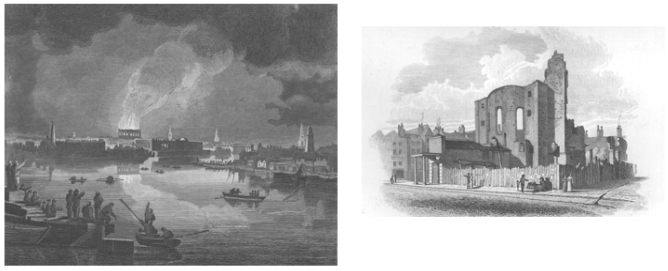

Figure 1: The Drury Lane Theatre during and after fire from Londina Illustrata circa 1825.

Henry Holland passed away in 1806; therefore little historical commentary on the effect of the fireproofing measures at the Drury Lane Theatre survives today. Aside from providing an interesting ice cream anecdote, the above story reminds us of some dangers in misinterpreting or over interpreting structural fire test results. The collapse of the Drury Lane Theatre illustrates the need to ensure that fire protection technologies are appropriately designed for the conditions to which they will be exposed (fuel load, ventilation conditions, scale, etc). Although fire science and engineering have evolved significantly since the work of Mahon and Holland, we are still today wrestling with the concept of how real fires influence real structural behaviour. This story therefore deserves preservation as a cautionary tale in fire engineering.

Digitised copies of the public domain reports which have been used to construct this article will be featured on the Open Access *Historical Documents of Fire Safety Engineering collection* when the project officially launches.

References

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