Wind effects on building fires in a multiparametric risk assessment with numerical modelling

dr inż. Wojciech Węgrzyński
Building Research Institute

It is beyond any doubt that wind strongly affects the fires. It was the case of the greatest disasters of our history (The Great London Fire 1666, Great Kanto Fire 1921) and for the ones we see (more, and more often) in the media – in California (2017, 2019), Portugal (2017), Greece (2018), Australia (2020) or in Poland – Biebrza National Park (2020).

Even though we understand that wind affects the fire, we have difficulties in determining "*how big wind is dangerous?"* and "*how dangerous is it?"* The case is even more difficult for buildings. In buildings, the fire is shielded from the external elements with the walls and roof – the same elements that lock the smoke and heat in the place, we want it the least: near humans. Our buildings are engineered in a way to protect us. They have smoke detectors to identify the threat and powerful ventilation systems to remove it. However, on a windy day these systems may not act as expected…

Strong winds will create a pressure distribution on the building envelope – a force that will either push against the walls and roof, or pull out away from the building. We know this forces may be very strong, we have witnessed roof shingles torn away from houses or destroyed structures that were not strong enough. Yet, to cause us trouble with our fire safety systems, the wind does not have to be of a force of a hurricane. In fact, we do not know what is the wind velocity that will cause us trouble… We know, that for certain wind directions and velocity the flows in the building caused by the wind will be opposite to the natural flow caused by the fire. In this scenario we will end up with conditions that make smoke removal very difficult. We also know that this can occur at wind velocities as low as 2,50 m/s (9 km/h). Sailors would refer to this wind as a breeze. We also know, that the higher the wind velocity, there will be more scenarios in which our smoke control effects are destroyed. But that is it. We do not exactly when and how it happens. It is quite a trouble, as reports show that over 60% of fires in which fatalities occurred were in some way driven by the wind.

Our lack of knowledge does not come from the lack of good questions, but rather from the difficulties in obtaining the answers. It is problematic to model wind and fire at the same time. Huge fire experiments (burning down the buildings) are performed in whatever wind conditions happen upon the ignition, and the scientists rarely get to say what weather they choose. To control the wind conditions, we may of course resort to our powerful wind tunnels…but not with fires in them. Unfortunately, the tiny scale of buildings necessary to model wind, prohibits the modelling of fires. As experimental efforts are highly unlikely, our best chance are computer models such as the Computational Fluid Dynamics (CFD) framework. They are not cheap, and definitely not easy in use, but allow us to capture the intrinsic features of wind and fire at the same time. Defining this use was what I have spent my last 3 years of the scientific career at.

As we have found the tool, now we are looking for the assumptions for our modelling. As the scientists say, you get what you put into the model (some actually say '*garbage in, garbage out'*). To obtain meaningful results that allow us to determine how often the wind is a problem for our buildings (on fire), we need to understand the statistical distribution of winds and the probability of certain fire types. This can be done through statistical modelling of the historical data – luckily, thanks to our dense meteorological station network we know the detailed history of wind in Poland in the last 50 years. All you need to do is ask the right question. For the fires, once you know what causes them, and what probability all the events leading to the fire have, you can calculate how likely a given fire is.

Once we have all of the elements (the tool, wind scenarios and fire scenarios) we can use risk-based methodologies to estimate how likely it is that the wind will affect the course and effects of a building fires. We will finally know, exactly, how big the problem is and at what wind velocity the problems arise. This will help us plan our preparedness for fires, design safer buildings and help us with the uncertain fire experiments. The project will also end up with a complete framework, ready for use for anyone having the same problems as us.

After the project, the wind will still affect the fires in our built environment. We will at least know how.