RESEARCH NEWS

Numerical models for the risk assessment of underground shock waves

Software Supports Safe, Controlled Detonations of Aerial Bombs

Time and again, unexploded aerial bombs from the Second World War need to be defused or detonated in controlled explosions. Researchers at the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI are working together with partners to develop models that predict fragmentation flight and simulate the underground spread of shock waves. This can help to reduce evacuation zones as well as improve forecasting of the risks to underground structures.

Hundreds of thousands of unexploded aerial bombs from the Second World War are still buried underground in Germany. The process of defusing a bomb is always associated with complex, large-scale evacuations, the closure of entire city districts and interruptions to rail transport in order to protect the population. But how large does the safety radius need to be to protect people from overpressure and flying fragments? And if a controlled detonation is carried out because neutralization is too dangerous, what effects does it have on nearby underground structures? A precise forecast of the expected hazards can limit evacuation radii and enable the impact on people, buildings and infrastructure to be evaluated more effectively.

Groundshock — evaluating underground effects of explosions

In the Schockanalyst project (see below), Fraunhofer EMI, virtualcitysystems GmbH and the Ministry of the Interior of the State of North Rhine-Westphalia are investigating the destruction that an exploding bomb can cause both at the surface and below ground, and analyzing how large the safety zone around the bomb actually needs to be. For this purpose, they are extending the VC BlastProtect simulation software, which simulates controlled detonations in a 3D city model. The development of the software began as part of the SIRIUS project. It enables the aboveground spread of the blast wave and the fragmentation flight of the bomb case to be simulated, taking into account surrounding infrastructure using detailed physical models. Until now, however, there has been no way of evaluating damping measures and the shock wave that spreads underground when a detonation is necessary and impacts structures such as pipelines, subterranean infrastructure and the foundations of nearby buildings. To solve this problem, Fraunhofer EMI is now developing a new numerical model. “We are extending the software so that explosive ordnance disposal services can compare different damping measures and better assess the effects of shock waves in the ground,” says

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Dr. Christoph Grunwald, a research scientist at Fraunhofer EMI. To prevent shrapnel from bombs flying several kilometers during an explosion, the explosive ordnance disposal service covers the bomb in the pit with sand or water, significantly reducing the radius of the flying fragments. "Using numerical codes developed at Fraunhofer EMI, we precisely calculate the spread of blast waves in the air and their effects on people and buildings. We are now also considering the influence of sand cover on fragmentation as well as groundshock; in other words, the vibrations and movements underground," the researcher explains. "When a bomb covered with sand explodes, a large amount of the energy is distributed in the ground. It is therefore important to forecast how the spread of the blast waves affects subway tunnels or basements, for example."

The process of simulating these extreme dynamic loads with precision is complicated by the properties of the soil. Gravel, clay and sandy soils behave completely differently under extreme energy inputs. "The behavior of the soil as a three-phase mixture (sand, water, air) poses a particular challenge," says Grunwald. Generic soil samples are first examined in dynamic laboratory tests, during which waves are applied at different strain rates and amplitudes, then enabling them to be simulated in computer models. "If our virtual results match those from the experiments, our models work."

Large-scale test in Mecklenburg-Vorpommern

A large-scale test on a former East German Army site in Mecklenburg-Vorpommern has already demonstrated how well the models reflect reality: Six buried 500-pound bombs were covered in different ways in realistic conditions (using various configurations of sand and water) and detonated close to a building. The damping measures were combined with precise sensors to measure blast and underground shock waves. In some tests, aluminum rings supported the walls of the detonation pit — as in real-life scenarios. The aim of the validation tests was, firstly, to obtain data to further develop the simulation models and, secondly, to provide explosive ordnance disposal services with insights on the effects of different damping measures that can be simulated in VC BlastProtect. One bomb was detonated uncovered as a reference. "We had forecast greater damage to the building, so our models err on the side of caution. Explosive ordnance disposal services will receive a much more precise assessment of the risk in the future and will be able to plan targeted steps on site to minimize damage," Grunwald summarizes.

Schockanalyst project

Research for civil security

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Project partners:
- Ministry of the Interior of the State of North Rhine-Westphalia, Düsseldorf
- virtualcitysystems GmbH, Berlin (software development)
- Fraunhofer EMI, Freiburg (numerical model development)

Fig. 1 Prepared 500-pound bomb

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Fig. 2 Experts prepare the pit containing the bomb for the controlled detonation.

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Fig. 3 Aluminum rings support the walls of the detonation pit.

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Fig. 4 The detonation of an uncovered bomb unleashes a huge fireball.

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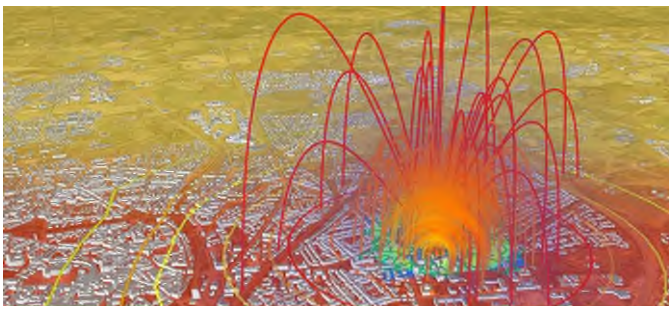

Fig. 5 VC BlastProtect simulates detonation scenarios in a 3D city model.

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