

Formula Calculates Thickness of Bombproof Concrete

Fraunhofer



Earthquakes and explosions produce tremendous forces. Pressures in the immediate vicinity of a car bomb are in the range of several thousand megapascals, and even further away from the detonation itself, pressures are still in the order of several hundred kilopascals. Pressure in a bicycle tire — at about three bar — corresponds to about 300 kilopascals. “So people at a good distance from the detonation point are not so much endangered by a pressure wave — our bodies can usually cope pretty well with them — it’s flying debris that poses the real danger,” explains Dr. Alexander Stolz from the Safety Technology and Protective Structures department at the Fraunhofer Institute for High Speed Dynamics, Ernst Mach-Institut, EMI in Efringen-Kirchener, a German town just north of Basel. This is exactly what happens to conventional reinforced concrete when it is hit by an explosion’s pressure wave: it is so brittle that individual and often large pieces are torn off and fly through the air uncontrolled.

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Dr. Stephan Hauser, managing director of DUCON Europe GmbH & CoKG, has developed a concrete that merely deforms when subjected to such pressures — and doesn't break. Behind the development is a special mixture made from very hard high-performance concrete, combined with finely meshed reinforced steel. The EMI has been supporting Hauser for many years in the optimization of his patented innovation. In particular, the researchers take responsibility for dynamic qualification testing of the material under extreme loads. This also involves characterizing the material and calculating characteristic curve profiles. The researchers have developed a mathematical formula that simply and quickly computes the required thickness of the new concrete for each specific application. "Calculations used to be based on comparable and historical values," says Stolz. "Now we can use a universal algorithm."

The formula was developed during a test series with the new shock tube in Efringen-Kirchen. "We can simulate detonations of different blasting forces — from 100 to 2,500 kilograms TNT at distances from 35 to 50 meters from buildings. And that's without even having to use explosives," says Stolz. The principle behind it is this: The shock tube consists of a (high-pressure) driver section and a (low-pressure) driven section, which are separated by a steel diaphragm. Air can be compressed in the driver section to a pressure of up to 30, bar, i.e. to approximately 30 times atmospheric pressure at sea level. The steel diaphragm is ruptured when the desired level of pressure is reached: the air is forced through the driven section as a uniform shock front that hits the concrete sample being tested, attached to the end of the shock tube. "With conventional concrete, the impact pressure ripped out parts of the sample concrete wall, which failed almost instantly, while the ductile and more flexible security version of the concrete merely deformed. There was no debris, and the material remained intact," says Stolz. Thanks to its ductile qualities, the security concrete is considerably less bulky and yet more stable than conventional steel-reinforced concrete. Thinner building components are possible. "As a rule of thumb, you get the same stability with half the thickness," says Stolz.

Formula also appropriate for earthquake and blast protection

Designing elements with the ductile concrete is easier with the new computational formula. The material's high load capacity, many years of experience in its use in a variety of applications, and ultimately its load limits under explosive charge led to it being used in the new One World Trade Center in New York. The building rests on a 20 story, bombproof foundation that reaches 60 meters underground. Overall, at points within the building where safety is especially critical, several thousand square meters of safety concrete have been used to shore up the construction. Over the past few years, the skyscraper has been growing steadily upwards on the southern tip of Manhattan, on the site of the old World Trade Center's Twin Towers. On September 11, 2001, an unprecedented act of terror resulted in the collapse of the towers, burying more than 3000 people under the debris. At 541.3 meters, the One World Trade Center is the tallest building in the USA and the third tallest in the world. "Our formula allows us to calculate the exact thickness of the concrete required to meet the safety considerations posed by such a special building," says Stolz.

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