Drop-weight impact tests on reinforced concrete beams

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Reinforced concrete (RC) is commonly used in defence and protection structures such as shelters and barriers. Such protective structures may be subjected to dynamic loads from explosions from conventional weapons or impacts from fragments or from ballistic attacks. When used for protection, such elements are designed to prevent shear-type failures, as they are brittle with low energy-absorption capabilities. This is undesirable for impulse-loaded structures. In the last few decades, several research studies have been conducted to understand different failure mechanisms of reinforced concrete. This paper aims to present an investigation focusing on the response of RC beams during dynamic and static loading conditions.

This paper's results are based on experiments conducted on 27 reinforced concrete beams, where 18 were tested dynamically and nine were tested statically. The experiments were carried out at KTH Royal Institute of Technology in cooperation with the Swedish Fortifications Agency and Tyréns. A mass was dropped onto the beams for the dynamic tests, while an MTS machine was used to perform the static testing. The beams were designed with both compression and tensile reinforcement and three different configurations of shear reinforcement: no stirrups and stirrups with 90 mm and 45 mm spacing, respectively. The tests were instrumented with load cells and accelerometers.

The recorded data were analyzed, focusing on three main factors: load position, shear reinforcement configuration, and dynamic versus static loading effects. The results revealed that shear failure occurred when the load was positioned closest to the support, while the failure mode transitioned to flexural shear as the load was moved further from the support. Additionally, acceleration, velocity, and displacement at midspan increased with a load at a greater distance from the support. Beams without shear reinforcement exhibited more inclined cracks, with a more significant shear influence and less contribution from bending. In contrast, beams with higher shear reinforcement content predominantly developed bending cracks with a diminished influence from shear. Furthermore, the beams exhibited a higher dynamic load capacity than their static load capacity, which may be attributed to the strain rate effect.

Keywords: Reinforced concrete beams, dynamic loading, shear failure, shear reinforcement configuration, load position, strain rate effect, impulse