Effect of impulse intensity for reinforced concrete elements

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Civilian or protective structures may, during their lifetime, be subjected to intense dynamic loads from explosions, ballistic impacts, fragment impacts or collisions. Such impulse-loaded structures sustain internal forces that may differ substantially from equivalent static loads. Large local shear forces could arise, especially for intense build-up of significant impulse, resulting in shear-type failures that differ from typical static failures. This has been observed for distributed air-blast loads, where local shear-type failure close to the support occurred during intense explosions. Similarly, intense impact loads due to high impact velocities have been shown to initiate local shear-plug failure at the contact zone. Both types of local failures are initiated by similar mechanisms, that is, large relative local velocities before a global deformation mode has been initiated.

Simulations were conducted on beams with concentrated and distributed dynamic loads to study the effect of an intense dynamic load with a short rise time of the impulse. The simulations with concentrated dynamic loads were modelled from previous drop-weight impact tests at KTH. Beams with varying shear spans were subjected to an impact from a 70 kg steel mass dropped from 2.4 m, resulting in an impact velocity of 6.3 m/s. The models using distributed dynamic loads were modelled from previous shock-tube testing using 2.5 kg explosive charges detonated 10 m from the face of the beams. For both types of tests, models were first validated against the experiments. The load was then parameterized, and the impulse was applied over a much shorter time or with a similar rate but higher magnitude.

The analyses showed a large influence of both load parameters, i.e. the impulse magnitude and rate. Generally, larger impulse magnitudes with a similar rate led to similar damage patterns with larger crack widths. Deformations and reaction forces also increased. This applies both for concentrated and distributed impulse loads. The damage mode changed as the same impulse was applied over a shorter duration. Significant local damage occurred for concentrated and distributed impulse loads, with larger reaction forces and displacements. The results indicated that the rate at which the impulse is applied also significantly influences the response, not just the magnitude, which is seldom considered in simplified design provisions based on SDOF models.