Abstract

In the modern day society there are an increasing number of explosions, either by accidental explosions or by terrorist attacks on civilian and military infrastructure. The main goals of this research are:

I. Field experimental investigation of the response of clamped mild steel plates to close range spherical air blast loads and examination of the effect of standoff distance on the structural response.
II. Development of numerical models for predicting the response of structures to close range air blast loads and validation of the numerical models using the field experimental data.
III. To demonstrate and assess the potential of blast mitigation technology using fluid-filled cellular polymer foam by performing field experiments and numerical simulations

In order to achieve the first objective, a series of close range blast experiments on mild-steel plates have been conducted at different scaled distances by varying the standoff distance and the mass of explosive charge. The plates deformed into conical or spherical-dome shapes, depending on the severity of blast wave and the permanent deformation profiles and the midpoint deflections of the plates were measured after each blast event. The air-blast pressure and the dynamic strains in the plates were also measured in some of the experiments.

Towards achieving the second objective, fluid-structure coupled numerical models for the field air blast experiments are developed using the commercial finite element hydrocode LS-DYNA to simulate the detonation of high explosive in air, blast wave interaction with the structure and the plastic deformations of the plate structures. With the physically consistent coupled numerical models and the material constitutive data evolved in the present research, a good agreement between the air-blast experimental data and the numerical predictions has been achieved. Further, a numerical procedure validated with experimental data is proposed to estimate the total impulse imparted to the structure under air blast loads. In addition, an empirical relation is formulated from the field experimental data to predict the midpoint deflections of the plates subjected to close range spherical explosions in air. Additional numerical simulations are performed with ANSYS-AUTODYN and ConWep codes and the results are compared with LS-DYNA ALE simulation results and the field air-blast experimental data to assess their relative performance in predicting the structural response to close-range air blast loads.

The third goal is addressed by conducting a series of air blast experiments, on steel plates covered with cellular polymer foam filled with water, at different scaled distances to vary the intensity of blast load. Further, the effect of foam thickness on blast mitigation is investigated by varying the water-filled foam thickness from 50 mm to 100 mm. The blast mitigation is quantified by the reduction in the plate midpoint deflection and the change in the deformation profiles of the plates by comparing the experimental data on plates tested with and without the water-filled foam protection. The experiments indicate that the blast protection offered by water-filled polymer foam depends on the intensity of the blast load and the thickness of the foam protection. It is found from the experimental data that with 50 mm as well as 100 mm thick water-filled foam protection, there is a reduction in plate midpoint deflection upto 49%. It is further observed that with 50 mm thick protective cover, depending on the intensity of the blast load, there is enhancement of damage to the structure in some of the experiments. Numerical simulations of the blast-protection experiments with fluid-filled foam indicate that the momentum transfer from the blast wave to the foam and water is the principal mechanism of blast protective action by fluid (water)-filled foam, that results in energy dissipation as increase in kinetic energy of water present in the foam, work done in expelling the water from the foam and atomization of water into fine droplets, increase in strain energy of the foam and energy expenditure in disintegrating and dispersing the foam.