ABSTRACT

Harmon, Joshua R., Purdue University, December 2023. Blast Resistant Design of Two-Way Steel-Plate Composite (SC) Panels. Major Professor: Amit Varma

SC walls have emerged as an advantageous alternative to reinforced concrete (RC) construction for blast resistant structures. SC walls typically consist of shop fabricated steel modules which can be erected on site and filled with concrete, without additional formwork setup or removal. The steel modules typically consist of steel faceplates, tie bars between faceplates, and optional shear studs. SC members offer advantages in strength, ductility, constructability, and construction schedule when compared with RC. The behavior of SC structures has been previously demonstrated for one-way behavior and adopted into many building design codes, but there is a knowledge gap on the behavior of SC members in two-way bending. The use of SC walls for blast resistant design motivates a desire for SC walls to be designed for two-way bending behavior. The behavior of SC panels in two-way bending was evaluated by analytical, experimental, and numerical methods.

Structural mechanics was used to develop simple predictions for the static behavior of rectangular, two-way SC panels under a uniform pressure loading. These predictions include the inelastic cross-section flexural capacity, the member static resistance function, the load-mass transformation factor for SDOF analysis, out-of-plane shear demands, and rotation demands. A quick-running SDOF computer algorithm was created to conduct blast load analysis using the nonlinear member behavior predicted by mechanics.

The two-way bending behavior of a SC panel was experimentally investigated. A SC panel was fabricated and experimentally loaded in two-way bending until flexural failure of the panel was reached. A series of concentrated loads applied to the panel was designed to simulate the yield line pattern of a panel under a uniform applied pressure. The experimental test demonstrated the deformed shape, inelastic capacity, and progression of yield lines throughout a SC panel in two-way bending. A 2D, layered composite shell finite element analysis was benchmarked to the experimental results. The finite element modeled the inelastic flexural behavior of the SC panel, closely matching the capacity, deformed shape, and development of yield lines throughout the panel.

The finite element modeling approach was used to validate the SDOF predictions of two-way SC panel behavior under static and blast pressure loadings through a parametric study. Detailed comparisons of the two modeling results were made. Iso-damage pressure-impulse diagrams for multiple SC panel geometries were developed.