

Blast Resistant Steel Stud Wall Construction

By Russell J. Norris and Robert Smilowitz, P.E.

As blast resistant construction continues to be investigated, new and innovative techniques are being developed to reduce the weight and the cost of the systems. One such system that was investigated by the US Department of State's, Bureau of Diplomatic Security is a steel stud wall construction technique that may be used for new buildings, or the retrofit of existing structures. This stud wall system is offered as an alternative to traditional cast-in-place, reinforced concrete construction processes, and may be used as a curtainwall for exterior façade or as a storefront system. Both configurations were subjected to numerous blast tests that validated and refined this work. The US Department of State is now ready to bring this body of knowledge into the commercial design and construction marketplace, where it can be used on public and private sector design projects.



The essence of the steel stud construction approach lies in the reaction of the studs to the blast loads applied. Instead of limiting the construction materials to elastic or minimal deformation, this system allows substantial plastic deformation of its members in order to capitalize on their inherent capacity to elongate and absorb energy. Commercially available steel studs that are attached web-to-web (back-to-back) in order to limit rotation provide the required level of ductility necessary to develop a tension membrane response to blast loading. In this state, the member deforms until the entire cross section

is placed in tension, whereby it sustains much greater elongation and deformation while still within its acceptable ultimate design strength limit. While the wall is absorbing a considerable amount of the blast energy through deformation, its connection to the surrounding structure must develop the large tensile reaction forces. In order to prevent a premature failure, these connections should be able to develop the ultimate capacity of the stud in tension.

In order to verify the efficacy of the proposed stud wall system, the Department of State employs the US Army Corps of Engineers, Engineer Research and Development Center (ERDC) to provide testing and evaluation. ERDC performed much of the engineering and test support associated with developing this concept, using 18 gauge steel studs and 16 gauge sheet metal outboard of the steel studs behind the cladding.

In addition to blast resistance, the Department of State requires the structural façade to provide forced entry and ballistic resistance (FE/BR) protection to the lower 5 meters (16 feet) of the building (typically the first level). Ballistic resistance may be provided for a range of weapons, and forced entry resistance delays a mob assault with common hand tools for a prescribed period of time. Therefore, these competing performance requirements must be accommodated by the stud wall system. Furthermore, the stud wall must accommodate different cladding materials ranging from stone, masonry, stucco or other finish systems. Often this cladding affords a measure of physical protection that varies in relation to its density and thickness. Ballistic testing of various building cladding materials revealed that this requirement is generally met if the cladding material features a nominal 100 mm (4 inches) thickness of stone, brick, masonry or concrete. However, forced entry protection requires a 6 mm (¼-inch) thick layer of A36 steel plate that is behind the building's veneer, and welded or screwed to the steel stud framing in lieu of the 16 gage

sheet metal. Thinner sections of the cladding materials, or stucco/EFIS systems of any thickness, will not provide the mandated ballistic resistance. These applications require an interstitial sheathing of 12 mm (½-inch) A36 steel plate. In both cases, the steel plate(s) are attached to the steel stud framework by welding or screwing.

"..the stud wall must accomodate different cladding materials..."

Steel stud exterior framework systems were tested by the Department of State. If the studs are run from the first level floor slab, continuously beyond the roof slab to form a nominal 1.5 meters (5 feet) parapet, test results show they only need to be rigidly attached at the first level floor slab to function in the blast loading environment. These connections are designed to cause the stud pairs to deform plastically and absorb the maximum amount of energy as the system transitions from a flexural to a membrane deformation. Attachments at successive floor slabs are driven by dead load, wind load and other normal design parameters. These connections must provide a finite amount of horizontal, vertical and in plane adjustment to account for variance in the concrete diaphragms to which the steel studs will be anchored. However, the steel stud's connection at the first level is a crucial element of this system's performance. Recent Department of State testing has refined this connection detail to make it more amenable for commercial curtain wall applications.

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Ideally this system would be constructed using continuous steel studs from the fixed attachment at the first level slab to the top of the parapet, if the overall building height permits this approach. Steel studs are commercially available in the US in 18-meter (60-foot) mill lengths; however, this is not likely to be practical for an overseas construction project.

Splice plates consisting of 400 mm (15¾-inches) long, 12 mm (½-inch) thick steel plate may require up to 12 bolts to develop the tensile forces. This design is intended to allow the spliced stud to produce its maximum strength and achieve tension membrane over its entire length. All stud splices are to be located directly in front of a floor slab. This location is least likely to interfere with the desired deformation of the steel stud frame as it absorbs energy and transmits blast loads to adjacent diaphragms.

This steel stud exterior wall construction system is amenable to many different construction and erection scenarios. The basic framework of steel studs, 6 or 12 mm (¼- or ½-inch) steel plate and 16 gauge sheet metal can be prefabricated horizontally. This assembly can then be manipulated into position and attached on the floor/ceiling/roof slabs. Once in position, additional exterior cladding can be installed as required by the construction documents. Alternatively, the system can be “stick built”, in place, as required by the project design. This sequence would begin with attachment of the steel studs to the building diaphragms and cycle through installation of 6 or 12 mm (¼- or ½-inch) sheet steel, 16 gauge sheet metal and finally the cladding material(s). There are numerous combinations and permutations for constructing this system, and the Department of State is amenable to a wide variety of construction methods.



The way rough openings are addressed will depend on whether they occur on portions of the building sheathed in 6 or 12 mm (¼- or ½-inch) steel plate or areas that receive 16 gauge sheet metal. Although the blast loads are transmitted to the adjacent structure and eventually to a building diaphragm in

either case, the steel plate condition is a bit more forgiving. For this case, the blast loads can be transmitted from the window frame to the steel plate sheathing, and finally to the surrounding steel stud frame work and adjacent diaphragms. As an example, the sub-frame assembly may be fabricated from steel angle stock and allows for mechanical and welded attachment between the window and surrounding steel wall sheathing. This has the advantage of taking these transitional sub-frames out of the construction critical path of the building's exterior walls, and they can be installed anytime prior to the actual window installation. Another benefit of this approach is that it allows removal, replacement or repair of the window without disturbing adjacent interior finishes.

Rough openings above the first level, in areas where the steel stud wall system is sheathed in 16 gauge sheet steel, are addressed differently. In these cases, the blast loads must be transferred *directly* to the adjacent steel studs. These connections must exploit the ultimate strength available from these studs and allow them to achieve tension membrane. A prefabricated steel sub-frame may be designed to transition between a blast window, for instance, and the steel studs that accept and transfer the resulting blast loads. If properly designed and fabricated, this approach could perform the same function as a traditional blast window embed and allow direct bolt up of the window to this transition sub-frame. If appropriately detailed and manufactured, this sub-frame could also be removed from the construction critical path for the skin of the building. Additionally, this approach provides the General Contractor (GC) with some vertical adjustability in the rough opening during fabrication of the steel stud frame. However, the GC must maintain very tight tolerances when laying out and welding up the steel stud frame on exact center-to-center spacing.

If the 16 gauge sheet metal is butted to an adjacent sheet, they will separate in response to the blast loading. The deformation and elongation in the studs allows for gaps to open up between successive sheets of this steel and may allow debris to enter the structure. It is therefore recommended that successive sheets be overlapped 25 to 50 mm (1- to 2-inches) to prevent this potentially dangerous condition. All explosive tests performed to date indicate no additional fastening or blocking is required at the horizontal joints.

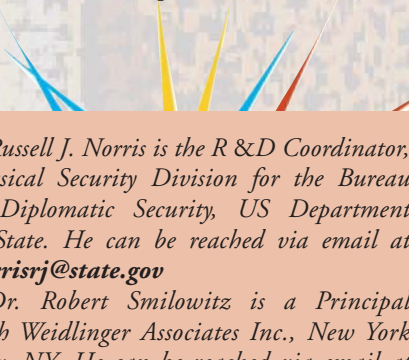
However, testing of the steel stud system revealed the importance of interior sheathing. Significant deformations are likely to be experienced during blast loading, and these have a tendency to detach gypsum wallboard with relatively low velocity off the interior face of

studs. Therefore, regardless whether a 6 mm (¼-inch) steel plate or a 16 gauge sheet metal is used, the interior face of the stud should be finished with a steel-backed composite gypsum board product until a determination can be made regarding the level of hazard associated with this debris. As an extra benefit, these interior cladding materials also improve the overall performance of this wall system.



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An extensive analytical and testing program that was conducted by the Department of State resulted in the development of a steel stud wall system that may be used for blast resistant construction. These innovative steel stud wall systems provide great potential for a wide variety of applications to a wide range of explosive threats. The potential benefits are so great, the Department of State Bureau of Diplomatic Security is continuing the development of this system. The Department of State is also sponsoring work through the ERDC and University of Missouri to develop the Steel Stud Wall Analysis Code (SSWAC) as a design tool to facilitate commercial applications of this design and construction technique.■



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