Assembling steel deck diaphragms with powder-actuated fasteners offers speed and performance.

BY WILLIAM GOULD, P.E.

Quick **Deck**

FASTENING OF STEEL DECK for roof diaphragms and composite floor systems traditionally has been done by welding. Innovative power-driven mechanical fastening systems are a recognized alternative that can improve connection quality and decrease installation time. Power-driven fastening systems may be powder-actuated or pneumatic driven. These systems generally consist of a tool, fasteners and a power source, either a powder-actuated cartridge or compressed air. Each system has its own attributes, resulting in quick, clean and high quality steel deck fastenings. A more cost effective steel deck fastening than welding can also result when considering today's high labor rates.

A Brief History

The origin of powder-actuated fastening (PAF) technology is considered as occurring in 1915 with the invention of a steel nailing tool by Robert Temple, a British marine engineer. Temple developed the system to repair damaged steel ship hulls. Since the 1950s, there have been many product developments of low-velocity powder-actuated fastening systems for construction and industrial applications including attachment of steel deck.

The theory behind powder-actuated fastening technology is well documented. The fastener holding mechanisms in steel base materials consist of friction welding and brazing effects as well as mechanical interlock or keying of the base steel with knurling in the fastener shank. The steel deck is mechanically attached and clamped to the supporting base steel by washers that are pre-fitted on fasteners that are qualified for this application. The washers also serve to provide added resistance to wind uplift forces.

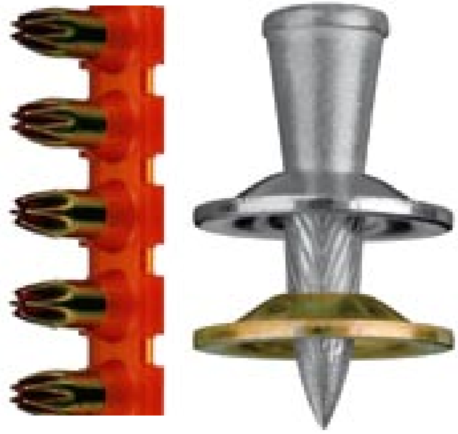
Recent breakthroughs in manufacturing and fastener technology have led to the development of full-tip fastener knurling, which greatly improves the application limits and allows for reliable installation in today's stronger and thicker steels. Design manuals, ICC-ES Evaluation Reports and design software are also available to assist the structural engineer with proper specification and optimized design of these fastening systems as part of the steel deck diaphragm.

Powder-actuated fastener research and building code evaluations have further demonstrated that these types of fasteners are extremely reliable and do not adversely affect the material properties of the base steel. Net section properties, performance on open web steel joists and base material effects also have been investigated as part of industry and academic research.

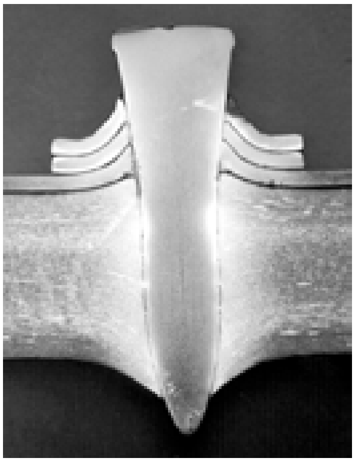
The Steel Deck Diaphragm System

The theory behind steel deck diaphragms is well documented in the Steel Deck Institute (SDI) *Diaphragm Design Manual* (DDM) and TM 5-809-10, *Seismic Design for Buildings*, a publication from the Departments of the Army, Navy and Air Force (also referred to as the Tri-Services Manual). These design references are based on small element connection tests as well as confirmatory large-scale diaphragm structural system tests.

Small element connection tests consist of structural frame connections of steel deck to base steel and sidelap connections for steel deck to steel deck. The predictive equations developed through the SDI and Tri-Services approaches are used to evaluate the strength and stiffness of the overall steel deck diaphragm and are applicable



Powder cartridges (left) provide the power to drive the knurled fastener, with washer attached, through the metal deck and into the steel below.



The driven fastener holding mechanisms in steel base materials consist of friction welding and brazing effects as well as mechanical interlock or keying of the base steel with knurling in the fastener shank. The steel deck is mechanically attached and clamped to the supporting base steel by washers that are pre-fitted on fasteners that are qualified for this application.

Attachment

for diaphragms subjected to wind, earthquake and combined lateral forces. Both methods provide the basic calculation models and equations that are then adjusted to establish close correlation with diaphragm system test data.

The steel deck connection strength and stiffness are essential to the performance of the diaphragm. These values are typically developed through small element lap-shear tests done in accordance with AISI S905-08, *Test Method for Mechanically Fastened Cold Formed Steel Connections*. The small element test data for connection strength and stiffness is then used in the SDI *DDM* or Tri-Services method equations to calculate the larger diaphragm system strength and stiffness. Other evaluations of full-scale steel deck diaphragms and the resultant diaphragm strength and stiffness determined through tests are presented directly.

ICC Evaluation Service (ICC-ES) and industry have established AC43 as the Acceptance Criteria for Steel Deck Roof and Floor Systems for recognition under the *International Building Code*. In AC43, both the SDI *DDM* and Tri-Services methods traditionally have been recognized as acceptable design references. Many evaluation reports and manufacturer's technical literature contain diaphragm strength and stiffness data based on these approaches. ICC-ES AC43 prescribes the full-scale diaphragm test set-up and the measurements that must be taken. AISI S907-08, *Cantilever Test Method for Cold-Formed Steel Diaphragms*, provides similar procedures. FM and UL also have equally important, but separate, test standards for steel deck wind uplift and assembly fire resistance.

Research Initiatives

Research has been conducted over the past decade into the cyclic and seismic performance of steel deck diaphragms and connections at Ecole Polytechnique Montreal by Robert Tremblay, Ph.D. Current manufacturer research into this topic is also under way at the Hilti Corporation's Fastening Systems Research Laboratory (FSRL) in Schaan, Liechtenstein, with Specialized Testing, Inc., an independent ICC-ES AC43 accredited test laboratory.

Findings show that the ductility of the steel deck diaphragm system depends on the type of steel deck connections. This research is yielding greater insight into the performance of steel deck diaphragms under earthquake loading with mechanically fastened and welded connections. Earlier research by Tremblay, et al., has found that mechanical fasteners provide superior ductility to the traditional arc spot welds without weld washers. Additional investigations into this effect are currently being conducted at the FSRL.

The test frame at the Fastening Systems Research Center in Schaan, Lichtenstein, simulates cyclic and seismic loading on an installed steel deck diaphragm.

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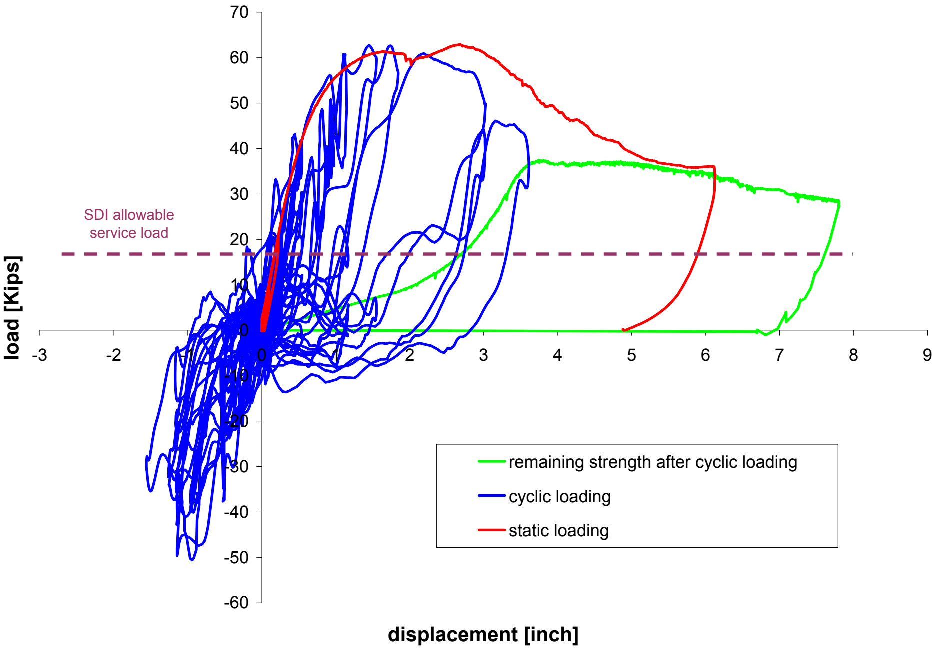

The data plotted from static and cyclic load testing shows displacement versus load, as well as the remaining diaphragm capacity.

Practical Benefits

Powder-actuated fastening systems offer a number of advantages including:

- ➜ Reliability
- ➜ Productivity
- ➜ Health, safety and welfare
- ➜ Appearance
- ➜ Safety training and technical support

Powder-actuated fastening systems also offer a number of health and safety advantages specifically for construction workers. Because the installation tool systems are self-contained and portable, potential tripping hazards posed by electrical power cords and compressed air hoses on the jobsite are minimized. Unlike welding, powder-actuated fastening does not involve burning away zinc coatings or paint on the steel deck surface, so inhalation of toxic fumes or "welder sickness" and fires are not potential hazards. Recent tool developments include upright, ergonomic systems that also help protect construction workers from back injuries. These finer points may seem as insignificant to the casual observer, however, this can directly translate into improved construction quality.

Economics

To optimize steel deck diaphragm design, frame fastening patterns, sidelap connector spacings and deck gauge can be varied by zoning. In some cases, deck design optimization can be accomplished by using thinner steel deck profiles and lighter fastening patterns. This performance advantage is confirmed through full-scale diaphragm system testing. Zoning the diaphragm must be balanced with constructability concerns in order to "keep it simple" and avoid confusion for the construction worker building the structure. Heavier fastening patterns

Specialized equipment enables reliable and rapid installation of powder-actuated fasteners from a standing position.

and thicker steel deck panels typically are used at the diaphragm perimeter where diaphragm shears and wind uplift demands are highest. Lighter patterns and thinner steel deck panels can be used at other locations where diaphragm shears and wind uplift demands are less.

Fastening costs should be viewed in a global sense considering all contributions to the overall cost per fastening point. Material unit costs are generally higher for mechanical fastening systems than for welding, and tool costs become insignificant over multiple jobs. However, higher material costs can be offset by the speed of the powder-driven fastening systems. Labor costs are constantly increasing, so the quicker and more safely the steel deck can be installed and fastened as specified by the structural engineer, the greater savings that can be recognized by the project team and building owner.

New, ergonomic stand-up powder-actuated fastening systems can produce up to 1,000 quality fastening points per hour of operation, depending on installer experience and other jobsite variables. These systems also offer the advantage of no need for re-work, touch-up painting or application of corrosion resistant coatings as often required when welding.

Inspection and Quality Control

Fastener manufacturers provide recommendations for visual checks of mechanically fastened steel deck. SDI and AWS D1.3 also provide guidance on how to check an arc spot puddle weld. The SDI *DDM* states that a typical arc spot or puddle weld should take from 3 to 6 seconds depending on the properties of parts being connected. This also depends on the skill of the welder and project site conditions and the formation of the weld effective diameter is of particular importance. Depending on the sheet steel thickness, multiple deck layers at endlaps and corner laps can present a challenge for arc spot puddle welding, but this can be accomplished using certain weld equipment, settings and techniques. Other conditions may also contribute to longer welding times. Recent research at Virginia Tech University has shed new light on arc spot welding of sheet steel.

AISI offers Ω and ϕ factors for diaphragm safety and resistance that are referenced in the SDI *DDM*. These factors have changed in the past, but are currently equivalent for mechanical fastening systems and welding when the diaphragm is subjected to wind loads. When the diaphragm is subjected to earthquake loads, higher safety factors (and lower resistance factors) are applied for welds.

In the end, if not inspected and enforced on the project site, the structural engineer and building owner may not get the welded connection that was specified and used in the diaphragm strength and stiffness calculations. A difference may exist between a project site weld on an actual roof deck structure and welding done as part of a research program in a test laboratory. With mechanical fastening systems, however, the installation quality is less reliant on the skill level of the installer, increasing the likelihood of reliable attachment.

Conclusion

Powder-actuated and other mechanical fastening systems can produce extremely reliable steel deck fastenings and represent a significant modernization in steel fastening on today's structures. Consistent and reliable performance, worker safety and increased productivity are some of the key benefits of these modern fastening technologies that can be tapped into by innovative structural engineers and contractors. MSC

Various references are available for download at www.us.hilti.com/decking, including "Powder-Actuated Fasteners in Steel Construction," (Hermann Beck and Martin Reuter, Stahlbau Kalender 2005) and "Strength of Arc Spot Welds Made in Single and Multiple Steel Sheets," (Gregory L. Snow and W. Samuel Easterling, Proceedings of the 19th International Specialty Conference on Cold-Formed Steel Structures, Missouri University of Science and Technology, October 2008). ICC-ES Evaluation Service Reports are available at www.icc-es.org.