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BY **MATT DESIMONE**
Senior Associate
Wiss, Janney, Elstner Associates, Inc.

Strengthening of Existing Structural Steel Floor Framing with Headed Shear Connectors

The owner or manager of a building constructed with structural steel floor framing is sometimes faced with the question of how to increase floor capacity to support new or additional loads. When strengthening a beam by adding a new steel shape to the bottom flange is determined to be inadequate as a standalone solution or is infeasible altogether, adding new headed shear connectors (or headed shear studs) by welding to the top flange of the beam can be a viable and economical strengthening solution.

When an existing structural steel floor framing system requires strengthening, consider adding new headed shear connectors to the top flanges of the steel floor beams.

It is often the case that the load-carrying capacity of a steel floor framing system needs to be increased beyond its original design capacity, for example, due to a proposed change in occupancy use classification or the addition of new finishes, storage units, or equipment. In this article, we briefly describe the limitations and challenges that are sometimes faced when considering traditional steel beam strengthening using a steel shape or plate welded to the underside of the beam, and we present another viable strengthening option—adding headed shear connectors.

Existing Steel Floor Framing Systems in Buildings

Existing steel floor framing systems may be categorized into one of two types of systems: non-composite and composite systems.

Non-composite Steel Floor Framing Systems

Prior to the early 1960s, steel floor beams were historically designed on the assumption that the cast-in-place reinforced concrete floor slabs they support act independently from the beams to resist loads. This independent (non-composite) behavior between steel beams and slabs resulted in heavier, deeper beams than would otherwise be required if the beams and concrete were to behave as one, hence resulting in less efficient structural design.

Composite Steel Floor Framing Systems

As a result of significant advancements in welding technology in the 1960s, nearly all new office and mixed-use structural steel building construction relies on developing composite action between the structural steel beams and the reinforced concrete floor slabs to support design loads. This reliance on composite action has resulted in much more structurally efficient floor systems. To minimize costs, however, these composite floors were typically designed using the minimum quantity of shear studs required to develop the target beam capacity (partial composite action). Hence, existing partially-composite steel beams have "untapped" load-carrying capacity and stiffness that can be utilized with the addition of more shear studs.

Challenges with Traditional Strengthening

When a steel beam in an existing floor framing system requires reinforcement to support new or additional loads due to a proposed change in occupancy use classification or the

Location:
WJE Philadelphia
601 Walnut Street, Suite 875W
Philadelphia, PA 19106

Contact:
T: 215.567.0703
E: mdesimone@wje.com

www.wje.com

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS
Wiss, Janney, Elstner Associates, Inc.

addition of new finishes, storage units, or equipment, it is common to reinforce the existing beam using the relatively simple and economical solution of welding a new steel shape to the bottom flange of the beam. Typically, this reinforcement consists of a continuous steel plate, known as a cover plate. Strengthening with a new steel cover plate or other steel shape comes with drawbacks and limitations, including the following:

- Strengthening from the underside of the existing beam may not be feasible due to (1) prohibited access by the tenant below, or (2) inadequate clearance below the beam due to the presence of existing ceiling finishes, suspended equipment below the beam, or limited floor-to-floor heights.
- Because the new asymmetrical section (with a larger bottom flange than top flange) has limited structural efficiency, adding a new steel shape to the underside of an existing steel beam in a non-composite floor system often proves inadequate as a standalone solution.

Another Viable Strengthening Option

When strengthening is deemed to be required at a non-composite or partially-composite steel floor beam, adding new headed shear connectors along the top flange of the beam creates composite action between the steel beam and the concrete slab. This is achieved by coring down through the existing concrete slab and welding new shear connectors to the top flange of the beam at regular intervals along the beam length, as illustrated in *Figures 1 and 2*.

A qualified licensed professional engineer or licensed structural engineer must specify the type, size, quantity, and locations of headed shear studs required to satisfy building code provisions and project-specific performance criteria.

The headed shear connector installation process typically entails the following procedure:

1. Locate existing shear studs and other embedded elements attached to the existing steel beam and embedded within the concrete floor slab. Location of embedded elements within the slab is typically achieved using ground-penetrating radar (GPR) (*Figure 3*).

2. Core through the existing concrete slab to the top flange of the existing steel beam, taking care to avoid elements embedded in the slab. The recommended core diameter is a function of the concrete slab thickness above the steel beam top flange and the required shear connector size, but typically ranges from 3 to 6 inches in diameter (*Figure 4*).

3. Mechanically abrade the concrete surface over the full depth and perimeter of the newly-cored hole, using a needle scaler, and subsequently clean the hole using an air-blast cleaning system (*Figure 5*).

4. Clean the top flange of the existing steel beam to bright metal and subsequently remove loose debris.

5. Weld the new headed shear connector to the top flange of the existing steel beam using a stud welding gun (*Figure 6*). Headed shear connectors are typically made from low-carbon steel and consist of a cylindrical shaft with a cylindrical head. The most typical headed shear connectors have a 3/4-inch diameter shaft and a 1-1/4-inch diameter head. Note that steel studs are manufactured to be welded using a stud welding gun, and that stick welding headed shear connectors typically results in poor fusion and inadequate strength.

6. Pour non-shrink grout into the cored hole, flush with the top surface of the slab (*Figure 7*).

7. Repeat the above steps at all shear connector locations along the beam length.

Benefits and Challenges of Strengthening with Headed Shear Connectors

Adding new headed shear connectors can provide the following benefits:

- The flexural strength of the floor beam may be increased by between 20% and 500%, translating to a 40% to 300% increase in live-load-carrying capacity .
- The flexural stiffness of the floor beam, which directly affects deflections and floor vibrations, may be increased by between 20% and 1,000%[1].
- Access to the floor below is avoided.
- Reduction of headroom below the beam is avoided.
- Removal and replacement of fireproofing is avoided.

[1] The reported increases in flexural strength, stiffness, and live-load-carrying capacity are approximations that are highly dependent on existing steel and concrete material strengths, beam size, beam span length, beam spacing, the number of new and existing headed shear connectors, and the locations and proportions of dead to live loads, among other factors.

While adding new shear connectors intermittently along the length of existing steel beams in a floor framing system is

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a fairly straightforward process that can often provide a great deal of additional load-carrying capacity and stiffness to the existing framing, it does come with a number of challenges and limitations, including the following:

- The existing steel beam must be weldable.
- Existing elements embedded within the concrete floor slab, such as existing studs, reinforcing bars, wire mesh, and electrical and plumbing utilities, may limit potential locations for new headed shear connector installation; alternatively, existing embedded elements may require removal or relocation to avoid interference.
- Core drilling and other operations typically required during installation create noise which may disturb surrounding occupants, and thus may necessitate after-hours work.
- If a wet core drill is used during installation, as is often the case, care must be taken to mitigate water infiltration into the space below.
- Existing floor finishes directly overtop of the beams to be strengthened must be removed and replaced.

It should be noted that, similar to adding a new steel shape to the bottom flange of a beam, adding headed shear connectors to the top flange of a beam improves beam strength and stiffness only; the strength and stiffness of other structural elements in the floor, such as existing reinforced concrete slabs and beam connections, are not increased by the addition of headed shear connectors. Thus, other structural elements in the floor must also be assessed to determine whether they, too, require strengthening.

Costs of Strengthening with Headed Shear Connectors

Construction costs for installation of new headed shear connectors on an existing beam can vary widely, as it is dependent on a number of factors, including but not limited to the quantity of connectors, the presence of existing embedded elements within the slab, and prevailing local material and labor costs. Nonetheless, anticipated construction costs are commonly in the range of roughly $4,000 to $8,000 per beam.

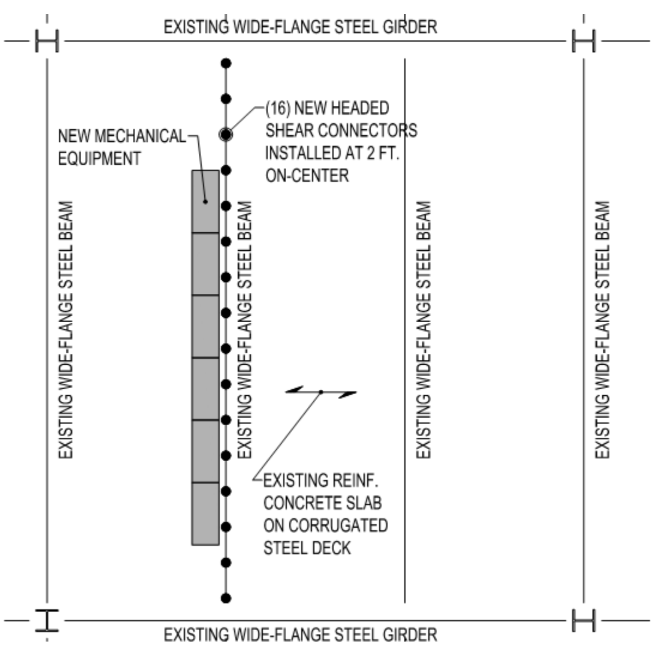

Figure 1. Floor framing plan, illustrating new headed shear connector strengthening.

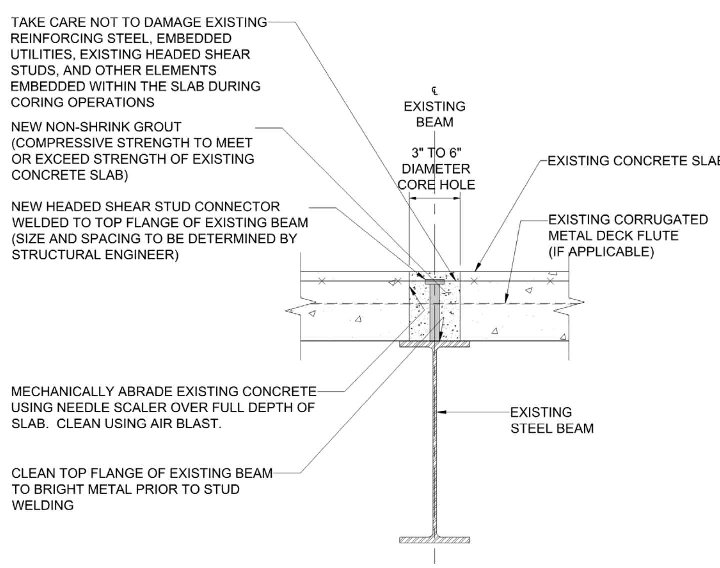

Figure 2. Typical headed shear connector strengthening detail.

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Figure 3. Marked locations where headed shear connectors are to be installed, spaced along steel beam below and identified using GPR.

Figure 4. Core holes in concrete slab spaced along span of steel beam below.

Figure 5. Mechanical abrasion at core holes.

Figure 6. Headed shear connector welded to top flange of existing steel beam.

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Figure 7. Non-shrink grout placement in core holes.

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Location:
WJE Philadelphia
601 Walnut Street
Suite 875W
Philadelphia, PA 19106

Contact:
T: 215.567.0703
E: mdesimone@wje.com