APPLICATION OF AXIAL LOADS IN CONNECTION DESIGNS:
LOAD PATHS, TRANSFER MEMBERS AND DESIGN CRITERIA

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SUMMARY

In Canada, steel fabricators generally design the various steel connections found in buildings. However, the building designer is responsible for providing all of the criteria needed to calculate these connections in addition to information on load paths and axial loads in order to ensure the building's structural integrity.

APPLICATION OF AXIAL LOADS IN CONNECTION DESIGNS

A number of previously published InfoTech Express articles have discussed the shear forces in the roof and floor that are transferred via the diaphragm (reference Diaphragm action at the roof level by Pierre Gignac, June 2010). However, these forces can also be transferred by a horizontal brace or a horizontal bracing system combined with the diaphragm.

The transfer of these loads to the vertical brace connections and directly to the foundation is called a load path.

What takes place between the steel deck and the vertical bracing is important as explained in the following paragraphs.

Load path
The factored load accumulated by the steel deck passes through "collector" beams. Each collector beam then transfers the axial load to another beam until the total load is directed to the vertical bracing (figure 1).

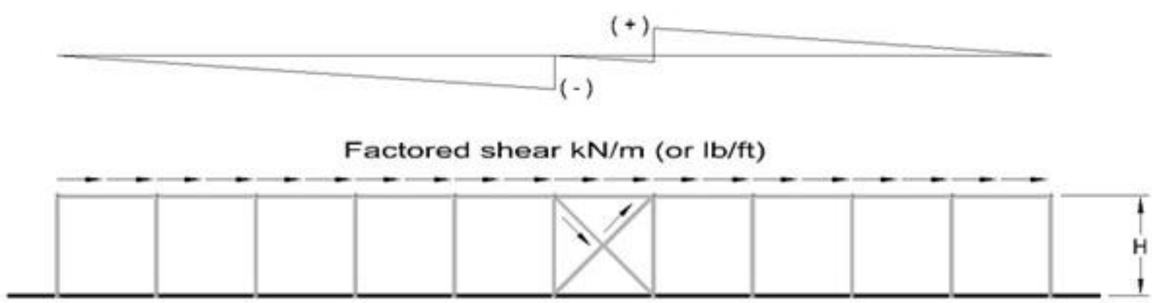

Figure 1
Accumulation of shear

Transfer members
Specific intermediary components are used to ensure that these loads transfer correctly between the steel deck and the collector beams.

In cases where a collector beam is perpendicular to the joists, the joist shoes can be considered as transfer members. However, the lateral capacity of the joist shoe is limited.

Another way to transmit a load to the collector beam is with the use of shear transfer elements (figure 2).

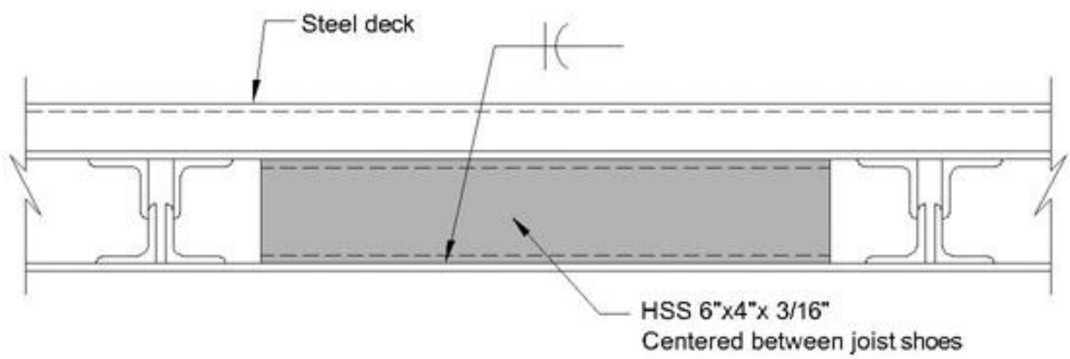

Figure 2
Use of a shear transfer element

Shear transfer elements are now widely used in Canada. They serve both as a support for the steel deck while also transferring the loads from the deck to the collector beams. HSS sections (hollow tubes) are commonly used as shear transfer elements.

For example, in the presence of steel deck with a depth of 1 ½ inches (38 mm), we recommend using a tube with a minimum width of 6 inches (152 mm) and a depth of 4 inches (102 mm). With this minimum size, we can be sure that the bottom flutes, which have a 4 ½-inch (114 mm) opening, will rest on the transfer elements. The steel deck can be attached to the transfer element with a weld or a mechanical connector.

With nails or screws, a minimum width of 8 inches (203 mm) is recommended, if the tube is aligned with the top fluting, as this prevents the steel deck from being connected in the rounded section of the tube.

There are also other ways to transfer loads to the collector beam such as the use of a perimeter angle which is an efficient and inexpensive method.

Axial loads in connection design

The final section of the load path towards the bracing is through the collector beam connections. The load produced at each end of the beam, called a pass-through force, must be taken into consideration when calculating the connections (figure 3).

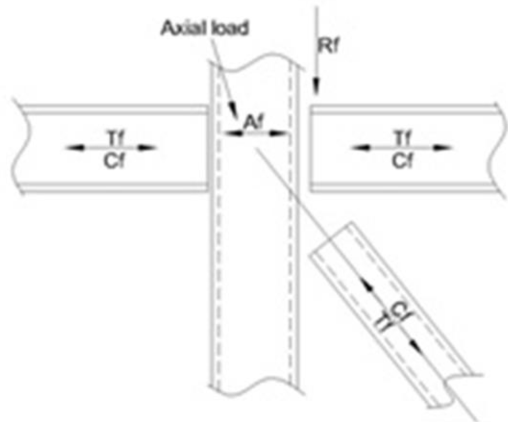

Figure 3
Collector beam connections

For consideration by the connection engineer, the axial loads must always be indicated on the drawings. Unfortunately, this is not always the case.

The connection engineer must also be informed of the nature of the load whether it be wind or seismic. When in the presence of seismic loads, specific requirements are outlined in CSA S16-9, Seismic design of steel structures, Clause 27, with regards to the design of the main structural elements and related connections.

For example, in conventional construction, $R_d = 1.5$ and $R_0 = 1.3$, when there is a short-term spectral acceleration ratio ($I_eF_aS_a(0.2)$) greater than 0.45, earthquake-resistant chord connections must be designed to withstand the combined gravity and seismic loads multiplied by the factor R_d (1.5). This load factor must therefore be taken into account in collector beam and brace connection designs as well as in other design situations.

However, if the necessary information is incomplete or missing from the contract documents, it is not possible for the connection design engineer to determine the loads to be transferred to the collector beam joints.

It is the responsibility of the building designer to provide, in the contract documents, all of the information required to properly design the connections including axial loads and any other pertinent parameters.

Connection design criteria
The building designer selects beam, column and bracing sections based on design criteria such as gravity, wind, seismic loads and deflection. However, if the connections joining these components are inadequate, the integrity of the entire building design is compromised.

The previously mentioned factors (R_d, R_0, ($I_e F_a S_a(0.2)$)) form part of the design criteria that must be made available to the connection design engineer. This information allows the connection designer to properly select the weighting coefficients that must be applied to connection design loads and to comply with CSA S16-9.

Beam connection designs are greatly impacted when axial loads are taken into consideration such as from the prying action exerted on bolts (reference Handbook of Steel Construction – Bolts in Tension and Prying Action, Part Three). Specific types of connections should also be selected or even prescribed directly in the presence of axial loads.

The same rule applies when designing joists, girders and related connections. Since the designer uses the axial loads shown on the drawings, the type and extent of these loads must also be specified (reference InfoTech Express, August 2005, The process of specifying joists: it's simple by Serge Dussault). There are limits to the amount of axial load a standard shoe can withstand so that adapted connections are therefore utilized (reference *Canam Joists and Joist Girders Catalogue*). Various examples of joist and girder connections are presented in Special connection conditions for a joist girder or steel joist by Manon Gauthier (InfoTech Express, April 2011).

CONCLUSION
The building designer is responsible for providing all design criteria directly on the drawings and in the specifications required to calculate connections. Steel fabricators who design and fabricate connections to such members as beams, columns, horizontal and vertical bracing, joists and girders, are responsible for applying these criteria in their calculations.

Well-designed buildings have all elements included from top to bottom which follow the logical movement of load paths and rely on hypotheses defined by the building design engineer.

COURSES REFERENCES ON LOAD PATHS
Low-rise steel buildings (CISC, 2005)
Seismic design of steel-framed buildings (CISC, 2006)

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