Differential Deflection

Introduction

The goal of this article is to give a better understanding of differential deflection, such as what it is and what are some of the issues that can occur due to differential deflection. Although not a mandatory requirement by code, differential deflection is addressed in the ANSI/TPI-1 2014 commentary, section 7.6.2, discussing vertical deflection limits.
A few example calculations will be done to help better understand this process, and explore ways to reduce and mitigate the effects of differential deflection.

Deflection

To understand differential deflection, we must first define deflection. Deflection is the degree to which any structural member is displaced under a load. The degree of which the member is displaced is dependent on two major variables, the member itself and the load applied to the member. This is best illustrated in the simply supported beam deflection equation subject to a uniform load.

$$\delta = \frac{5wl^4}{384EI}$$

Where:

- w=Load Carried by Beam
- l=Span of Beam
- EI= Stiffness of Beam
- δ =Deflection of Beam

Breaking this equation down, it can be seen how the different elements within that ratio, can affect the deflection. The two factors of the stiffness of the element, 'E' known as Modulus of Elasticity, used to determine the beam resistance to deformation and the 'I' known as Moment of Inertia, used to determine the beam resistance to bending, are both located in the denominator region of the ratio, while the load and span elements are both located in the numerator region. We can see that as the beam stiffness increases the deflection value will drop, while an increase in load or span causes an increase in the deflection value.
The following example calculations will show how the deflection changes with respect to stiffness.

Example 1.

12' long simply supported beam 2x8 SP No 1 lumber with uniform loading
E= 1,600,000 psi I= 47.63 in^4 DL= 20 psf LL= 40 psf Spacing= 16"o.c. L=12'
w = (DL + LL) x spacing = (20 psf + 40 psf) x 1.33 ft = 80 plf
w = 80 / 12 = 6.667 lb/in; l=12 x 12 = 144"

$$\delta = \frac{5wl^4}{384EI} = \frac{(5)(6.667)(144)^4}{(384)(1{,}600{,}000)(47.63)} = .49 \text{ in}$$

Example 2.

Increase stiffness by doubling the member (increase the Moment of Inertia)

12’ long simply supported beam 2x8 SP 2 PLY No 1 lumber with uniform loading

[E= 1,600,000 psi I= (47.63 x 2) = 95.26 in^4 DL= 20 psf LL= 40 psf Spacing= 16”o.c. L=12’]

$$\delta = \frac{5wl^4}{384EI} = \frac{(5)(6.667)(144)^4}{(384)(1,600,000)(95.26)} = .24 \text{ in}$$

Example 3.

Increase stiffness by using a deeper member (increase the Moment of Inertia)

12’ long simply supported beam 2x12 SP No 1 lumber with uniform loading:

[E= 1,600,000 psi I= 178 in^4 DL= 20 psf LL= 40 psf Spacing= 16”o.c. L=12’]

$$\delta = \frac{5wl^4}{384EI} = \frac{(5)(6.667)(144)^4}{(384)(1,600,000)(178)} = .13 \text{ in}$$

Example 4.

Reduce span by adding interior support

12’ long simply supported beam 2x8 SP No 1 lumber with uniform loading and interior bearing

[E= 1,600,000 psi I= 47.63 in^4 DL= 20 psf LL= 40 psf Spacing= 16”o.c. L=12’]

$$\delta = \frac{0.0052wl^4}{EI} = \frac{(0.0052)(6.667)(72)^4}{(1,600,000)(47.63)} = .01 \text{ in}$$

The deflection curves for three of the four examples above are shown in Figure 1, this shows how much stiffening a member or adding additional bearings can affect the deflection of a member. Example 3, omitted from the figure for clarity would be between lines 2 and 3 of the figure. It can also be noted that the addition of an interior bearing not only reduces the max deflection but can also change the location of maximum deflection.

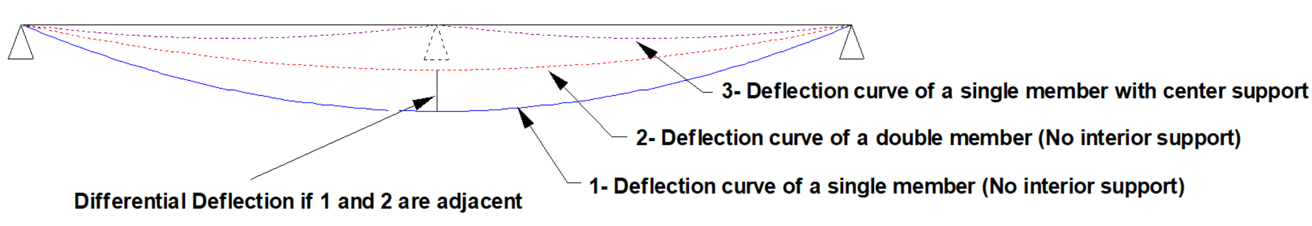

Figure 1: Deflection Curves

Differential Deflection

Differential deflection by definition is the deflection of one component relative to the deflection of an adjacent component. Every building system is made out of different components, and each component in this system will have its own deflection. In a roof or floor system these components are the trusses and every truss will deflect differently based upon its characteristics, loading, and its location within the framed system.

When the differential deflection between any adjacent two components in this system is high, it can lead to many undesirable outcomes; such as cracks in drywall, uneven surfaces and sagging in your floor system even doors and windows operating improperly. Under extreme cases it can affect building stability.

Differential deflection is always occurring but there are a few instances where it is more of a concern. For example when a continuously supported truss is adjacent to an identical truss that is only supported at its ends; another example is in a hip system when a shallower, heavily loaded girder truss is adjacent to a deeper, lightly loaded truss; others involve a truss with a flat bottom chord adjacent to a scissor truss or having a heavily loaded partition wall orientated parallel to the floor truss; also a longer span truss next to a shorter span truss. These are all framing situations where differential deflection can be a problem.

ANSI TPI-1 does not specifically state any requirements for differential deflection and it does state the building designer is responsible for specifying any limitations regarding differential deflection between adjacent trusses per Section 2.3.2.4 of ANSI TPI-1. However; within the ANSI TPI-1 commentary, section 7.6.2, it provides a suggested limit of $\delta \leq \frac{2\ x\ Ls}{Limit}$ for differential deflection, where 'Ls' is the spacing between adjacent trusses and the 'Limit' is the correct vertical deflection limit given from table 7.6-1 of ANSI/TPI-1.

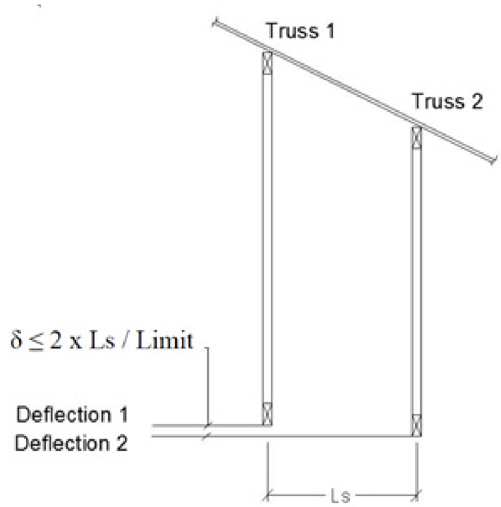

Figure 2: Differential Deflection (Figure C7.6-1 of ANSI/TPI 1-2014 Commentary)

Using the example data from above and having the beam in Example 1 located parallel and adjacent to the end wall. The calculated differential deflection at the beam mid-point would be .49” with respect to the top of the wall, located 16” away, and providing the level ceiling line. Plugging in the numbers into the limit equation, it can be determined that differential deflection is a problem since

$$.49 > \frac{2\ x\ 16}{180} = .1778$$

A shorter or stiffer member is needed to reduce the large differential deflection occurring at the end of the building. Figure 3 gives a visual representation of differential deflection. Ultimately this is just a suggestion and not a requirement by ANSI TPI-1 and is up to the judgement of a qualified engineer on how to address the problem or if it is a concern.

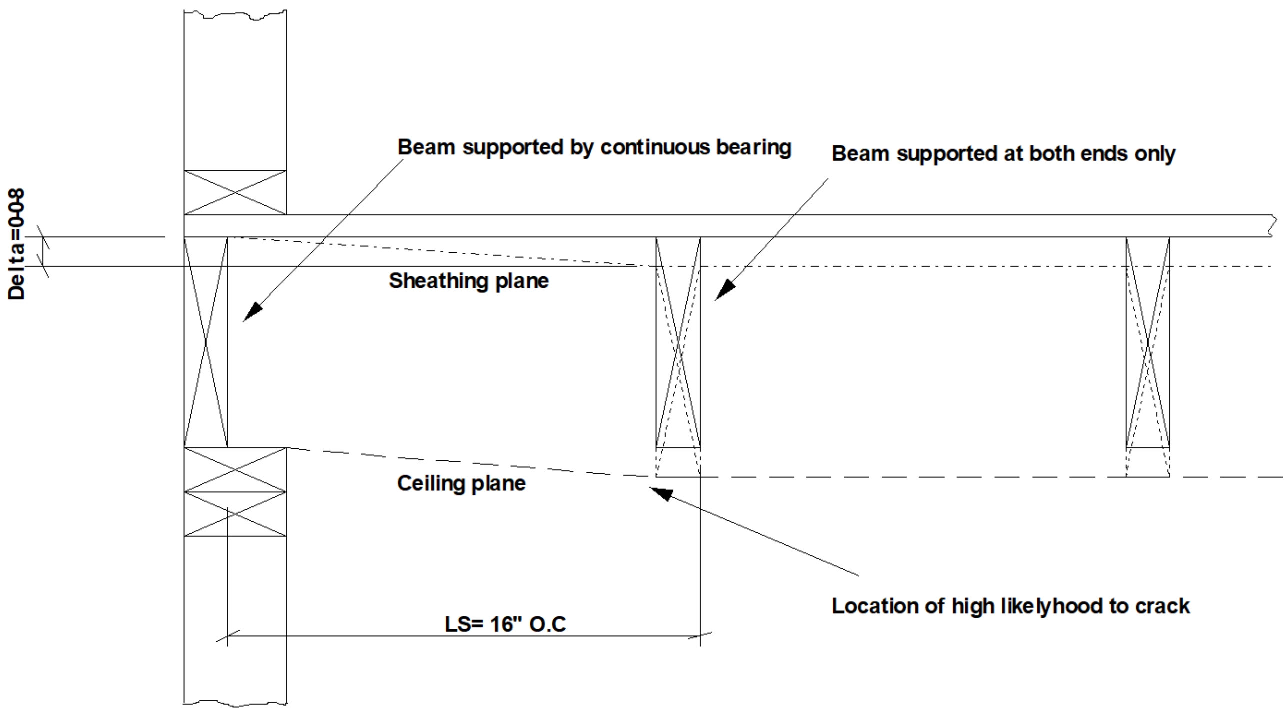

Figure 3: Differential Deflection between Beam Members

Conclusion

Differential deflection is the difference in deflection between two adjacent components, a high differential deflection can cause unwanted complications in the structure. There are several ways to mitigate deflection on trusses either by material or geometry. The use of Strong-back in floor truss system is one measure of evening out deflections in the system, another recommendation includes minimizing span changes or framing directions. Equalizing member stiffness's within an area is also a good practice to minimizing differential deflection, and in the absence of any defined guideline use the suggested ANSI TPI-1 equation of $\delta \leq \frac{2\ x\ Ls}{Limit}$ to limit differential deflection.

For additional information, or if you have questions, please contact the MiTek Engineering department.