



Analysis and Design of Steel Structures According to AISC 360 And Eurocode 3

An Online Continuing Education Course for Engineers

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Credit: 3 Hours / 3 PDH / 3 CPD

Analysis and Design of Steel Structures According to AISC 360 And Eurocode 3

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Introduction

In this course, the focus will be on the design of a typical portal frame structure. However, the main objective is for learners to develop proficiency in structural steel design. Thus, structural steel design will be thought of within the context of the design of a portal frame structure. The skills gained from this course can be transferred to the design of other types of steel structures.

The intent of this course is not to teach an engineer how to design using any specific Code of Practice. Principles from Eurocode and AISC will be covered. However, this should not distract from the basic structural steel design principles required to design a steel structure successfully. The best Codes in the world are tools that need to be referenced once a full understanding of the structure has been developed.

A portal frame building was specifically chosen because it requires a broad scope of structural steel design skills. There is some prior knowledge necessary for the design of a portal frame, such as:

- Identifying and tracing horizontal and lateral load paths in a structure.
- Understanding the mechanisms used to provide stability to steel structures.
- Understanding member stability and dealing with instabilities such as buckling and lateral-torsional buckling.
- Understanding the fundamental principles of steel connection design

The topics listed above will be tackled first. Once these topics are understood, the principles of designing a portal frame building will be presented. The role that every component plays within a portal frame building will be covered.

Some calculations are provided for a typical portal frame. These are hand calculations that can be used as a preliminary design. The calculations provided are for frame stability and design verification of the rafter using Eurocode and AISC 360-16. The columns and connections were excluded from the calculations to limit the course length.

Basic Structural Engineering Principles

The two fundamental requirements of any structure made of any material are equilibrium and stability. Equilibrium is satisfied for the column in Figure 1. The horizontal and moment reactions at the base resist the lateral wind load. Removing the reaction moment will cause the structure to rotate and collapse. A

stable structure can return to its equilibrium position after an applied perturbation, as described in Figure 2.

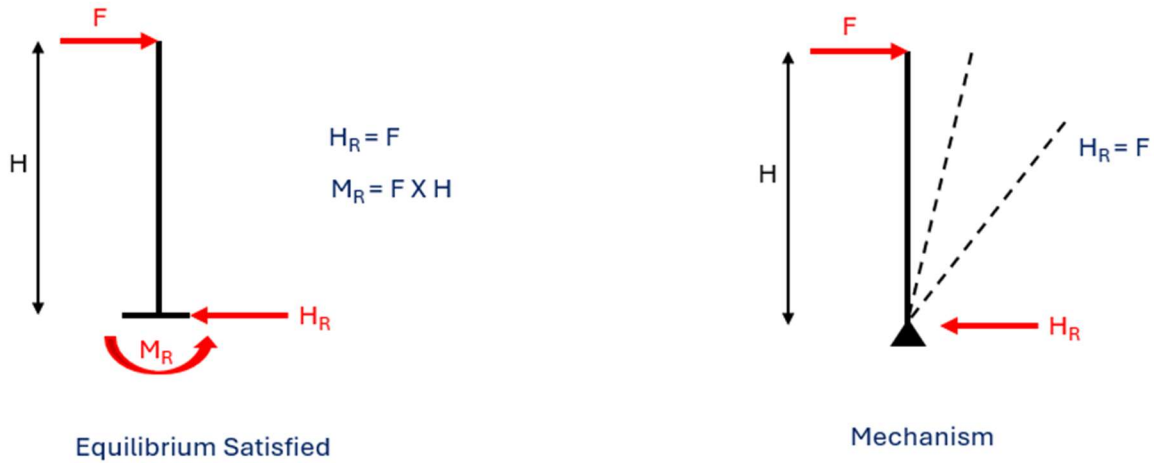


Figure 1: Equilibrium

Stable System – Perturbation will return ball to equilibrium position

Unstable System – Perturbation will cause ball to fall

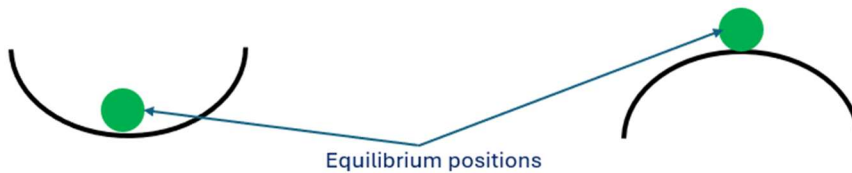


Figure 2: Stability

Equilibrium and stability require an understanding of a structure’s load path. All structures will experience a lateral and vertical action that will transmit through the structure and safely to the foundation. It is, therefore, critical to have a clear understanding of the load path through a structure. The paragraphs that follow describe some typical horizontal and vertical load paths.

Load Paths:

All structures must have a properly defined load path. This is something that may seem obvious to all structural engineers. However, the horizontal load path is less intuitive and often overlooked. Horizontal load paths are particularly important to ensure the stability of the steel structure.

One continuous load path should be provided for every type of load. It is sound structural engineering practice to provide a simple sketch to communicate the way in which the load is transferred. The sketch will be easily and successfully conveyed to the design engineer responsible for reviewing the concept design and the design intent.

Another important reason for performing this load path exercise is that you, as an engineer, have an opportunity to fully familiarize yourself with your design. It is a chance to intimately interact with your proposed concept design and gain a full grasp of the behavior of the structure prior to building a model on a structural analysis software package. By doing this, you will confidently verify that the qualitative and quantitative output from structural analysis software is correct when performing a detailed design. You would know that the model you developed on a computer agrees with the design you conceived.

Examples of typical vertical load path sketches are shown in Figure 3. These have been drawn on PowerPoint. However, the load path can be drawn by hand-drawn sketches, which are also effective and much quicker. These load paths communicate the type of structural system used and the way in which the load is carried. On the left, we have a piled foundation that resists load through friction and end-bearing behavior. In the center is a two-way spanning slab supported on columns. On the right is a frame experiencing bending in beams and compression in the columns. The sketch also suggests the use of simple connections. These are all simple sketches that aid in conveying the design intent of the engineer. The thought process of the design engineer is clearly encapsulated in these sketches.

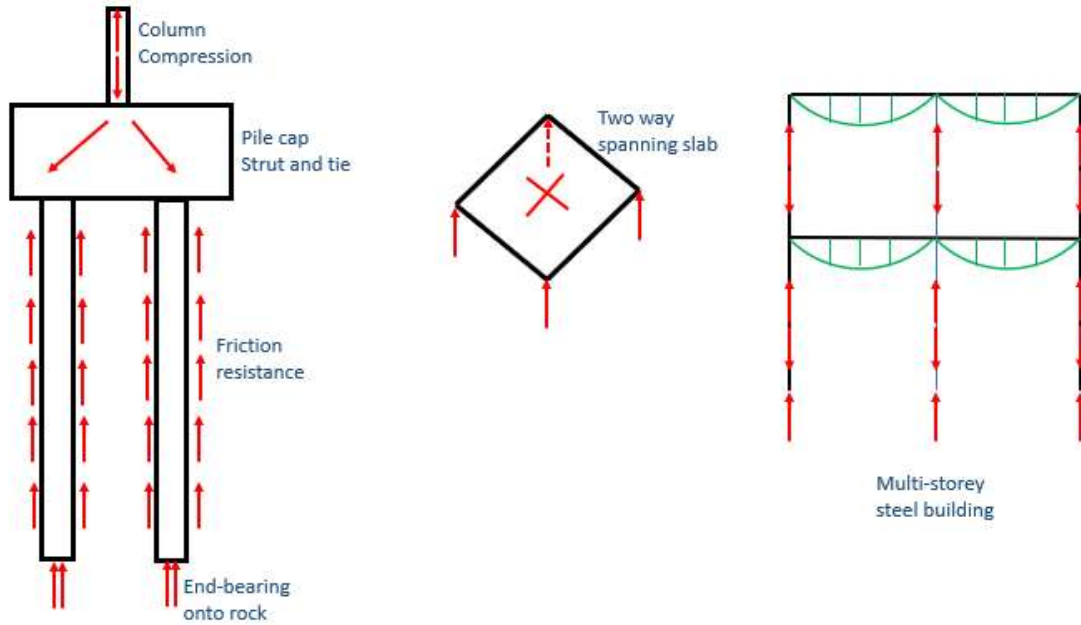


Figure 3: Vertical Load Path Diagrams

Lateral loads that are applied to structures are usually due to wind. These loads can be applied to a braced frame or shear wall in plan and elevation. Figure 4 shows the lateral load as applied to a braced steel frame. Once again, the design intent is explicitly clarified. The columns that are windward-facing will experience bending and axial tension forces. The remaining members will only experience axial forces in the form of tension or compression.

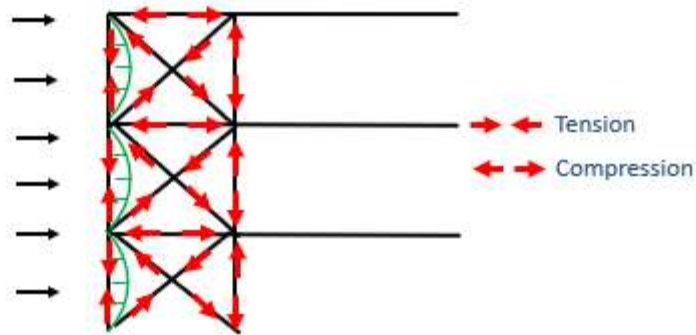


Figure 4: Horizontal Load Path

Stability:

It must be noted that there is a strong correlation between lateral load transfer and lateral stability. All steel structures must remain stable under lateral loads in both orthogonal directions. Lateral stability prevents the collapse of structures subjected to lateral loads. The structure should also not sway a significant amount. There are two methods of providing stability to a structure. These are by using a braced frame or a moment frame, also referred to as a sway frame.

To understand the importance of stability, let us consider the frame shown in Figure 5. On the left is a simple frame that only has hinges at the joints and is subject to lateral loads. Hinges allow for free rotation at the joint. From basic undergraduate mechanics, the structure will overturn, as shown in Figure 6. This is a structure that does not provide any stability. This may seem obvious, but many engineers tend to forget about stability, especially when loads are predominantly vertical. When adequate lateral stability is not provided, failure would occur to the building. So, how would you provide stability to the structure? There are two options used in steel construction. You may either use a braced or a moment frame.

For the case of a braced frame, a bracing system such as that shown in the center of Figure 5 can be used. In this case, the bracing members will experience compression and tension forces only. A moment frame is shown on the right of Figure 5. Developing a moment frame requires a rigid joint at the beam-column connection. This rigid joint will provide rotational stiffness, implying that the beams and columns are not allowed to rotate relative to each other, as they do in Figure 6. The incorporation of a moment joint is usually expensive, and the concern is that the lateral sway of the frame may be too excessive. In this case stiffening the structure by increasing member sizes will reduce the magnitude of the sway but also increase cost. The use of moment frames is often unavoidable (for example, portal frame structures), so certain codes deal with the issue of excessive sway by acknowledging that the support is not truly pinned and allow for a small rotational stiffness to be used at the supports to reduce sway.

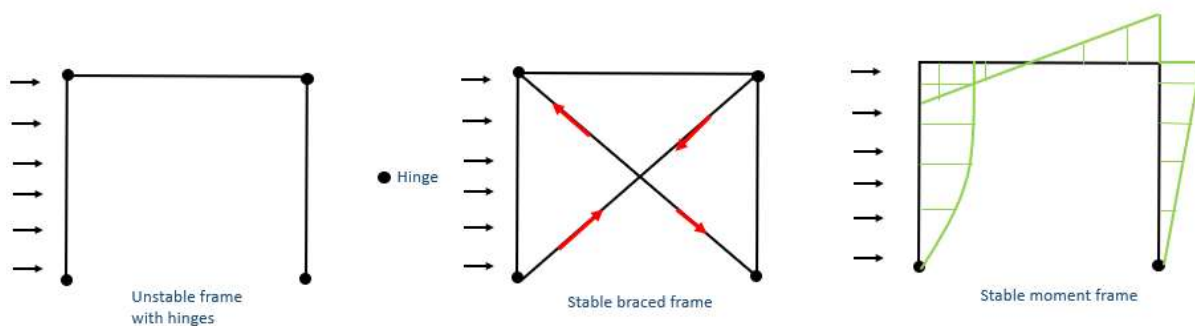


Figure 5: Stability Systems

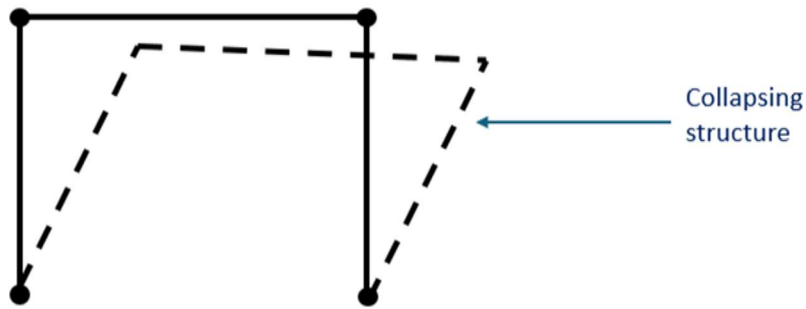


Figure 6: Frame without adequate Lateral Stability

The source of the lateral loads shown in Figure 5 is the only lateral loads that should be considered. Another force that is applied horizontally at the base to simulate the behavior of the structure as part of the design of the structure.

For the moment, it is sufficient to discuss the location of braced bays.

Basic Principles of Stability

Member stability:

In the previous section, the concept of member stability is meant to prevent overall structural failure due to buckling in steel structures. The instability is understood to be buckling. However, this is not necessarily true all the time. A more accurate definition of instability is when a structure's stiffness becomes less than 0. A column can buckle into a second state of equilibrium, which is still stable. However, for this discussion, buckling is assumed to result in instability.

The most common form of instability is the "classical" form of buckling. Simply put, a column is compressed, and after some time, the column will "aggressively" displace laterally, as shown in Figure 7. The amount of load to be applied before buckling takes place depends on the slenderness of the element. Slenderer elements will buckle at lower loads; thus, columns can buckle before any material yielding can take place. To prevent this behavior, slender elements should only be used where properly designed for economic reasons.

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