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THE BASICS OF FIXED CONNECTION IN ANALYSIS AND DESIGN OF STEEL FRAMES

MUANGSANGOP SENIWONGSE

Bermello Ajamil and Partners, New York, USA

This paper is concerned with the out-of-date design criteria in the assumption of end boundary conditions in computer analysis and design of steel building frames in some sectors of heavy industry. The two major concerns are addressed: one is the use of pinned end for the steel column base plates whose details are fixed end, and the second is the use of pinned connection design of steel beam to steel column in lieu of using moment connection. A typical frame is shown for demonstration purposes. The typical connection details used are shown. The author presents the pinned and fixed connection definition with reference to AISC Specification for Structural Steel Buildings. Examples of actual pinned end and actual fixed end are shown with reference to actual structures. A simple structure of a single column traffic sign post with a cantilever beam at the top of the column was selected to demonstrate a fixed end column base and a beam to column moment connection. It is the aim of this paper to clarify this simple but significant concept of fixed connections of column base plates and moment connection of beam to column, which in turn will lead to significant savings in the construction of steel buildings.

Keywords: Baseplate, Bolt, Computer, Moment, Pinned, Rotation, Welding.

1 INTRODUCTION

This paper refers to the structural steel analysis and design practice in some sectors of heavy industry in USA using computer software. The concerns are on at least two major assumptions in computer modeling that should be reconsidered and updated to reflect the actual details and structural behavior. In a certain specialized heavy industry, the design and build is usually exclusively awarded to a few big well-known companies which have been in the business for more than 30 - 40 years. This criterion of prequalification has its own advantages and disadvantages. Using the argument that the structures built with existing design criteria for the past 40 years are still standing up and hence any suggested revision or improvement are ignored. The author points out herein three modeling criteria that would improve the future design, which would result in a more successfully outcome to all concerned parties, leading to easier- to-build and cheaper structures. The cost reduction can then be passed on to the consumers. Most importantly, it concerns the basic understanding of fixed and pinned connections of professional engineers, which needs to be addressed and corrected.

2 OUT-OF-DATE DESIGN CRITERIA AND GROUP THINK

Without naming the industries, the typical interior steel frame of the industrial buildings housing heavy machinery is shown in Figure 1. The buildings usually have one or two mezzanine levels.

The length of the buildings is in the order of 300 ft. The portal frames are spaced at 30 ft to 40 ft across the entire length of the building. The ground floor is usually of concrete mat foundation on grade or on piles depending on the soil foundation. The mezzanine floors are either concrete slab on steel beams or steel grating on steel beams.

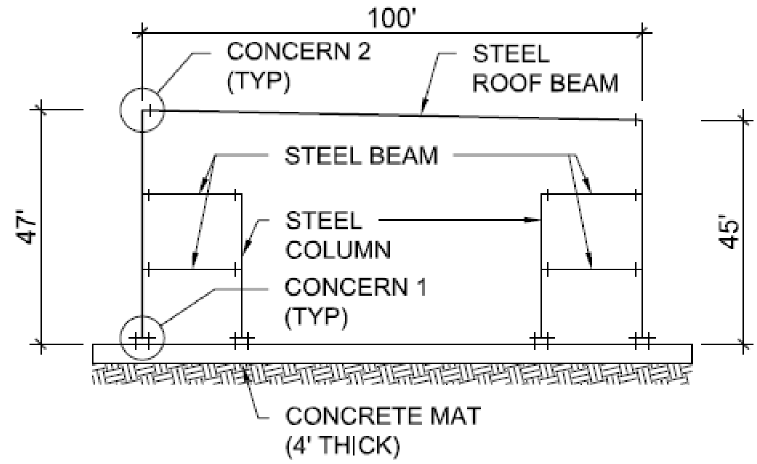

Figure 1. Typical steel frame of concern.

The concerns in this paper are the Out-of-Date Design Criteria and the Group Think Mentality. The Establishment imposed the following design criteria.

1) All steel column bases are assumed pinned ends, while the design detail used are actually of fixed ends.
2) No field welding is allowed in any steel structural members. All steel connection design for field connection must be bolted connection only, with no exception, while much smaller steel pipes and equipment supporting steel angles inside the buildings are allowed to be field welded.
3) The steel beams supporting concrete floor slab must be designed as non-composite sections, while the composite design would have reduced the size of the steel beams.

The reason given by the Group Think was these criteria have been used repeatedly for more than 40 years and there have been no problems. The first two of the above three criteria will be discussed in this paper for education sake and for saving of steel from wrong design assumptions.

Figure 2 shows a typical column base plate similar to those used for the steel frame in Figure 1. It is shown for demonstration purpose only. Typical column sizes are W36 and the base plates 2” to 3” thick, 44” x 48” in plan with 10 to 16 high strength bolts of 2” to 2 ½” dia. The bolts are cast-in-place and embedded some 3 ft deep in the concrete mat foundation. The W36 column is fully welded all round to the steel base plate. It is obvious that there is moment resistance at the welds at the W36 base, and there is moment resistance at the bolt group at the mat concrete foundation. The steel base plate itself has moment of inertia for moment resistance. Yet, all column bases of this type were input in the structural analysis programs as pinned ends, that is the computer was told the column bases have no moment resistance and are all free to rotate, which is not the case.

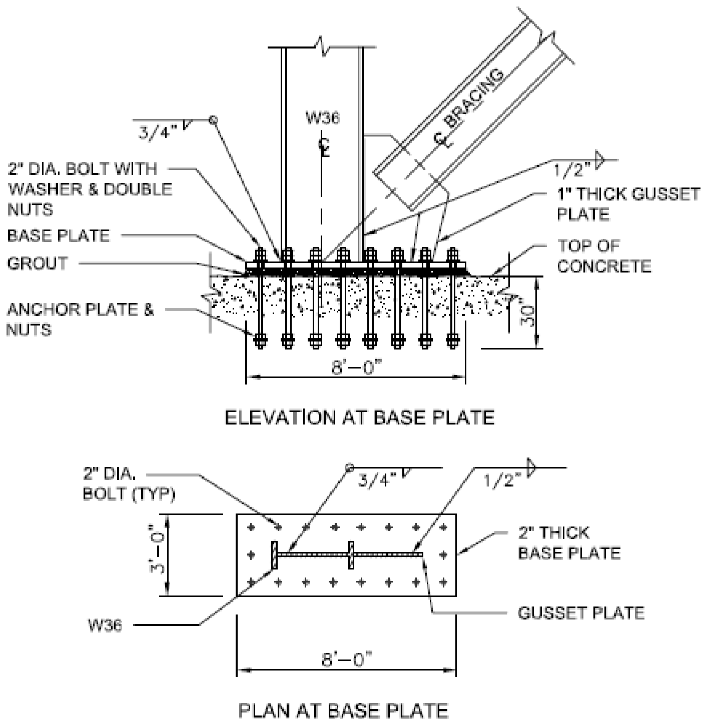

Figure 2. Typical column base plate and anchor bolt details.

Figure 3 shows typical steel connection between the roof beam and the column. The beam is W36 and the column is W36. Shear tab pinned connection was used as mandated by the design criteria. The primary purpose of the out-of-date criteria given by group think was to avoid field welding.

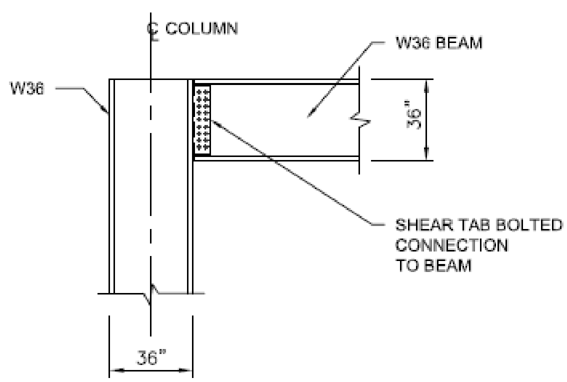

Figure 3. Shear tab pinned connection of steel beam to column.

It must be pointed out that the shear tab connection in Figure 3 can be easily improved to moment connections as shown in Figure 4(a) with field bolting and 4(b) with full penetration welding at the top and bottom flanges. These details or similar are commonly used around the world. But, the details were prohibited by the establishment. The sub-consultants and the contractors did not question the design criteria as long as they got paid for what they were told to do. Hence, the cycles continue.

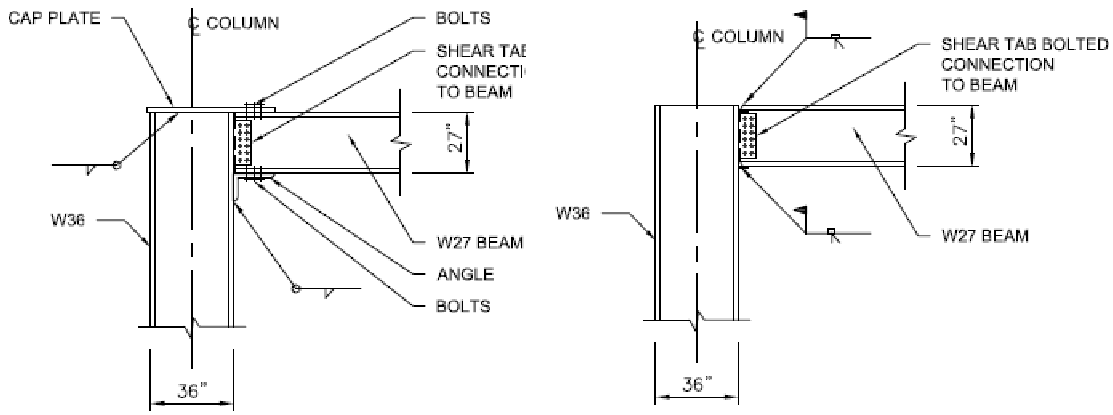

Figure 4. Moment connections: (a) by bolting at the flanges, (b) by field welding at the flanges.

3 PINNED SUPPORT VERSUS FIXED SUPPORT

Figure 5 shows the legend and definition of fixed and pinned supports taken from AISC (1989)[1]. Pinned support is free to rotate, having no resistance against rotating forces or moments. Fixed end is fixed against rotation and translation and is the most stable type of support. The structural details for pinned support and fixed support are different and are shown in the next sections.

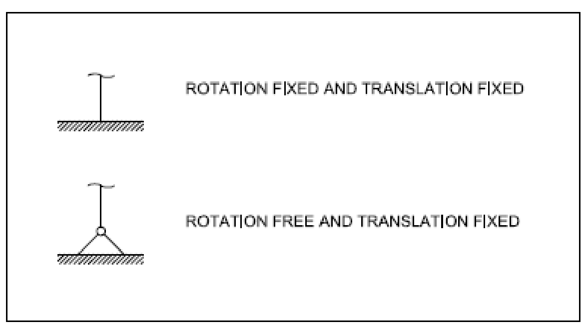

Figure 5. Legend and definition of fixed against rotation and free to rotate (AISC 1989).

3.1 Pinned-end Detail

The examples of pinned-base details are shown in Figures 6 and 7. The support is provided with an elastomeric bearing (Figure 6a) or a pin or roller (Figure 6b) to behave as a pined-end, free to rotate.

[1] Part 5 Chapter C, Table C-C2.1, page 5-135.

Figure 7a shows the actual pin used at the bottom of the right column, which the design engineer wanted it to behave as pinned-end. It was there for a reason, not by chance. The picture was taken in an International airport in Europe. Figure 7b shows a pinned connection detail of the steel columns that support the roof of Turkey International airport (Celtikci 2001).

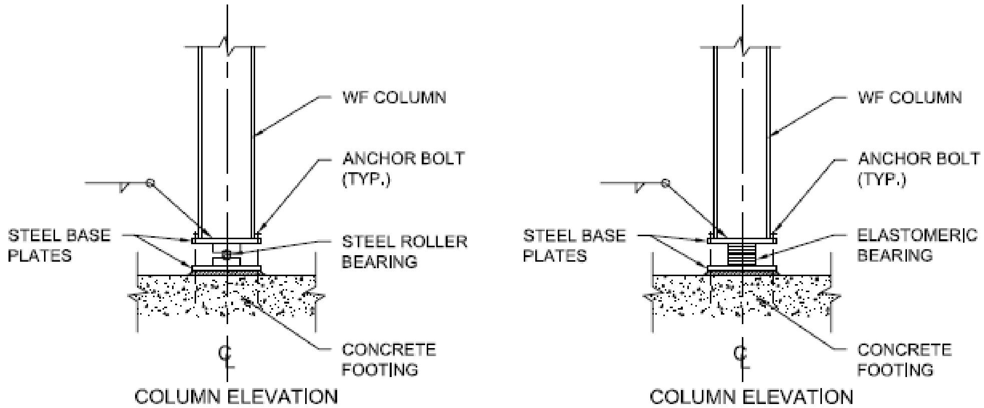

Figure 6. Column base details for pinned support – free to rotate.

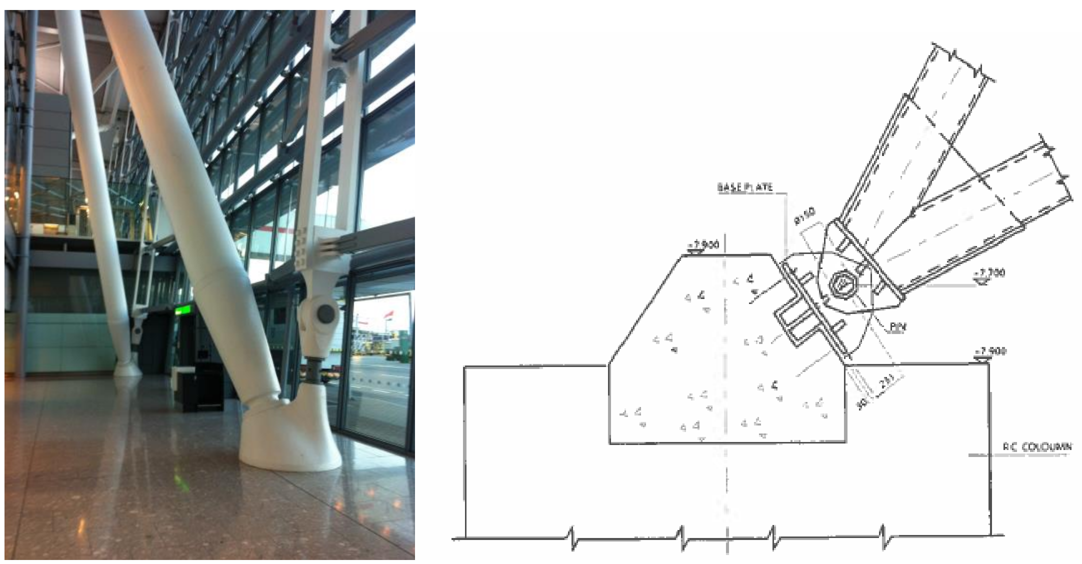

Figure 7. Pin connection (a) at the base of the right column, (b) at the base of steel columns at Turkey International Airport (Celtikci 2001).

3.2 Fixed- end Detail

Fixed support by direct definition is fixed. Fix means no movement. Fixed support is a stable support and can resist forces and moments that act on it or transferred to it. The typical fixed-end support for steel column is shown in Figure 2. The base plates and the anchor bolts do not have to be oversized to behave as a fixed base as shown in Figures 8 and 9. Figure 8a shows a traffic sign post with overhanging cantilever beam on a small steel base plate with 4 anchor bolts (Figure 8b). This support is a fixed or moment connection, the post is stable against the lateral forces and moments that act on it. Figure 8a also shows the cantilever steel beam is connected to the top of the post with four bolts. It is obviously a moment connection, otherwise the post and the cantilever beam would have rotated and collapsed under lateral wind loads. Note that the base plate and bolts in Figure 2 are much larger than the base plate in Figure 8b. It is very obvious Figure 2 detail is a fixed support detail, not a pinned support.

(a) (b)

Figure 8. Base of traffic post moment connection (fixed connection).

3.3 Beam to Column Moment Connection

Refer to Figure 3 of the roof beam connection to top of column. It is a pinned connection for the beam. If the fixed or moment connection (Figure 4) is used, the beam size would be reduced in this case from W36 to W27. The mid-span deflection will also be reduced. The portal frame would be a rigid frame and can resist horizontal transverse forces due to the joint rigidity without the need for the horizontal diagonal bracings. Hence, much construction time and cost would have been saved. Figure 8a above demonstrates beam to column moment connection is simple to achieve.

4 CONCLUSIONS

This paper has addressed two major concerns of the incorrect assumption in the existing design criteria of steel building frames of some major heavy industry. One concern is the use of pinned end column computer input instead of using the fixed end coding. The other is the use of pinned connections to columns for all the beams in the entire buildings. These two incorrect or in appropriate assumptions have led to grossly over designed steel frames. Due to its grossly over-design, nothing has ever happened to the structures. But this does not mean a good engineering practice, besides engineers have the duty to provide “Duty of Care” for the work performed, and to attempt to give the Clients the most optimum structure.

References

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Celtikci, N., Istanbul Sabiha Gokcen Airport, Turkey International Terminal, *Modern Steel Construction*, 55, August 2001.