

Zachary S. Wolcott

SEAO Education Award 2021

April 2<sup>nd</sup>, 2021

### The Welded Unreinforced Flange - Welded Web

The Welded Unreinforced Flange – Welded Web (WUF-W) connection is a prequalified moment frame connection from ANSI/AISC 358. The WUF-W connection uses only welds to connect the beams and columns together. This connection is one of the prequalified, non-proprietary connections that has been approved to be used after the 1994 Northridge earthquake in the United States. This earthquake showed that steel connections, previously designed to resist seismic forces, were not adequate. These prequalified connections have all been rigorously tested to show that they can meet the requirements and demands for a moment frame connection in an earthquake or other heavy lateral motion events. In this report I will discuss how the connection is constructed and its limitations. I will review the connection’s behavior which includes the location of the plastic hinge, hysteretic curves, story drift ratios, and possible failure modes. Lastly, I will go over potential costs and construction considerations when using the WUF-W connection.

The WUF-W connection connects the beam and columns together using a plate welded from the column flange to the beam web, Figure 1. The connection also utilizes a complete joint penetration (CJP) groove weld on both the top and bottom of the beam to connect the flanges to the column. This creates a fixed connection to the

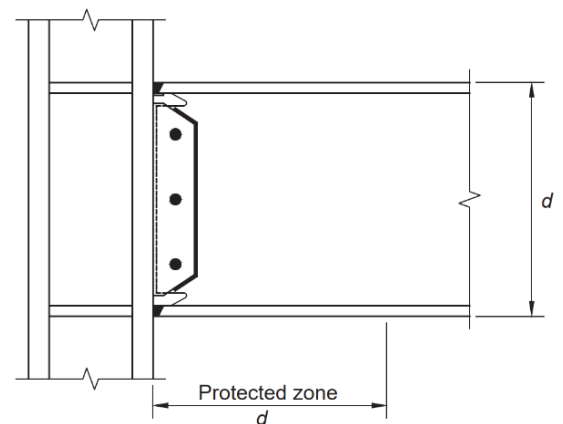


Figure 1: WUF-W Connection (AISC 358-18)

column. In order to install this connection erection bolts are required as well as access holes in the top and bottom of the beams web to ensure a continuous CJP weld can be installed, Figure 2. The use of the CJP welds, and being an all-welded connection, allows this connection type to achieve a very ductile response (Manning, 2021). The WUF-W connection can be used when an intermediate moment frame or special moment frame category has been selected based on the seismic design criteria.

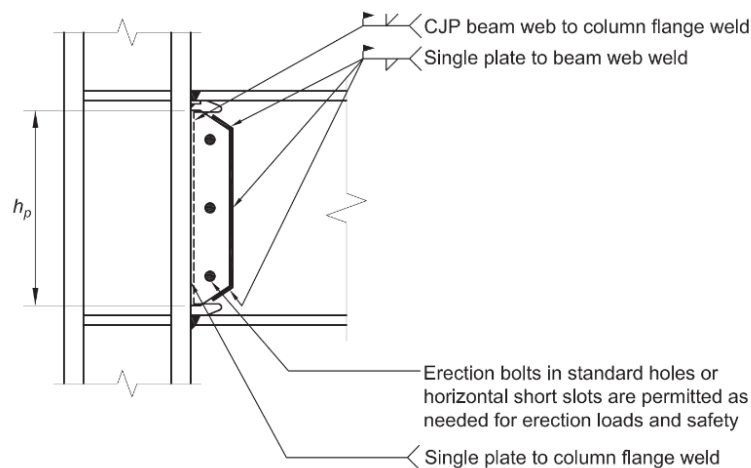


Figure 2: WUF-W General Detail with Weld Call outs (AISC 358-18)

The WUF-W connections will behave in a way that the connection will yield primarily in the beam region adjacent to the column (AISC 358-18). In order to make sure that the beam yields first, special detailing is required so that the connection does not rupture. This detailing includes the weld between the beam and column flange, the access hole shape and finish, and the weld connecting the beam web to column flange. The primary goal of this connection is to prevent failure of the connection by designing the beam so that the plastic hinge forms in the protection zone beyond the connection and not in the column, in other terms designing a “strong” column and “weak” beam.

Through research and testing of the WUF-W connection, hysteretic curves have been created. These curves evaluate the performance and test how slight modifications in the connection can increase or decrease strength and effect story drift. The hysteretic curve of this connection shows very good results in both directions and limited total story drift. Figure 3 shows a sample hysteretic curve from a study done on how the beam depth and panel zone strength ratio affects the performance of the WUF-W connection. This study found that specimens with a depth of 900 mm (35.44 inches) or greater did not meet the criteria as prescribed in AISC 358 which led the study to conclude that the access holes need to have more stringent regulation on its slope (Han, 2014). This study proves the reasoning behind the Federal Emergency Management Agency (FEMA 350) limiting the maximum beam size to be a W36 for special moment frames (Volovar, 2011). The hysteretic curve also provides information on the values of the possible story drift when using a WUF-W connection.

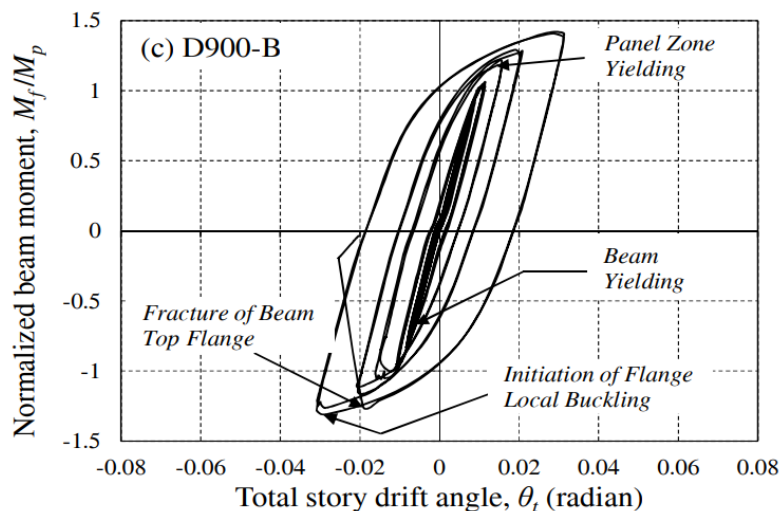


Figure 3 Sample Hysteretic Curve, (Han, 2014)

In a study conducted by the University of Turkey, the university tested 3 different pre-qualified connection types and compared the strengths and weaknesses of each connection under seismic loading. The WUF-W connection's story drift was found to be between 2% and 7% with

values above 5% potentially causing local buckling in the beam flanges and web (Yilmaz, 2018). A separate study conducted by Hanyang University, tested the WUF-W connection using different grades of steel and found similar results with a drift ratio of 4% before the beam started to deform (Lee, 2016). AISC 7-16 limits the story drift to 2.0% of the story height. These results and sample hysteretic curve show that the WUF-W connection is a suitable connection to be used in the design of structures in a seismic region.

The WUF-W connection from the testing seen above has been proven to provide the adequate strength for a seismic event, given you meet the parameters set out in ANSI/AISC 358S1-18 Chapter 8. However, strength is only one aspect to consider when picking a connection type in a seismic area. The cost to complete a WUF-W connection in a building can be more expensive than other connection types because it requires field welding. Shear plates can be welded to columns in the shop and come to the site ready for installation, but a CJP weld (up to 1" thick) and fillet weld need to be performed onsite to connect the top and bottom flange and beam web to the column. Another aspect that increases the cost is the location and access to the weld. The top flange is not as big of a problem, but the bottom flange can cause welders to take longer as they must move from one side to the other to fully weld the flange. This also is a key factor in the constructability of the connection. The main two welds on the top and bottom are CJP welds. These welds come with additional inspection requirements, a welder that needs to meet American Welders Society (AWS) prequalification and requires a lot of welding rods to build up enough material. All of this is added cost to this connection type.

Advantages with using this connection type are, an engineer does not have to coordinate design documents, shop drawings, and loading requirements, with a proprietary company that adds another person to the project. Additionally, if a seismic event were to occur this connection

allows for easy repairs to the structure. The beam is designed to yield before the connection and a new beam or section of beam can be installed to replace the one that has yielded. The WUF-W connection is one of the more costly connections but the benefits you gain in strength and ductility can help offset some of that cost over the life of the structure.

The Welded Unreinforced Flange - Welded Web (WUF-W) connection is a quality, non-proprietary, option from the approved connections that have been designed and tested following the 1994 Northridge Earthquake. Although this connection is possibly more costly depending on the building parameters, it has proven to provide adequate strength in both directions as well as limit the total story drift. The higher cost comes from it being an all-welded connection and with these welds being a CJP groove weld that braces the top and bottom of the beam flange. Using an all-welded connection, like the WUF-W, allows for the beam to develop a highly ductile response and is most economical to be used in special or intermediate moment frame applications. This connection type provides good story drift ratios as was seen in Figure 3. In conclusion, the WUF-W connection is a reliable connection to be used in a structure in a seismic area for the many benefits in strength and ductility that this connection provides.

Works Cited Page

1. *ANSI/AISC 358-18. Prequalified Connections for Special and intermediate steel moment frames for seismic applications including supplement No. 1: (AISC 358-16) ; and supplement (ANSI/AISC 358s1-18). American Institute of Steel Construction (AISC), 2018.*
2. *Seismic Behavior of Welded Unreinforced Flange-Welded Web Moment Connections.* S. W. Han, J. Jung, K. H. Moon, Han 2014. 10NCEE Frontiers of Earthquake Engineering July 21-25, 2014 Anchorage Alaska. Web 3/2/2020  
<https://datacenterhub.org/resources/12184/download/10NCEE-000859.pdf>
3. Kirk P. Volovar, *Steel Moment Resisting Connections subject to Earthquake Loading (PowerPoint)*, April 2011, University of Maryland. Web 3/2/2020  
<https://user.eng.umd.edu/~ccfu/ref/SeismicConn.pdf>
4. *Seismic Performance of Post-Northridge Welded Connections.* Orkun Yilmaz & Serkan Bekiroglu. Yilmaz 2018. Web 3/2/2020 <https://www.scielo.br/pdf/lajss/v15n2/1679-7825-lajss-15-2-e18.pdf>
5. *Cyclic Behavior prediction of WUF-W Connections Using FEW.* Changseok Lee, Namhum Kim, Taro Kim, Sangwhan Han, Lee 2016. 2016 International conference of Architectural Engineering and Civil Engineering (AECE-16), 2016 Web 3/2/2020  
<https://datacenterhub.org/resources/12184/download/10NCEE-000859.pdf>
6. Manning, Shayne. Personal Video Interview, April 1, 2021.