BOLTING MECHANISM OF ONE-SIDED BOLTED CONNECTION IN PREFABRICATED STEEL STRUCTURE

Sharal Thirumeni[1], Manish Jose[2]

[1] M.Tech student, Dept. of Civil Engineering, St. Joseph's College of Engineering & Technology, Kerala, India
[2] Assistant professor, Dept. of Civil Engineering, St. Joseph's College of Engineering & Technology, Kerala, India

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Abstract*- Steel bolted connections are common connection technique that we used in mechanical engineering, but these types of fasteners also play a inevitable role in civil engineering sector. Bolting steel section is desirable because of the easiness of its erection and durability of the joint. However, bolting an Standard High-strength Bolted on Hollow Structural Section (HSS) is herculean task, since there is no access from inside. So, in order to make simpler the bolted connection, we can opt a One-side Bolted Connection instead of conventional hexagonal head bolted connection. Alternatively, Hollo-bolt, Slip-critical Blind Bolt, Thread-fixed One-side Bolt, T-shaped One-side Bolt, T-headed square neck one side bolt, BOM Fastener, Ajax One-side are other kind of fasteners that shows almost similar properties of normal hexagonal headed bolt connection. This paper emphasis with a review regarding various one-sided bolt and the importance of preload force on bolts.*

1. INTRODUCTION

Prefabricated steel framed structures consist of many merits over conventional on-site built structures, including faster construction, reduced pollution, and greater quality control. The usage of prefabricated modular steel buildings aids in the buildup of industrialization in construction [1]. Prefabricated modular steel structures are now used mostly in low-rise buildings; their applicability in high-rise and multi-story buildings is still undergoing boundless research and development. There pose distinguishable researches in vibrational analysis of prefabricated modular steel structures for high-rise and multi-story buildings. The stability and load-carrying capacity of a structure can directly influenced by the performance of beam-to-column and beam-to-beam connections. These prefabricated steel sections are generally connected through welding or bolting. By the situation of applications, the type of fasteners will change and both poses some demerits too. Although both kinds of bolted connections were consisting of high rotational stiffness and load-carrying capacities, welding quality is susceptible to environmental and human influences, and welding process will lead to formation of significant stress concentrations [2,3].

Bolted connections are mostly used fasteners in prefabricated steel framed structural due its flexibility of assembly and disassembly sections. The connections considered as the weakest point in the steel framed structures. In many cases, bolted connection can be responsible for determining the overall durability and safety of the whole structure. A normal bolted connection emphasis with a threaded fastener, a nut, washer and other parts that would be used for clamping the bolt. Preloading of bolt is a process of applying pretension force on the bolt, in order to transfer various loads through the clamping action of bolted connection. The vibration of connections plays an inevitable role that can influenced the stability of entire structure. So, beyond the textbook knowledge, we have to think about more, regarding the effectiveness of the connection from seismic conditions. Connections with extra energy dissipation elements [4,5] and the self-centering connections that reduce severe earthquake displacement and overturning.

The reliability of normal bolted connection is mainly determined by both the initial preload level and rate of decay of clamp load over the life of the joint, which is signified by the residual amount of the clamp load. Hundreds of variables affect the preload level and its rate of decay; these variables are mostly related to material properties of the various components, design and analysis methods, fabrication, surface treatment, tolerances, assembly tools, and process control [6].

Table-1: Bolt pretension force values [21]

Bolt grade	Designed bolt pretension force (kN)
M20 Bolt	155
M24 Bolt	225

On the basis of property class, bolts are graded as 4.6, 4.8, 5.8, 8.8, 9.8, 10.9,12.9. Among this 4.6 to 5.8 grade bolts are categorised as bearing type bolts and the remaining bolts are distinguished as High Strength Friction Grip Bolt (HSFG). The values represent the ultimate and yield strength of bolt. The bearing action between bolt shank and bolt hole establishes the load-transfer mechanism for such a connection. The resistance of the connection is determined by the bearing between bolt and steel plate [7]. Although, the connections with HSFG bolts are designed to allow for slip and be sufficient to avoid tension failure. The shear failure and the resistance of the bolted connection is found out by analyzing the bearing strength between bolt and steel plate. Bolt fracture, bolt thread failure, and nut thread failure are the three most common failure types in bolted connection

[8]. High strength steel with a nominal yield strength =460 MPa has improved material strength compared to normal strength steel. In high-rise buildings, bridges, and enormous space structures, High-Strength Steel (HSS) is widely being used. As a result, a thorough understanding of the bearing strength of bolted connections between HSS components is required. In order to make the analysis simplier, Single-bolt connections are commonly used to assess the connection's bearing resistance. Although, as in building practice at least two bolts were generally used for bolted connections. [9].

Fig-1: Standard hexagonal headed bolt

Bolts have a number of significant advantages, including the capacity to support relatively heavy weights, moderate costs, easiness of installation and execution, and adequate reliability. Apart from the benefits, bolted joints are compressed of certain flaws, which can leads to the damage to the structure or equipment. Stress concentration, cracks, corrosion, and looseness are some of the sources of such faults [10]. Because of its acceptable vibrational performance and convenience of fabrication on site compared to welded connections, the usage of bolted connections has grown in popularity. Under cyclic loads, bolted connections provide better ductility & energy absorption capacity before brittle failures occur.

2. HOLLOW STRUCTURAL SECTION

A Hollow Structural Section (HSS) is a void cross-sectioned steel form. HSS contributors are available in a variety of shapes, along with circular, rectangular, and square portions, elliptical sections are also available. HSS in rectangular and square geometries are generally termed as box section. When compared to open section members, Hollow Square Steel Tube (HSST) members have superior mechanical qualities, such as stronger torsional stiffness and the same flexural stiffness along both axes of symmetry. However, the normal hexagonal headed bolts cannot be inserted inside in an HSST, it should be only used where both sides of the connection get access for inserting the bolts in bolt holes.[11]. To alleviate this problem, one-sided bolted connections were introduced.

3. ONE-SIDEDED BOLTED CONNECTION

The HSST causes problematic situations in the bolt installation with Standard High-strength Bolted Connection (SHBC), since there is no access from inside of HSST. At present scenario, there uses a variety of one-side bolts, such as Hollo-bolt, Slip-critical Blind Bolt, Thread-fixed One-side Bolt, T-shaped One-side Bolt, Ultra-twist Bolt, Huck Bolt, BOM Fastener, T-headed square neck one side bolt Flowdrill Bolt, Molabolt and Ajax One-side Bolt, etc. [12-14]. Hollobolt [15,16], another type of one-sided fastener having spreadable legs is refer in Fig 2(b) (see Fig. 1b). The bolt tail is placed into a predrilled hole, and the bolt is torqued from the bolt head side with a torque wrench. The torque imparted causes the cone to move toward the connection's outer side, expanding the legs and forming a fix against pulling out. The hollobolt one sided fasteners are derived as in two types, they are Reversing Mechanism Hollobolt (RMH) Fig 2(a) and Extended Hollobolt (EH) Fig 2(c). The components of RMH are similar to those of Hollobolt, however the expanding part is inverted.

Wang et al. [17] introduced a new kind of one-sided bolt named as, Slip-Critical Blind Bolt (SCBB) and conducted a low-frequency cyclic loading test on eight full-size beam-column connections using SCBBs. The specimens almost show the same behaviour as the connection were bolted with Standard High-strength Bolts (SHB). The analysis on Slip-critical Blind Bolt (SCBBs) was to be done by connecting the endplate with HSST columns & investigated their application by considering collapse of beam to column joints.

Fig-2: Types of hollobolt

The Thread-fixed One-side Bolt was proposed by Liu et al. [18] and Zhu et al. [19], who conducted a series of experimental tests on the Thread-fixed One-side Bolted T-stubs Connection (TOBTC) under tension. According to test results, tensile capacity of TOBTC will be considerably increased by the application of backing plates. Wulan [20] performed numerical simulation & parametric analysis TOBTCs. The results of the analysis revealed that TOBTC might prevent thread failure. The shear behaviour of lap connections utilizing Thread-fixed One-side Bolt was investigated experimentally and numerically, and test findings revealed that the Standard High-strength Bolt (SHB) may be replaced with Thread-fixed One-side Bolt in shear lap connections.

Sun et al. [21] presented a kind of T-shaped One-side Bolt (TOB) Fig 3 and performed Finite Element (FE) simulation on the HSST to I-beam endplate connection. The bending moment capability of TOBs bolted beam-column connections shows a reasonable value than that of normal hexagonal high strength bolted connection.

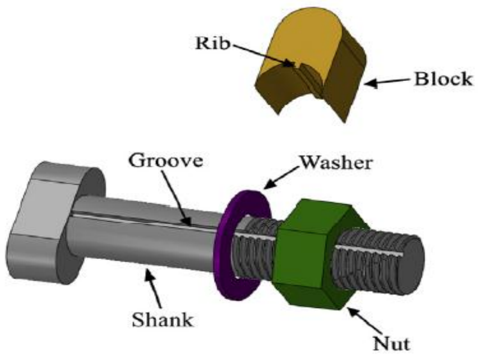

Fig-3: T-shaped One-side Bolted endplate Connection

Wang et al. [22] investigated the bending moment and low-cycle loading characteristics of a thin-walled beam-column composite connection connected with Hollo-bolt. According to test results, the failure of connection was occurred due to the breaking out of bolt. Ma et al. [23] investigated the vibrational analysis of steel-concrete composite beam which is connected to HSST framed column Bolt, by using Finite Element Model (FEM) analysis. The connection exhibited better ductility and energy dissipation capability, and there was no plastic deformation in the connection zone.

Lee et al. [24] used Ajax One-side Bolt to investigate tension and compression of a T-stub fastened connection to an HSST. According to the findings, the present component technique could accurately determine the connection's initial stiffness and bending capacity. Blind oversized mechanically locked bolt (BOM), Huck high strength blind bolt (HSBB) & Ultra-twist are three varieties of one-sided bolted connection with similar, fastening technique. These fasteners perform one-side assembly by producing a lock head on the inaccessible side of the connection with a deformable component [25,26]. The installation of BOM fasteners are figure out below (Fig. 5). These three kinds of one-sided bolts are installed by the application of special electric wrench.

Wang [27] proposed an advanced one-sided bolting system by introducing a T-head Square neck One-side Bolt (TSOB), which is Similar to a SHB. The TSOB emphasize with three elements: bolt shank, washer, and nut. TSOB shank can be geometrically divided into four parts, which are T-head, square neck, circular neck, and threaded shank, as figure out below (Fig.5). Analysis of TSOB were carried out by comparing four failure modes such as, (1) column yielding, (2) column yielding with bolt hole shear, (3) T-stub flange yielding, and (4) bolt failure.

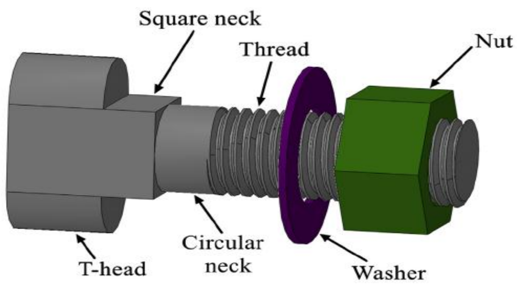

Fig-4: T-headed square neck one side bolt

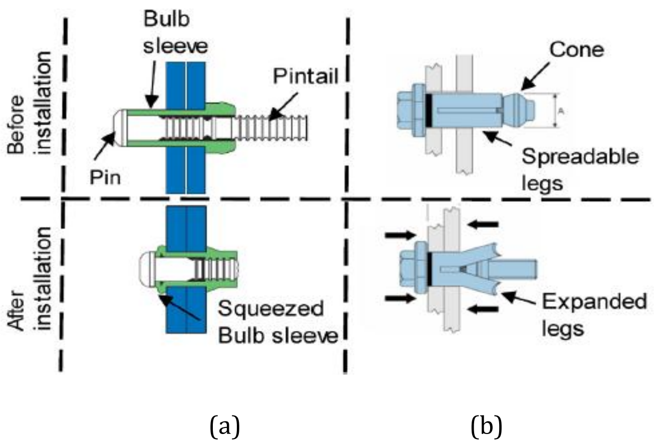

Fig-5: Installation sequence BOM a) BOM b) Hollobolt

The Ajax One side [27] is another variety of one-sided bolting component. It mainly consists of bolt, collapsible washer, nut and other special installation tool. The collapsible washer can bear against the steel section with bolt head and nut when it tightened from outside. The minimum clearance for Ajax fasteners are larger when compared with conventional fastener, i.e.for M12 grade Ajax bolts, it demanded minimum 18mm of clearance and 13mm for ordinary M12 bolts. The slotted bolt hole can influence a large localized deformation under tension loading, it leads the bolt to pull-out failure. While compared with normal bolt hole, slotted bolt must increase gauge and pitch distance and it tends to reduction of bolt numbers.

4. ASSEMBLYING OF BOLTED JOINTS

The safety and stability of bolted connections are considerably influenced by the effectiveness of the fastener's tension, which is usually achieved by the turning of either bolt head or nut. When a load is placed on the bolted section, it would be restricted to amount of load that the bolt can handle before failure occurs. Suppose, if a bolt is fastened against the connecting plates, it allows the bolt to distribute the loads entirely through the connecting plates, so only a portion of loads will bear by the bolts. This implies that, such bolting mechanism can hold notable higher load when actual amount of tension is applied. This pre-applied force is named as preload tension.

When a bolt is tightened by sufficient preload tension, it can able to distribute the enough load across the plate nearer to the head of bolt. We will refer to this as the bearing plate. This means, if a bolt is installed properly in connection, it can withstand heavier loads. When service load is applied to fastener that has not been preloaded with required pretension force, the entire force will carry over by the bolt itself and it leads to failure of connection. So, the entire structure would be totally dependent on the bolted mechanism. Due to the application of preload tension, it can minimize number of bolts, as the material (bearing Plate) will play a major role in holding the working load. This will not solve the entire flaws of the bolted connection, but can ensure durability of the connection. Moderate frictional variations are specifically common in industrial applications that would plays a notable impact on both the level and the stability of clamping force in bolted joints. The frictional torque components depend upon bearing and thread friction coefficients, the thread and fastener geometry, and the fastener tension. [28][29].

4.1 Use a torque wrench

This will not be the actual measure of bolt pretension force. If a bolt is tightened to its demanded torque, it can be considered as a pretensioned bolted connection. Each bolts have their own pretension value & this value will be differed according to the variation of the bolt grade as shown in table. 1[21]. In this method wrenches are manually used to tightening the fastener. So, there will be chance for spun and looseness. This will inversely affect the strength of the connection. That's why we consider this method as not effective compared with the other [29][30].

4.2 Torque control bolt pretension

Torque control tightening is one of most common ways for bolted connection, and it is considered to be effective, particularly at lower pretension levels. By using this metho, the bolt is tightened within the elasticity limit, i.e., the elongation and axial tension of the bolt are proportionate, and the bolt-fastening process terminates when a certain peak torque is attained. When a bolt is tightened, it experiences elongation strain and it results direct stress on the bolt, as well as torsional stress. The higher frictional value results the failure of connections, by the application of higher magnitude of torsional stress that combined with the direct stress, an equivalent stress.

In order to enhance bolted joint reliability, design engineers must use tightening processes that would consistently achieve the desired clamp load with minimum scatter. The pretension torque can be determined by below equation.

$$T = KDF$$

where, T is tightening torque, D is nominal bolt diameter, F is the desired bolt preload, and K is a dimensionless constant called the nut factor.

5. CONCLUSION

This review paper mainly discusses about a hollow structural section which is connected by bolted mechanism and the difficulty for using normal hexagonal headed bolts to connect the steel structural joints. In order to solve this, various one-sided bolted connections were introduced by researchers and perform various analysis too. From analysis conducted, each among have their own features. The main advantage of the specific bolted system is that, we can insert and tightened the bolt from one side itself and there is no need to hold the other end for applying preload torque or force. Among this, T-head square-neck one-side bolts are the latest one-sided bolted system. Along with details regarding the various one-sided bolted connections, here also explained about the importance of tightening the bolted connections and its flaws. The tightness of connection will also play an inevitable role to maintain the durability and reliability of the prefabricated steel structural joints. So, in order to ensure this, we have to maintain an applied preload torque for tightening the bolt. Else, there will arise a problem regarding the looseness of the connection, hence results the failure of connection.

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