Experimental Study on the Behavior of Tension Member Under Rupture

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Abstract. A steel structure is naturally lighter than a comparable concrete construction because of the higher strength and firmness of steel. Nowadays, the growth of steel structures in India is enormous. There are so many advantages in adopting the steel as structural members. Almost all high-rise buildings, warehouses & go-downs are steel structures and even some of the commercial buildings are made of steel. Tension members are the elements that are subjected to direct axial load which tends in the elongation of the structural members. Even today bolted connections play a major role in the connection of hot rolled structural steel members. In this experimental study the behavior of tension members (TM) such as plates, angles & channels have been studied under axial tensile force. There is strong relation between pitch and gauge (with in the specified limit as per IS 800:2007) in determining the rupture failure plane. In this study we intensively tested the behaviour of TM for different fasteners pattern by changing the pitch, gauge, end & edge distance and by adopting the different patterns or arrangements of bolted connection in it.

Introduction

Steel is a structural member which is extensively used in industrial buildings, warehouse, residential buildings as a tensile member. Due to its tensile property, industrial buildings and warehouses are completely constructed with steel. When using steel entirely in buildings, duration of the construction can be significantly reduced [1]. In future, usage of steel in construction is going to be increased. So, we are determining tensile strength [2] of steel by testing the steel as per IS standard with varying connections such as chain pattern, zig-zag pattern, diamond pattern with varying pitch and gauge distance.

Cold-formed structural steel plates of thickness 1.5 mm can be lap joined with bolted connections which are designed as per IS 800-2007[3]. The final load-supporting potential connection considered to feasible failure modes, which includes bearing, give-up tear-out, bolt shear, block shear [4], rupture, etc... $fy=550\text{MPa}$, G300 ($fy=300\text{MPa}$) sheet plates were inspected. From the result we concluded that both the Australian/New Zealand (AS/NZS 4600, “cold-shaped metallic” and the Iron and metallic Institute (AISI, “1996version’ 1997) layout requirements cannot be used to expect the failure modes of skinny-sheet-steel bolted connection loaded in shear.

Commonly, the internet-phase fracture is predicted looking at outcomes displayed that bearing distress in the sheet metal is the controlling mode. Likewise, suggestions are made regarding the modern-day method to become aware of the bearing-failure modes [5]. Furthermore, a detailed discussion is equipped with the test data that being used inside the improvement of the AS/NZS 4600 (“cold-shaped steel” 1996) [6]and AISI (“1996edition’ 1997) design equations used for connections.Several different types of bolted connections, including shear connections at the ends of coped beams, tension member connections, and gusset plates, can be regulated by a block shear
failure [7]. A tension force in the splice causes the flange plates to deform in normal loading conditions [8]. Bolted connections are often favoured over other forms of mechanical fasteners, such as split rings [9].

Figure 1. Universal Testing Machine

Figure 2. Testing of Metal Plate

Materials Used

1. Thin Metal Sheet of thickness 1.5mm
2. Fastener of size 12.75 mm
3. Driller for holes

Figure 3. Thin Metal Sheet of 1.5mm thick

Figure 4. Fastener of 12.75mm

Thin Metal Sheet

Thin metal sheet is used because of its many advantages like it is resistance to corrosion and prone to all weather conditions. The sheet metallic fabrication is idealized for used in today's environment in which various weather and climatic conditions and it is more durable. The sheet metals are sufficient to resist pressures and it is easy to make a drill on it. The thin sheet metals of thickness 1.5mm are designed on the length of 120mm and width of 75mm respectively (Refer with: Figure 3). The thin metal sheet is designed and cut to the required size for the different patterns of bolted arrangements.
Fastener
The fasteners used in this project are the Mild Steel fasteners of diameter 12.75 mm.(Refer with: Figure 4)

Methodology
Preparation of bolted metal sheet - Lap Joint
Initially, the thin metal sheet of thickness 1.5 mm are purchased in market and cut for our desired length and width to do our experiment purpose. Then after cutting in suitable size and width, do measures to make the lap joint for the metal plates. To ensure twice it was placed in a current position to make holes in it. The bolt arrangement will play a major role in it. Totally there are nine plates, the pattern consists of zig-zag of 3 sets, diamond of 3 sets and finally the bolt are arranged as chain pattern. After placing, mark with chalk piece for putting holes to hold the fastener in it. By the help of drillers, we need to drill the hole after tightly fix in a drilling machine then turn on the drilling machine to make the hole. After the drilling was done ensure that the fastener will fix in it and finally place the fastener and tight it as a lap joint connection.

Testing of Bolted Metal Sheet – Lap Joint
After the metal plates with lap joint get ready, it is supposed to test in the lab for identifying the failure modes of the fastener and the bolt arrangement to check where it gets failed, whether it is safe or unsafe and all. The machine used for testing these plates is named as Universal Testing Machine (UTM) (Refer with: Figure 1) which can withstand up to 40 tones. Initially, turn on the UTM and push the up bottom or down button to make space to fit the thin metal bolted lap joint sheet in the machine. After got placed in the machine we need to tight it up and down manually (Refer with: Figure 2). Then we are supposed to give load for that particular metal bolted sheet and carefully note the reading when the needle in the meter reaches the value and suddenly get back. We need to take the reading, when the needle starts from the point back to zero. This value is known as the edge value of the bolted connection. Then the same procedures are repeated for the further designed bolted metal plates of lap joint. Then after completing the tests for all the nine plates compare and conclude the value.

Thickness of a Bolt = 15 mm
Diameter of a Bolt = 12.7 mm
Area of a Single Bolt = 126.61 mm²

Shear Calculation:
\[ A_{nb} = 0.8 * A_{sb} \]
\[ = 100 \text{ mm}². \]
\[ V_{nsb} = \frac{400}{\sqrt{3}} (1+100) \]
\[ = 18.656 \text{ KN} \]

End / Edge Distance:
Minimum Distance = 1.5 * \( d_o \)
= 21 mm.

Pitch & Gauge Distance:
Minimum Distance = 2.5 * \( d_o \)
= 35 mm.
Maximum Distance = 16t.
Single Bolt Value = 16.154 KN
4*Total Bolt Value = 32.308 KN.
Result and Discussion

Provided Edge Distance as per IS 800:2007:

Table 1: Edge distance provided as per IS 800:2007 recommendations.

| Provided Dimension and Calculated Value | Obtained Result | Type of Failure |
|----------------------------------------|-----------------|----------------|
| ![Image](image1)                       | ![Image](image2) | RUPTURE FAILURE |
| Gross yielding=25.58KN                 | Result 23KN     |                |
| Rupture strength=20.31KN               |                 |                |
| ![Image](image3)                       | ![Image](image4) | SHEAR AND EDGE FAILURE |
| Gross yielding=25.56KN                 | Result 24.6KN   |                |
| Rupture strength =23.39 KN             |                 |                |
| ![Image](image5)                       | ![Image](image6) | BEARING FAILURE |
| Gross yielding=28.2 KN                 | Result 28KN     |                |
| Rupture strength =20.83 KN             |                 |                |

The testing is done in Steel Plates with the edge distance as same as codal recommendations. In Chain Pattern as per codal recommendations the edge distance is provided as 20 mm, in that a calculated Tensile Strength is 25.58 KN. But, in tested it occurs a failure at 23 KN and a rapture failure is occurred. Next, In Zig- Zag Pattern edge distance is 20 mm, in that a calculated Tensile Strength is 23.34 KN. But, in tested it occurs a failure at 24.6 KN and a Shear and Edge failure is
occurred. Next, In Diamond Pattern edge distance is 20 mm, in that a calculated Tensile Strength is 20.81 KN. But, in tested it occurs a failure at 28 KN and a Bearing Failure is occurred (Refer with: Table 1).

**Reducing Edge Distance**

*Table 2: Reduced Edge distance than recommended by IS 800:2007.*

| Provided Dimension and Calculated Value | Obtained Result | Type of Failure |
|----------------------------------------|-----------------|-----------------|
| ![Diagram](image1.png) Gross yielding=27.48KN Rupture strength =22.48KN | ![Image](image2.png) Result= 21.8KN | RUPTURE FAILURE |
| ![Diagram](image3.png) Gross yielding =22.37KN Rupture strength =20.14KN | ![Image](image4.png) Result=22.6KN | SHEAR AND EDGE FAILURE |
| ![Diagram](image5.png) Gross yielding = 25.83KN Rupture strength = 17.513KN | ![Image](image6.png) Result=25KN | BEARING AND SHEAR AND EDGE FAILURE |

The testing is done in Steel Plates with the reduced edge distance of 15 mm. In Chain Pattern the calculated Tensile Strength is 22.48 KN. But, in tested the rapture failure occurred at 21.8 KN and the plates gets a buckled. In Zig- Zag Pattern edge distance is 15 mm, in that a calculated Tensile Strength is 20.14 KN. But, in tested it occurs a failure at 22.6 KN and a Shear and Edge failure is
occurred. Next, in Diamond Pattern edge distance is 15 mm, in that a calculated Tensile Strength is 17.51 KN. But, in tested it occurs a failure at 25 KN and a Bearing Failure is occurred (Refer with: Table 2).

**Increasing Edge Distance**

*Table 3: Increased Edge distance than recommended by IS 800:2007.*

| Provided Dimension and Calculated Value | Obtained Result | Type of Failure          |
|----------------------------------------|-----------------|--------------------------|
| ![Diagram](image)                      |                 | RUPTURE FAILURE          |
| Gross yielding= 30.29KN                | Result=20.8KN   | RUPTURE AND EDGE FAILURE |
| Rupture strength =28KN                 |                 | BEARING AND RUPTURE FAILURE |
| ![Diagram](image)                      |                 | SHEAR AND EDGE FAILURE   |
| Gross yielding=25.14KN                 | Result=26KN     | RUPTURE FAILURE          |
| Rupture strength =23.14KN              |                 | RUPTURE FAILURE          |
| ![Diagram](image)                      |                 | RUPTURE FAILURE          |
| Gross yielding=27.45KN                 | Result=26.8KN   | RUPTURE FAILURE          |
| Rupture strength =21.51KN              |                 | RUPTURE FAILURE          |

The testing is done in the Steel Plates with the increased edge distance of 25 mm. In Chain Patten the calculated Tensile Strength is 21.48 KN. But, in tested it occurs a failure at 20.8 KN and a rapture failure is occurred. In Zig-Zag Pattern edge distance is 15 mm, in that a calculated
Tensile Strength is 23.14 KN. But, in tested it occurs a failure at 26 KN and a Shear and Edge failure is occurred. In Diamond Pattern edge distance is 20 mm, in that a calculated Tensile Strength is 21.51 KN. But, in tested it occurs a failure at 26.8 KN and a Bearing and Rupture failure is occurred (Refer with: Table 3).

**Conclusion**
As the experiment is done in 3 different methods by changing the edge distance from the reducing and increasing and same as the code provided. in that experiment and come to conclusion that by changing the edge distance in increasing the edge distance in zig zag connection obtained a higher strength then the code provided by its failure under a buckling an edge plates is gets a tear and got failure it is not recommended while designing a connection. In other connections are obtaining a strength less than the code provided. So, edge distance provided in code is better for designing a connection.

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