FINITE ELEMENT ANALYSIS OF BEAM-BEAM BOLTED CONNECTION UNDER PURE MOMENT

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Abstract - *In structural engineering, the main purpose is to maintain structural stability against the effect of various forces acting on the structure. Also, when comparing steel and RC structures, the design of the steel structure focuses primarily on the joints. Proper and effective connections play an inevitable role in maintaining the structural stability of the steel structure. Currently, bolts are widely used fastener to connect steel connections. This project is an attempt to determine the influence of shear capacity by gauge distance on bolted connection. In order to achieve this objective, Finite Element Analysis were carried out in Ansys workbench 2021 r2. The analysis consists of 24 parametric studies that are carried out on 24 models. Each models are differ by the types of bolt hole clearance, bolt diameter, gauge distance and cleat angle used. The entire parametric study is mainly followed by using 10.9 High Yield Friction Grip (HYFG) bolt of diameter 16 mm and 20 mm.*

Key Words: **Bolted connection, Finite Element Analysis**

1. INTRODUCTION

Any steel structure is made up of various members, such as beam, columns, and tension members, which are fastened or connected to one another, usually at the member ends. Many members in a steel structure may themselves be made of different components such as plates, angles, I-beams, or channels. These different components have to be connected properly by means of fasteners, so that they will act together as a single composite unit. The advantages of prefabricated steel structures include rapid construction, less environmental pollution and better-quality control than the conventional on-site built structures. The use of prefabricated steel structures helps to achieve the industrialization of construction.

Any structure's connections are a crucial component and are constructed more conservatively than its members. This is due to the fact that connections are more difficult to analyse than members, and there is a significant gap between analysis and real behaviour. Design and details are crucial for the economy of the structure because it makes up majority of the cost for structural work. Prior to designing the structural system and its members, the type of connection to be used must be chosen because it affects member design. For instance, the net area is estimated when designing fastened tension members by assuming an appropriate no. of bolts and bolt diameter, based on experience.

Steel constructions' connections go into one of three categories: 1) riveted, 2) bolted, or 3) welded connections. Bolted connections will progressively take the role of riveted connections, which are still utilised in some situations. This is brought on by the connection's intrinsic inefficiency, the expensive cost of installation, and the weak rivet strength. Because no holes need to be bored in the member, welded connections have the advantage of being more efficient. But field welding having their own challenges and time-consuming. Welded connections are also prone to failure by cracking when subjected to repeated cyclic loads from fatigue, which may be brought on by working loads like trains crossing a bridge (high-cycle fatigue) or earthquakes (low-cycle Fatigue). It has been discovered that a particular kind of fastened connection using High Strength Friction Grip (HSFG) bolts performs better under such circumstances than the traditional black bolts meant to resist primarily static pressure. The alloy steel used to create HSFG bolts ranges in grade from 8.8, 10.9, and 12.9. The most typical contain a medium carbon concentration and a so-called general grade of 8.8, which makes them less ductile. Bolted connections are also easy to inspect and replace. The choice of using a particular type of connection is entirely that of the designer and he should take his decision based on a good understanding of the connection behaviour, economy and speed of construction.

Bolted joints are one of the most common elements in construction and machine design. They consist of fasteners such as, bolt. Bolt is a metal pin with a head at one end and a shank threaded at another end to receive a nut.to prevent the treaded area of the bolt from bearing on the connecting pieces and to evenly distribute the clamping strain on the fastened member, steel washers are often placed under the bolt head and nuts. End connections in tension and compression members can be made using a bolt connection. By creating an appropriate balance between the joint and bolt stiffness, the bolt and clamped components of the tension joint are designed to pass an applied tension load through the joint via the clamped components.

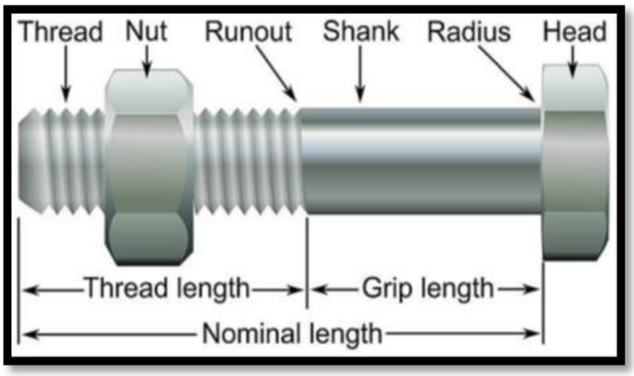

Fig 1: Hexagonal head bolt

1.1 Effect of bolt holes in beam

When beam connections are made with bolts/rivets, holes will be punched or drilled in the web or flanges of the beam. The tests on steel beams reveal that their failure is based on strength of compression flange even though there may be bolt holes in the tension flange. The effects of bolt holes in the tension flange of beams, particularly for flexure, are negligible and are not serious for two reasons. Bolt holes reduce the section modulus and thus affect the bending stresses. As regards the bolt holes, the normal practice is to deduct all the holes even on the compression flange. This is because the strength of a steel beam depends on the strength of its compression flange and thus any open hole in the compression flange affects the beam strength more that by a hole in tension flange.

In case if holes are made for pipes and conduits, extra plates are provided all around the holes to stiffen the cut portion. When holes are made in the web, these do not reduce the section modulus; the shear is minimum and may have little effect on the strength of the girder. If the hole is located near the support in the region of high shear, the additional bending stresses produced by this shear must be added to the conventional bending stresses from the applied beam load.

2 AIM & OBJECTIVE

- To determine the shear capacity of beam-beam bolted connection.
- To determine a relation between center-center bolt hole distance and shear capacity of bolted connection.
- To determine the influence of direction of slotted bolt holes.

2.1 Material properties

Primary beam section: ISHB350
Primary beam length: 1500mm
Secondary beam section: ISHB250
Secondary beam length: 750mm
Bolt diameter: 16mm and 20mm
Cleat angle section: 150x150x8mm, for M16 bolts
170x170x10 mm, for M20 bolts
Yield tensile strength of beam: 250 MPa
Ultimate tensile strength of beam: 460 MPa
Bolt grade: 10.9 grade
Yield tensile strength bolt: 900 MPa
Ultimate tensile strength bolt: 1000 MPa

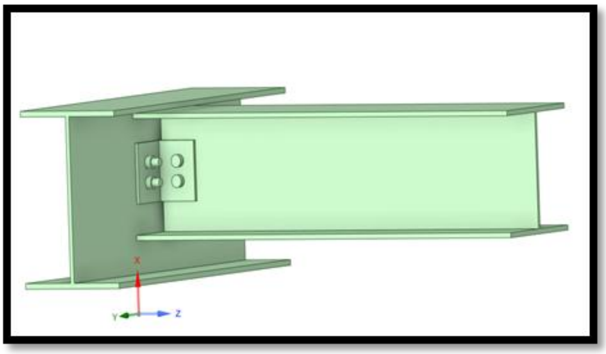

Fig 2: Geometry of beam-beam connection

2.2 Parametric Study

The ultimate purpose of this project is to determine the influence of gauge/pitch distance on shear capacity of bolted connection. The analysis is take over by covering around 24 models and each model is differ by the type of bolt hole clearance, gauge distance, bolt diameter and cleat angle. The bolt of 16mm and 20 mm diameter with High Yield Friction Grip (HYFG) bolt of grade 10.9 are used to perform the analysis. The 10.9 grade bolt implies, they can bear an ultimate tensile strength of 1000 MPa and yield tensile strength of 900 MPa. Since it's a HYFG bolted connection, each bolt recommends a pretension force, which is followed as per IS 4000:1992. According to IS 4000:1992, this pretension force will vary according to the diameter and grade of bolt. The load transferring in a HYFG bolted connection is mainly depends upon the frictional support, that offering by the contact surfaces. So, tightening of bolts plays a crucial role to achieving sufficient frictional support. As already said, the parametric study for the analysis are follows;

Table 1: Parametric study

Model No.	Bolt Diameter (mm)	Gauge Distance (mm)	Type Of Bolt Hole Clearance
1	16	40	Normal clearance
2	16	48	Normal clearance
3	16	56	Normal clearance
4	16	64	Normal clearance
5	16	40	Vertical slotted
6	16	48	Vertical slotted
7	16	56	Vertical slotted
8	16	64	Vertical slotted
9	16	40	Horizontal slotted
10	16	48	Horizontal slotted
11	16	56	Horizontal slotted
12	16	64	Horizontal slotted
13	20	50	Normal clearance
14	20	60	Normal clearance
15	20	70	Normal clearance
16	20	80	Normal clearance
17	20	50	Vertical slotted
18	20	60	Vertical slotted
19	20	70	Vertical slotted
20	20	80	Vertical slotted
21	20	50	Horizontal slotted
22	20	60	Horizontal slotted
23	20	70	Horizontal slotted
24	20	80	Horizontal slotted

2.3 Modelling of beam-beam bolted connection

The variation of gauge distance were taken on the basis of minimum gauge distance as per IS 800:2007. The code recommended a minimum gauge distance of 2.5 times the nominal bolt diameter (D). For first model I prefer a gauge distance of 2.5D. Then it gradually increases as 3D, 3.5D, 4D respectively for normal, vertical slotted and horizontal slotted bolt hole clearance. For all models, support condition and loading mechanism are same.

Instead of normal loading, cyclic loading were applied on the beam section as shown in fig 3. Fig 4 & 5 shows the support condition and application of moment in primary beam section respectively.

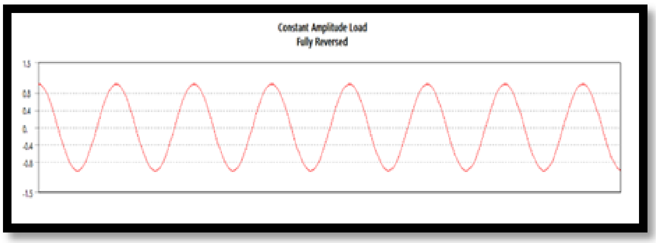

Fig 3: Graph of loading type

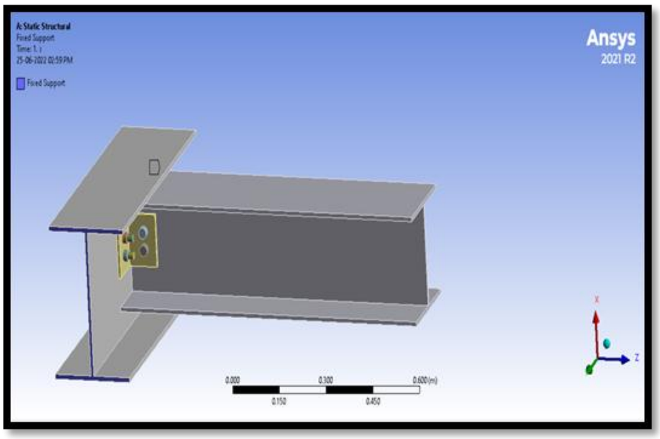

Fig 4: Support condition

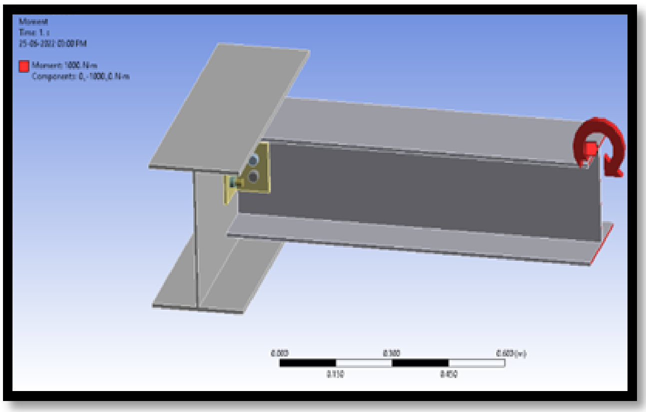

Fig 5: Moment application

3. RESULTS AND ANALYSIS

3.1 Analysis of M16 bolts

Chart 1: Shear capacity of 16mm bolt with horizontal slotted bolt hole

The above graph shows that, while increasing the gauge distance from 2.5 times the bolt diameter (D), the shear capacity of the bolted connection increases from 54.64 KN to 131.68 KN. For further increment of gauge distance the shear capacity slightly falls down. When the gauge distance cross 3.5D to 4D the shear capacity value slightly falls down, because of the reduction in compressive force between the contact surfaces which formed due to the pretension force on bolt.

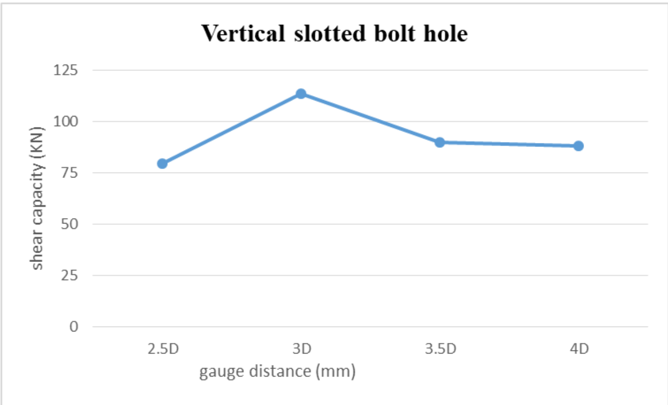

Chart 2: Shear capacity of 16mm bolt with vertical slotted bolt hole

The above graph shows that, while increasing the gauge distance from 2.5 times the bolt diameter (D), the shear capacity of the bolted connection increases from 79.675 KN to 113.54 KN. For further increment of gauge distance the shear capacity slightly falls down to 88.24 KN. While compared with the normal bolt hole clearance the maximum value obtained at 3D.

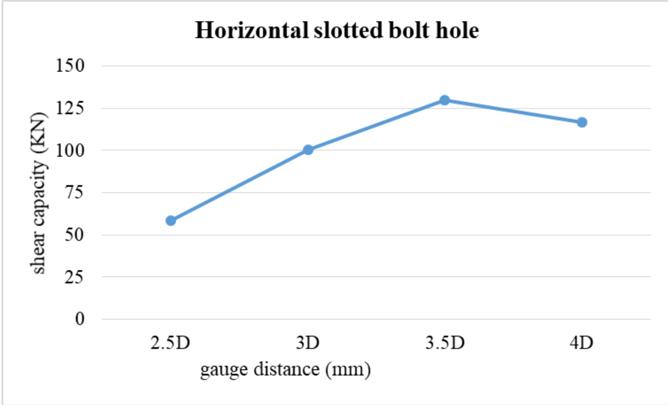

Chart 3: Shear capacity of 16mm bolt with horizontal slotted bolt hole

Chart 3 shows that, while increasing the gauge distance from 2.5 times the bolt diameter (D), the shear capacity of the bolted connection increases from 58.72 KN to 129.54 KN. For further increment of gauge distance the shear capacity slightly falls down to 116.582 KN. While compared with the normal bolt hole clearance the maximum value obtained at 3.5 D.

3.2 Analysis of M20 bolts

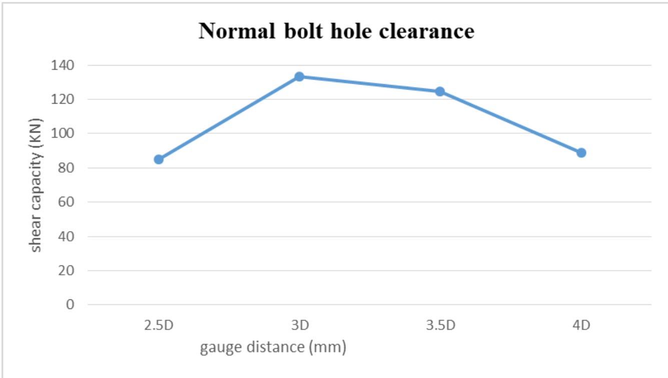

Chart 4: Shear capacity of 20mm bolt with normal bolt hole clearance

The above graph shows that, while increasing the gauge distance from 2.5 times the bolt diameter (D), the shear capacity of the bolted connection increases from 85.12 KN to 133.48 KN. For further increment of gauge distance the shear capacity slightly falls down. When the gauge distance cross 3D to 4D the shear capacity value slightly falls down.

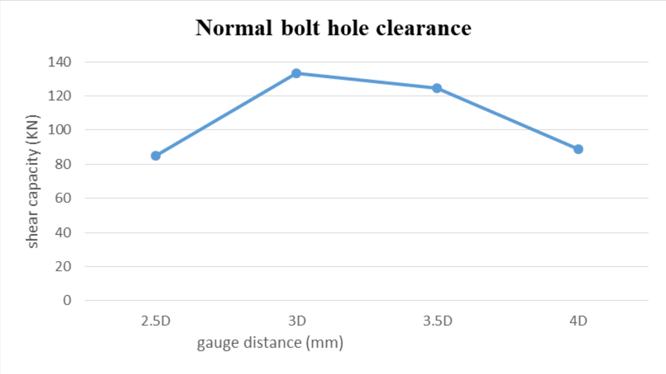

Chart 5: Shear capacity of 20mm bolt with vertical slotted bolt hole

Chart 5 shows that, while increasing the gauge distance from 2.5 times the bolt diameter (D), the shear capacity of the bolted connection increases from 93.36 KN to 116.28 KN. For further increment of gauge distance the shear capacity slightly falls down to 88.80KN. When the gauge distance cross 3D to 4D the shear capacity value slightly falls down.

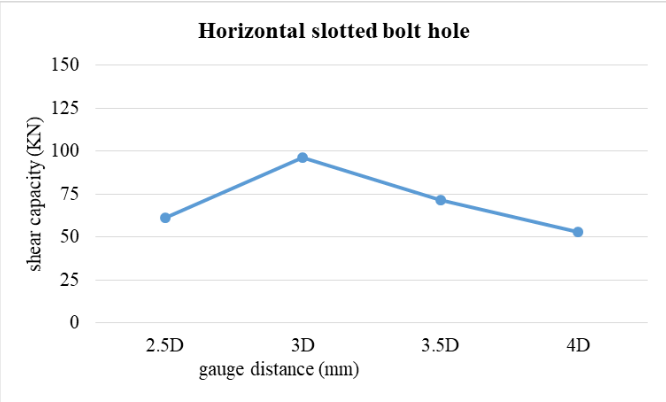

Chart 6: Shear capacity of 20mm bolt with horizontal slotted bolt hole

Above graph shows that, while increasing the gauge distance from 2.5 times the bolt diameter (D), the shear capacity of the bolted connection increases from 61.68 KN to 96.32 KN. For further increment of gauge distance the shear capacity slightly falls down to 52.97 KN. When the gauge distance cross 3D to 4D the shear capacity value slightly falls down.

CONCLUSION

The study follows the Finite Element Analysis (FEA) on beam-beam bolted connection under various parametric study. Conclusion of this analysis were performed by comparing the results obtained from 24 models. Here shows the detailed conclusion, which are

- While analysing the results of M16 bolt with normal bolt hole clearance, and horizontal slotted bolt hole, (model 1-4 and model 9-12), we can able to conclude that ,the shear capacity of the connection were increases when gauge distance changes from 2.5 times the bolt diameter, D (40mm) to 3.5 D. For further increment of gauge distance the value slightly drops down.
- From the analysis of 16mm bolt with vertical slotted bolt hole (model 5 to model 9), we could understood that the shear capacity on the bolted connection were increases when gauge distance changes from 2.5 times the bolt diameter, D to 3 D. For further increment of gauge distance the value gradually falls down.
- By comparing the first 12 models, it is understood that there will limitations to increasing the gauge distance for vertical slotted bolt holes. Not only that, the bolts in a row (as per model) can arrange in two ways. Both bolts at upward portion of slotted hole and both are in downward portion of the slotted hole. Similarly for horizontal slotted bolt hole too. Since we doesn't apply any lateral force, it doesn't show any considerable changes in values, that as per applied loading condition.
- By analysing the models from 13 to 24, the maximum shear capacity were occurred at 3D gauge distance. For further increment of centre to centre bolt hole distance, shear capacity decreases. M20 bolts are used for performing the analysis on these models.

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