studying of the prying action effect in steel connection

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Abstract

Nonlinear finite element analyses are performed to simulate the behavior of top-and seat angle connection. The result of test on seven model beam–column connection is presented and discussed. These studies were carrying out in order to provide insight into the behavior of the set angle in the beam- column connection. The main variables tested include the: 1) material properties of bolt 2) bolt diameter 3) gage distances on top angle and angle thickness. In particular, the respective stress state of the steel connection under static loading are calculated by taking into account the development of plastification zone and the unilateral contact and friction effect of describing the between connection member. .

Key words: Analytical studying, Prying action, Top and set angle

1. Introduction

Before the Northridge (1994) and Kobe (1995) earthquake designed and also the code at that time were in favor of welded connections designed for force coming from earthquake motion. After these earthquakes bolted connection are more common. Usually two type of force are transfer by bolted beam-column connection: shear and moment. A connection may be designed to transfer shear force if the beam is supposed to be hinge connected to the column only. Semi-rigid connection has been become more common in the area of steel frame. The investigation includes an analytical study of the factors which govern prying action in bolted tee-connection and effect of prying action on the behavior of the bolts in the connection. A view of the connection is shown in Fig. 1.

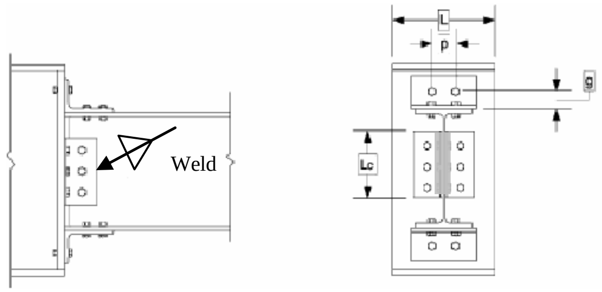

Fig 1: Top-and seat- angle connection.

2. Data and Material

The basic configuration of the final element comprises three thicknesses in the top angle, and the distance of g that the general characteristics of the modeling are given Table1.The other connection parameter are kept constant in all connection model. The specimens consisted of FE 350(Grade50) W12x96 beams with a length of 150mm bolted to W14x43 columns. The connections were made with twenty bolts transferring the shear and moment to the beam flanges. All the connection models listed in Table 1.

connection	Angle section					Bolt diameter (mm)
	Angle	g (mm)	L (mm)	Lc (mm)	p (mm)	
c1	L6×4×3/8	64	190	220	140	22
c2	L6×4×1/2	64	190	220	140	22
c3	L6× 3 1⁄2 ×3/8	51	190	220	89	22
c4	L6× 4 ×3/4	64	190	220	140	22
c5	L6× 3 1⁄2 ×3/8	51	190	220	140	22
c6	L6×6×3/8	114	190	220	140	22
c7	L6×4×1/2	63.5	190	220	140	19

Table 1. Geometric properties

The model includes a variable bolt stiffness that captures the changing behavior of the bolts as a function of the loads they are subjected to this study. Strain hardening and membrane action are catered in the model by adjusting the material properties from elastic values to strain-hardening value, and by applying solution for the deformation that takes account of large deflections. The material properties of the top and seat angles and high strength bolts required for the finite element analysis were acquired through the preliminary coupon test, as shown in Table 2.

connection	Angle		Bolt	
	Yield stress (N/mm2)	Tensile Strength (N/mm2)	Yield stress (N/mm2)	Tensile Strength (N/mm2)
C1,2,5,6,7	365	550	635	830
	365	550	830	1038
C4	365	550	635	830
	250	400	635	830
C3	297	517	635	830

Table2. Material Properties

3. Research Methodology

Nonlinear finite element analysis is an attractive tool for modeling connections and its complex behavior. In this study the moment-rotation relationship of bolted connection are presented. The angle connection with three different thickness were analyzed where another angle are welded to the beam web and bolted to the column flange. First, the results of the three-dimensional analysis were used to replace the angle by equivalent nonlinear spring.
The behavior of top-and seat angle connection was also simulated using 3D finite element models (Ahmed, Kishi et al.2001). This model includes contact formulation with coulomb friction between contact pair surfaces. The ABAQUS software package was used [1] to model the seven sections which showed in Table1. The solid element was used in the meshing process this will give an accurate representation o the actual spread of plasticity and yielding behavior of the model.

The nonlinear stress-strain model that was chosen in this case is the Bilinear Kinematic Hardening behavior, which uses a simplified bilinear stress-strain curve. This option assumes that the total stress range is equal to twice the yield stress. It is recommended for small strain use for materials that obey the Von Misses yield criterion, which includes steel. The accuracy of the finite element study is controlled by the mesh refinement. The mesh pattern of model and bolt is shown in Fig. 2.

The beams and columns were ASTM A992 steel, the connection plates and angles were ASTM A36 steel, the 19-22mm diameter bolts were ASTM A325 and A490 steel, and E70XX weld material was used.

The finite element models are prepared by using displacement-based nonlinear that applying in the end of the beam and Symmetric cyclic loading, described in Table. 3. [2]

A bilinear elastic-plastic stress-strain relationship with isotropic hardening rule is assumed for all connection members taking Young's modulus of elasticity E = 209 GPa and Poisson's ratio n= 0.

Load point displacement (mm)	Number of cycles

12.4	8
18	8
20.6	8
29	6
41.5	6
59	4
78.6	2
105	2
165	2

Table 3. Cyclic Loadoing Protocal

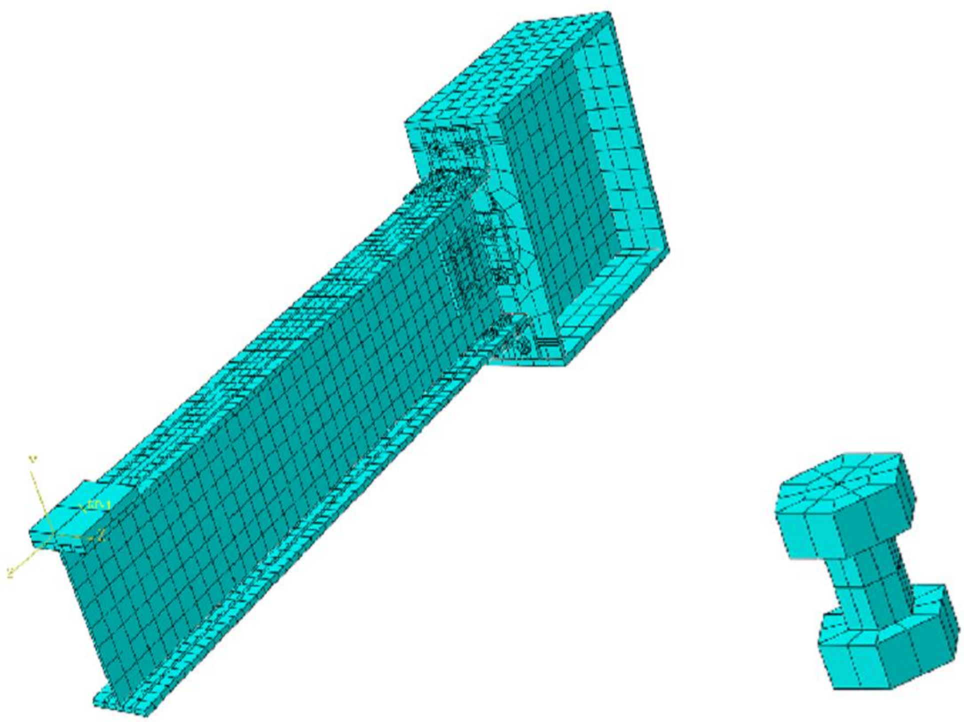

Fig. 2: Mesh pattern of model.

4. Results and Analysis

Existing finite element analyses of the top and seat angle connection have attempted to determine the stiffness and strength of the connection with the use of parameters including the friction coefficient between materials and the top angle thickness, and the gage distance of the high strength bolts. Main objective of this research are to analyze the behavior of the top angle while increase bolt's force with utilize of the moment-rotation curve. Fig.3. shows the bolt force to applied force curve of the top and seat angle connection in both phases, when the connection includes with/ without prying force [5]. It is shown that the slope of the curve increases when the connection considering the prying action. As you see in Fig. 3 prying force led to raise bolt's force in connection.

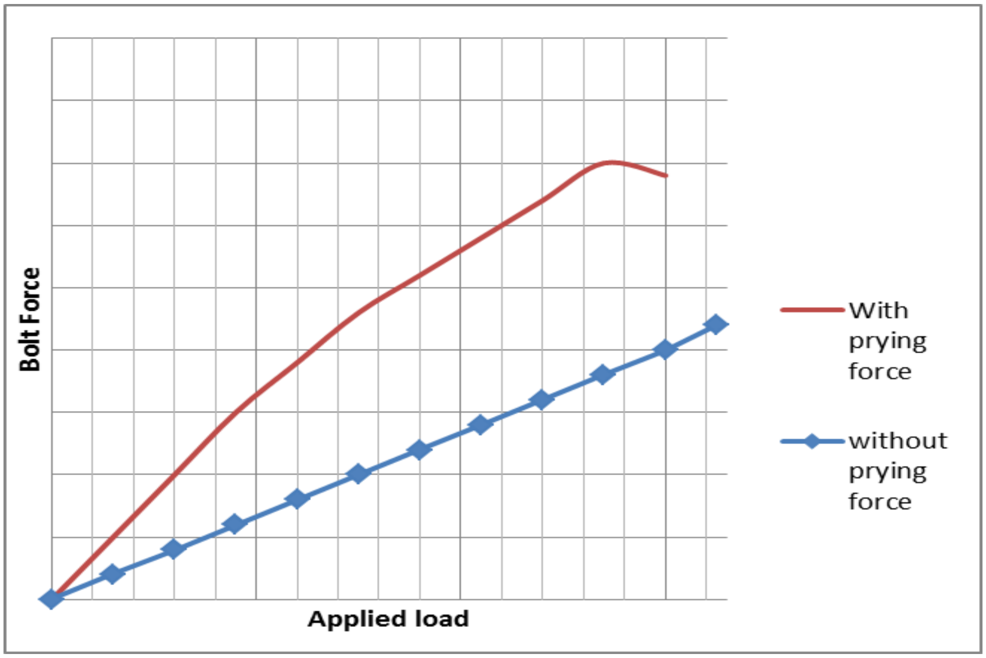

Fig. 3: prying force

A) Influence of mechanical properties of Bolt

Fig. 4 show the distributions of bolt force in cases changing grade of bolts as A325 and A490, these Fig is for model of C2. From this figure, it is observed that the bolt force is increased when we use of higher strength of bolts.

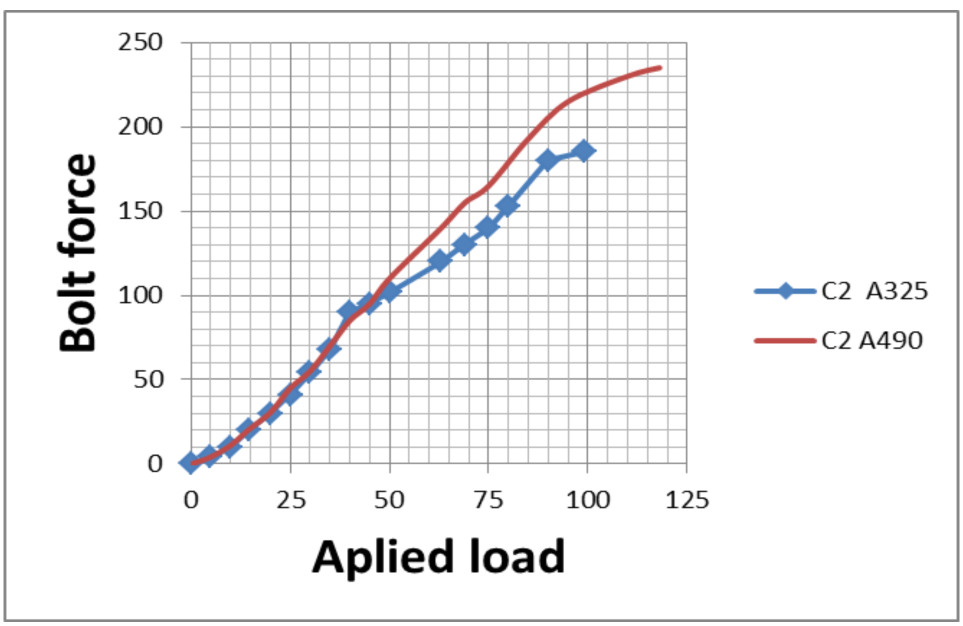

Fig. 4: Influence of mechanical properties of Bolt

B) Influence of Bolt diameter

The influence of bolt diameter on bolt force was investigated using numerical results obtained by inputting d= 22 mm and 19 mm for bolt diameter. Fig. 5 shows the comparisons of distribution of prying force from two models of C6 and C7.

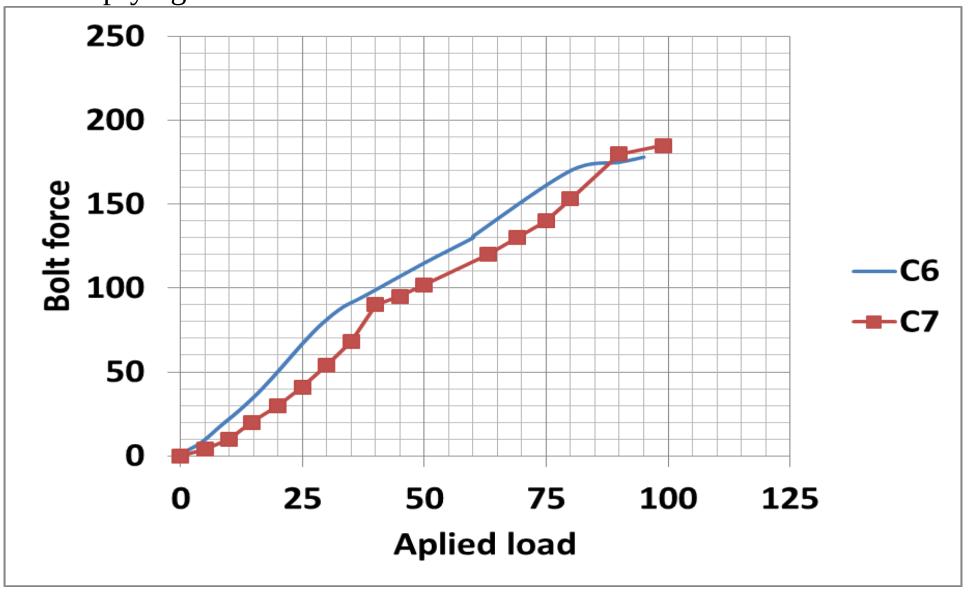

Fig. 5: Influence of Bolt diameter

C) Influence of gage distance

Fig. 6 shows the distributions of bolt force curves, and initial connection stiffness in cases varying gage distance from top angle's vertical leg as g = 51 mm, 64 mm, and 114 mm, in which those are for models of C5, C1, and C6, respectively. From this figure, it is confirmed that prying force increased whit increase of gage distance.

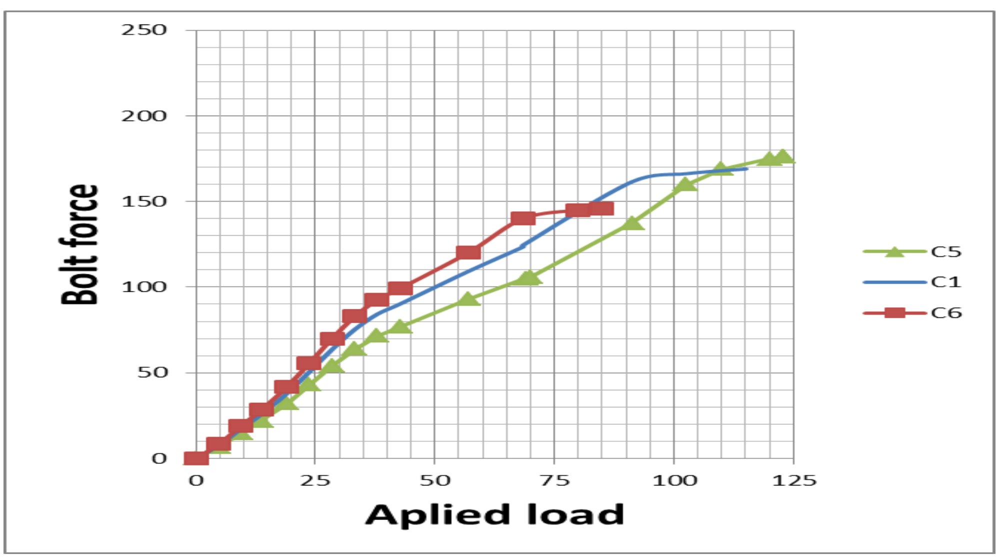

Fig. 6: Influence of gage distance from angle

D) Influence of angle thickness

To investigate the effects of angle thickness on bolt force curve of connection, numerical analysis were performed for connection model C4, C2, and C1 in which those angle thicknesses (t) are assigned to be 9.5 mm, 12.7 mm, and 19.1 mm, respectively. Fig. 7 shows the comparisons of bolt force curve and initial connection stiffness among those three connection models. From Fig. 7, it is seen that, the thinner the angle thickness is, consisted the bigger prying force.

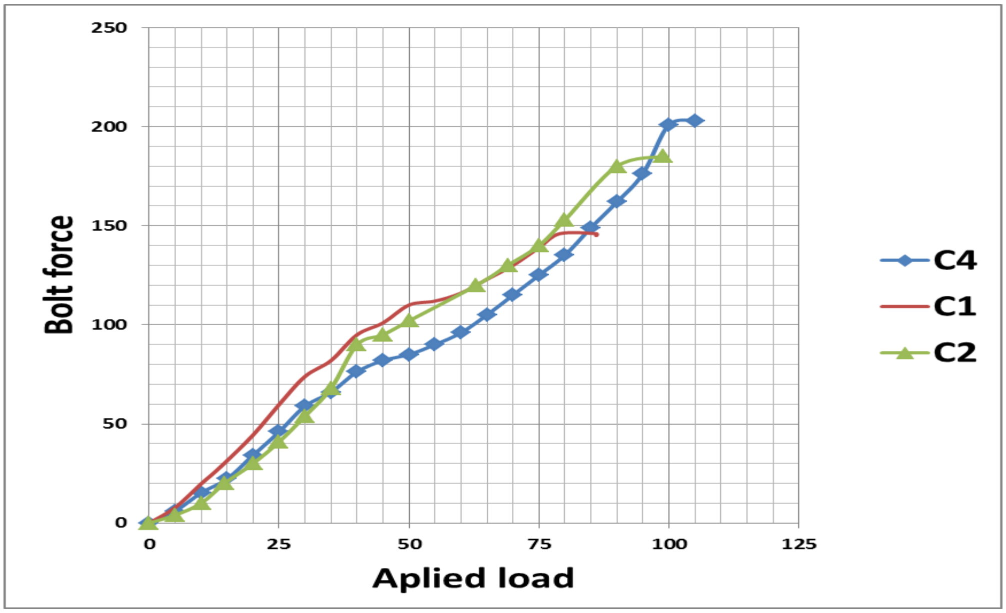

Fig. 7: Influence of flange angle thickness

5. Conclusions

The semi-rigid connection usage is very limited in today's structural engineering era. However, this type of connection is satisfactory in both economy and safety [3, 4, and 6]. The remaining problems for these connections with regards to use in engineering practice are related with the structural analysis with this type of connections and the reliability of the analysis.

In this study, one way of analysis namely 3-D nonlinear finite element analysis of such complicated connections are performed and results are discussed.

The following can be listed as the main conclusions of this thesis:

1) Use of stiffer bolts in connection increases the prying action.
2) With use of bigger bolt diameter develops higher prying action.
3) That prying action increase rapidly in connection with larger gage distance.
4) Prying action develops faster for lesser thickness of angle.

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