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Post-Tensioned Steel Connections Self-Centering Behavior Using the Finite Element Method

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Abstract

Due to lack of the proper and well behavior of steel moment-resisting connections subjected to the great and major earthquakes, excessive researches have been conducted to mitigate the damages on the primary elements and connections. Therefore, elimination of residual drift and increasing the plastic rotation capacity for the connectors in the panel zone are required. The main purpose of this study is to numerically investigate the behavior of the recent kind of the steel moment connections which are called as steel self-centering post-tensioned connections. The steel post-tensioned connections consisted of some high strength strands for self-centering feature plus energy dissipater angles for adjustment of plastic deformation. This paper studies on the steel self-centering post-tensioned connections using the finite element method. The obtained results are verified based on the experimental study. Accordingly, the energy dissipation, rigidity percentage, and ductility factor of the connections are determined. Results revealed the perfect self-centering with the proper ductility factor. Furthermore, it was observed that the post-tensioned steel connections have a high plastic rotation capacity without any damages to the column and beam.

Keywords: Steel Post-Tensioned Connections, Self-Centering Feature, Finite Element Method, Ductility Factor, Dissipation Energy

1. Introduction

The main reasons for the popularity usage of the steel moment frames except to provide enough space as an architectural point of view are sustainable ease of implementation and economic issues, high ductility, resistance against plastic deformation and rotations are the other parameters. Northridge earthquake in 1994 and 1995 before Kobe earthquake steel moment frame connections for conventional beam-column include full penetration welds were shot in the wings up and down. The connections have been designed with consideration of expansion joints, plastic deformations in beams. However, after the mentioned earthquakes, several of the steel moment connections with penetration welding breaks, before welding shear failure in the boundary layer beam and column. In order to prevent failures of welding and plastic deformations in the beam and on the outside of the panel, researchers suggested several options to reduce this type of failure. One of the crucial problems was the Movement of residual. Special steel moment connections post-tensioned inspiration from post-tensioned precast concrete connections was proposed to reduce losses and prevent residual handling and dissipation energy.

Analytical study on the seismic behavior of precast concrete frame did discontinuous components of the system without wasting energy [1]. A new type of steel moment connections with strands connected in parallel to the beams and columns and angles up and down to create energy dissipation offered, and this type of frame, first in the lab, and then in-app items analyzed [2]. Beginning a post-tensioned steel moment connections consisting of beams, columns, angles, strands, screws, sheet and plate separator reinforcement subjected to the cyclic loading [3].

Some 3-dimensional finite element model of post-tensioned steel beam-column connection was developed using ANSYS. They were relied on reference laboratory model and modeling software due to the lack of a proper. In other words, the

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effects of various parameters on the behavior of beam-to-column post-tensioned needs to be analyzed. Several studies have been done to determine these parameters, such as yield stress and strain-hardening steel corners, the value of the elongation of the cables and the use of metal reinforcing beam flange [4-5]. On the effects of hard corners of the upper and lower, researches proposed a series of numerical equations to predict the behavior of this type of connection provided. The results showed that hardenings of resistance to relatively high increase in displacement and deformation hysteresis in angles are increased as a result of energy dissipation. In the end, two connecting bolt correction factor was proposed to predict the corners geometry functions [6]. The results showed that, in addition to energy dissipation resistance of components, arc action (or bending) continuous shooting and post-tensioned cables of the main parameters to determine progressive collapse capacity of steel frame [7]. Most recently research on cyclical performance of beam-column joints and angles SMA centralized were released with steel screws. The screwed influences of several parameters were examined, for example the initial strain SMA, screw length, thickness, and angles were considered for eight samples. The results of the laboratory analysis showed that only non-linear deformation curves and angles SMA was observed, because the beam and column remained in a state of elastic or linear. The maximum equivalent amount for viscous damping was detected between 11 and 15 percent [8].

In this study, treatments of post-tensioned steel moment connections are performed using Abaqus simulation. Accordingly, it was validated based on the laboratory data. The laboratory validation consists of force-displacement diagrams of connector. Numerical simulation of post-tensioned connection was conducted using 3D volumetric elements. Finally, comprehensive comparisons are accomplished to evaluate the connectivity, form factor of the amount of energy dissipation, the rigidity of the connection, and joint classification.

2. Describing the behavior of post-tensioned steel moment connections centripetal

Figure 1 shows the connection of the strands using the high resistance and post-tensioned configuration. This connection linked the compressed beam flange to the column. The plates strengthen connections uses to reduce the plastic deformations of the plates, as well as adaptive beam flange mounted between the flanges of the beam and column to prevent damage on the beam web [9].

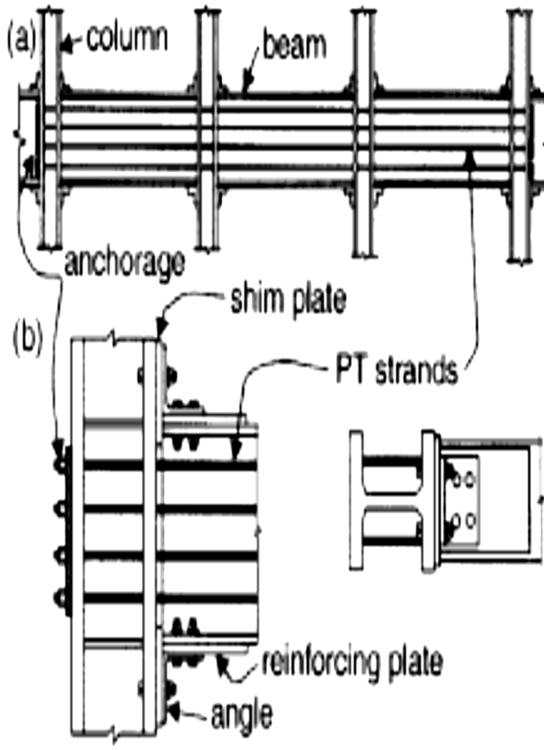

Figure 1. a) Schematic view of the steel moment frame pulled a class b) Connection Details [3]

The main responsibility of the created connection's angle is to dissipate the energy. Also, it helps to create a degree of uncertainty to the power transmission mechanism for the shear beam and column-ends. Shim plates have been placed on both the beam flange and the column flange to linked beam flanges and reinforcement plate's to the column flange surface using the contact surface [10]. Figure 2 demonstrates the ideal behavior of moment-rotation of post-tensioned connection steel. Expected to rotate the order of rotation, the main advantage of this type of concoction is the separation between beam and column under loading. The connection performance works with the opening or gap which created between post-tensioned beams and columns when loading and unloading are applied. Although, the connecting pulled behaviors and its characteristics are similar to the fusion bonding, anchor moment of the connection clamped shows the half results. The primary difficulty connecting prior to the opening issue is the same welded or clamped connection, which turns the opening period to zero.

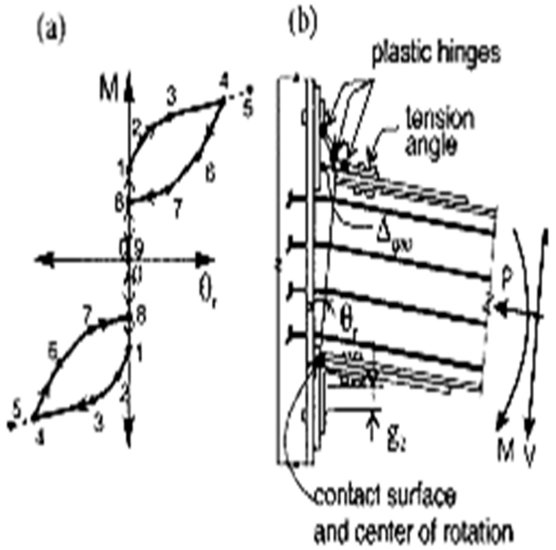

Figure 2. a) Behavior moment- rotation b) transformation of post-tensioned connection [3]

Secondary difficulty stems from the combination of the hard corners and hard-core connecting cables. Loading continue to be part of the submission connection with corners in point 4 above behavior in curves and corners are completely surrendered at the surrender point 5 strands. Anchor relationship happens because of the difficult period of axial cables in points 3 to 5 is linear. When unloading is conducted the corners energy dissipates, as well as closes the gap between the beam flange and the column flange. After shooting connect the behavior pulled into the depth, power strand, Anchor resistance and hardness and elastic resistance depends post-tensioned strands.

3. Profile of laboratory samples

A Centralist drawn sample is selected by Garlock[11-12] and colleagues after the simulated connection, using the connection 36S-20-P analytical laboratory sample. Figure 3 shows cross-shaped connection with two beams on either side of a column, strand, angles, plate strengthening, plates double and continuity. This is an example of the connection between bending-resistant frames which is given from an office building in Los Angeles, America. Boundary conditions at both ends of the beam are roller bearing beam which can move in the horizontal direction and the top end of the column is connected to a hydraulic load. The cyclic load applied to the top of the column in the horizontal direction. Fulcrum bottom of the column was also the type of joint that can move in both directions during the vertical and horizontal columns. Beams are3048 and 4169 mm far from the wing with side support columns to prevent the relocation of off-page sample during loading. The samples that are uniform in height and 36 cable, beams have been pulled on both sides. The number of column flange holes are 12, which means that at any level three cable can be connected together and the three cable passes through a hole column flange.

Continuity plates with a thickness of 25mm in the flanges on either side beams or columns have been put to prevent the plate deformation and the buckling of the column flange. The double plates with a thickness of 19 mm are used on both sides of the panel to avoid yielding the web of the column. It should be noted that the initial post-tensioned force is 89 KN. Also, the plastic moment capacity of the beam (MPa) is equal to 3282 KN.m.

According to the results of the laboratory, the connection is able to reach 96 percent of plastic moment capacity, while the beams and columns remain quite resilient. Also no connection damage has been observed. The maximum relative rotation between the beam-column model 36S-20-P is obtained 0.033 radians. Table 1 shows the details of the components specification which were used in the connection area.

4. Modeling post-tensioned steel moment connections self-centering

Numerical Modeling studies of great importance, because it could be revealed the precise details such as the distribution of stress and strain analysis and various other parameters. As described in the previous section, in this study, a sample circuit 36S-

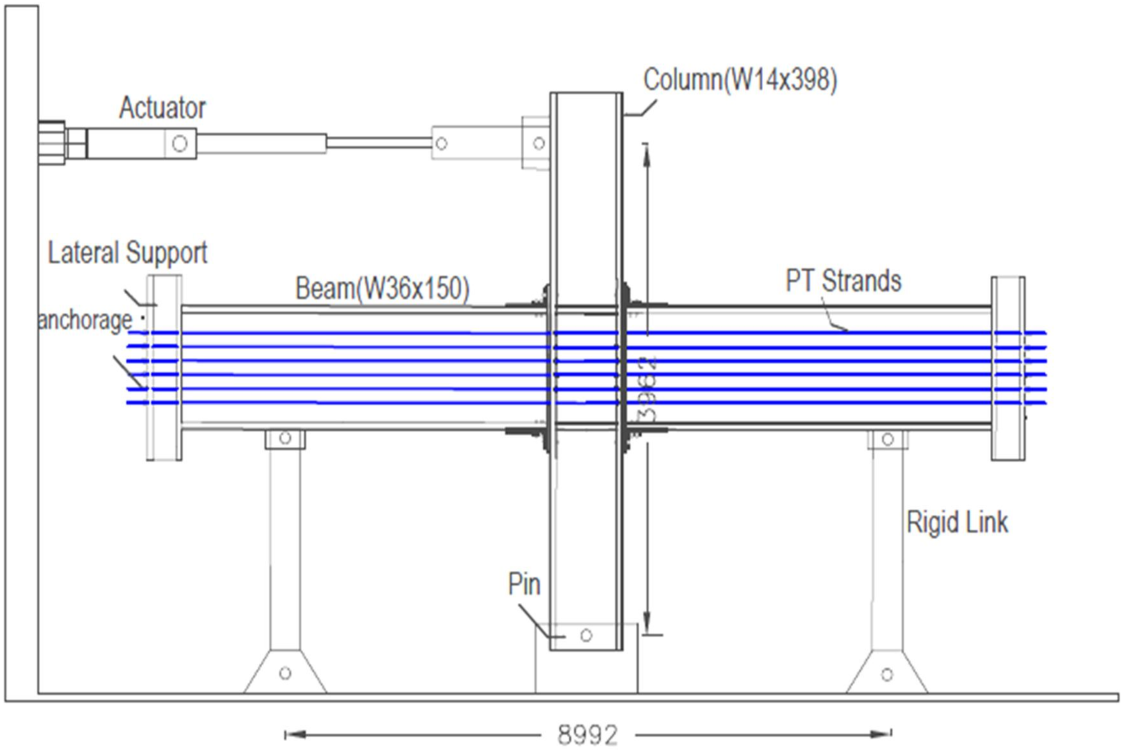

Figure 3. Connecting a special laboratory [13]

Table 1. Component Specifications Connection - mm and KN units [14]

Column	W14X398
Beam	W36X150
Angle	L203X203X19.05
Reinforce plate	1372X356X25
Shim plate	406X292X32
Pitch	A490-M32
Number strand	36
T0	3194

20-P in the finite element software ABAQUS simulation is considered. Because of the complexity of the model and the massive computing process, some assumptions have been considered in order to solve these problems. Due to the symmetrical shape of sections and connecting components such as beams, columns, plates and sheets of strengthening the beams, the conditions and numerical simulation is used for the symmetry properties. In other words, using the symmetry, half of the beam-column connection is modeled the number of screws and cable model are halved. Figure 4 shows a view of the simulated connection.

The properties of the steel material used in the connection area are given in Table 2. The values of tensile testing in the laboratory components are calculated in accordance with ASTM [15] standard (ASTM 1991). For all materials the behavior of stress-strain is approximated as the bilinear behavior. For bilinear stress-strain curve definition, there is a need to define the yield, ultimate stress and strain (failure). The tensile stress, modulus of elasticity, and thermal expansion coefficient, respectively are 266 KN, 199 GPa and 12E-6.

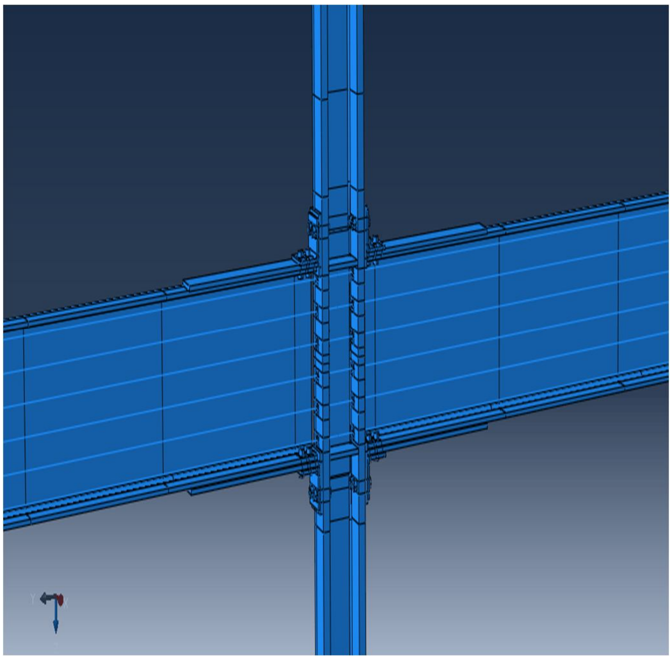

Figure 4. Overview of the number and placement connectivity components

Table 2. Specifications of Materials

Component	f_y (MPA)	f_u (MPA)
Column flange	356	499
Column web	345	496
Beam flange	362	498
Beam web	414	527
Reinforce plate	397	574
Angle	383	545
Shim plate	345	496
Continuity plate	345	496
Pitch	940	1040
Strand	1620	1900

The main components of connection (beams, columns, plates, sheets strengthened, screws, and sheet forehead of elements) are modeled using volumetric 3D solid 8 nodes with integral dropped (C3D8R). However, the cable elements are modeled using Germans beam (B31). Figure 5 shows the meshed model.

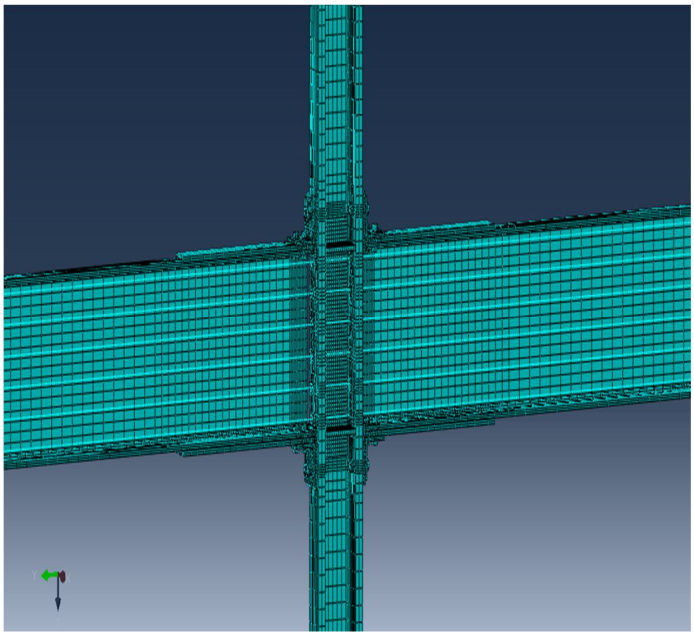

Figure 5. How post-tensioned steel grid connection

The interaction between the main components of structures has a huge impact on the accuracy of the obtained results from the nonlinear analysis of the numerical model. Model is used the behavior of welded components using TIE. The interaction between other components such as the tangential and vertical are defined in two directions. In the vertical direction, for all parts, components have an influence on each other to prevent interaction as HARD CONTACT. The coefficient of friction between steel surfaces is selected about 0.33.

The pre-tensioning screw is equal to the minimum in (ANSI) [16]. Bolt Load options are used for the prestressing screws which the screw is required to define the axis for the inner surface. Because of a number of components in the calculation model, Wire cables have been used to reduce the number of parts of the model.

5. The results of the analysis

To validate of the obtained results from the finite element model, the post-tensioned connection are compared with Garlock laboratory sample results. Built-in software model is simulated with regard to the laboratory specimens. Figure 6 shows the comparison of the experimental and numerical results using the hysteresis diagram.

As can be seen from Figure 6, the finite element model is able to predict the cyclic behavior of centripetal and simulate post-tensioned connection.

Figure 7 depicts the stress distribution and the opening of the drift which is 4% of the 36S-20-P plug-in software. Time position at the junction of the connections between beams and columns are rotated.

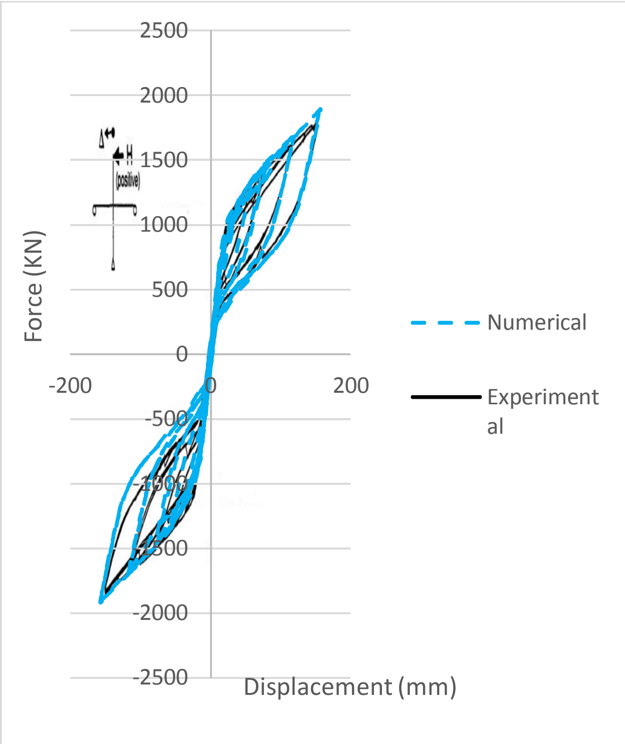

Figure 6 - Compare the response force - displacement experimental and numerical examples

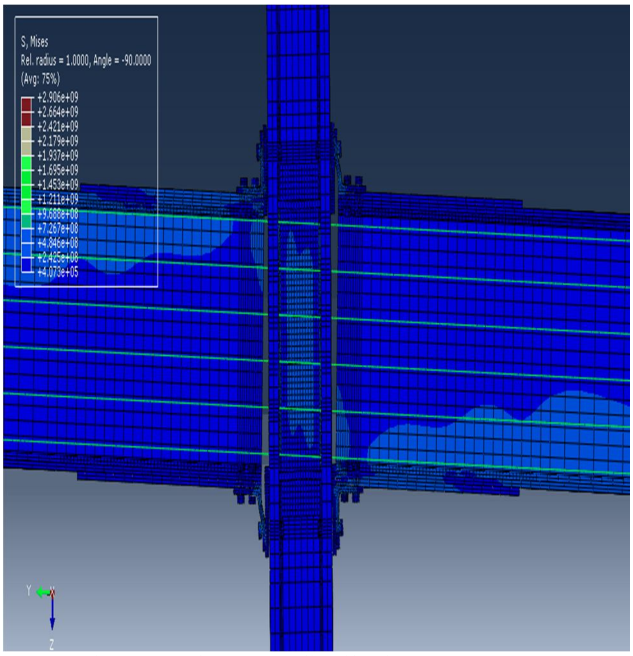

Figure 7. The stress distribution of 36S-20-P

The results of experimental and numerical analysis of the samples were compared with the percentage of error between both values. It was observed that the maximum error between experimental and numerical results is less than 5%. Table 3 presents the obtained results. where T0 is the force after the initial tension cables, Tu is final power cables, Tmax denotes the maximum power cables in drift after 4% elongation, Md refers to the moment the verge of separation, Mmax is the maximum bending moment in the beam drift 4 percent, θmax is the maximum drift floor (4 percent, for example 36S-20-P), θrmax represents the maximum relative rotation between the columns, and Δ is the created for the splitter beam opening.

6. The ductility factor of post-tensioned steel connection

Standards in seismic design of steel structures are important. One of the main seismic characteristics is the connection ability to connect the provide the sufficient inelastic deformations and proper ductility. Therefore, there is need to improve the simple connection resistance behavior. Absolute or relative rotation angle connector is an important value in its category in terms of ductility. For example, the final period θu connection or connection ductility index of θu / θy is used where θy much time is elastic connection. To calculate the elastic limit during the first yield moment My connection is considered using My = Cy * Mu. Where, Mu is the ultimate moment tolerated and Cy connection is calculated according to the equation (1): [17].

$$C_y = \frac{1}{C_{pr}\dfrac{Z_{be}}{S_b}} \qquad (1)$$

Where, Cpr is maximum coefficient of resistance Sb is the elastic cross-bow, and Zbe shows the effective on plastic cross bar which is consider about 1.2. Accordingly, the corresponding point (θy) of the curve anchor-age is calculated and finally the coefficient of plasticity is achieved. Parameters of yield moment, the ultimate moment, and area of submission ductility factor are shown in Table 4.

Table 3. Comparison of experimental and numerical analysis

Sample Model	T_0 (KN)	θ_{max}	$\frac{M_d}{M_{Pn}}$	$\frac{M_{max}}{M_P}$	$\frac{T_{max}}{T_u}$	θ_{Rmax}
Experimental Model	3194	4%	0.47	0.96	0.55	0.033
Numerical Model	3123	4%	0.487	0.995	0.0551	0.0325
Error Percent	2%	0	3.62%	3.65%	0.18%	1.5%

Table4. Ductility factor

Specimen	**Mu (KN.m)**	**My (KN.m)**	**θy (Rad)**	**Ductility Factor**
Numerical Model	3794	2743	0.019243	2.078678

7. Capacity of energy dissipation

Energy dissipation and post-tensioned steel connection depend on the performance of the upper and lower angles of the convector; in fact angles dissipate the energy using the plastic behavior as well as friction force between plates and angles. As can be seen in Figure 8, the residual of energy will be increased by time.

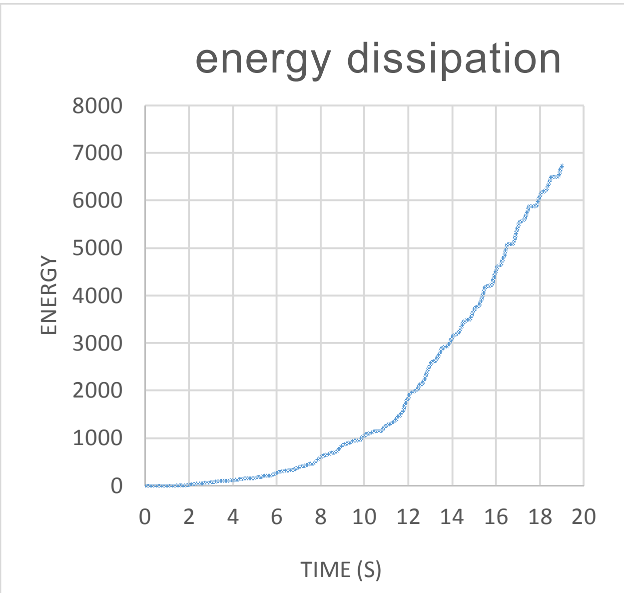

Figure 8: The binding energy dissipation post-tensioned steel centripetal

8. Summary and conclusion

In this study, post-tensioned steel moment connections are investigated to remove the rigid welded connection problems. The major feature of this connection is the opening and closing gap between the beam–columns area. The opening is created to provide the relative displacement actions. Unlike conventional connections, the main components of the connections are connected with no welding, and they are attached using some the screws. Although the connectivity components are very high, simulate this kind of connections are more complex and time consuming. After calibration of the laboratory sample, the validity of the obtained results of the molded post-tensioned steel connection was assessed. Accordingly, the form factor was determined which was obtained about 2. Furthermore, the percentage of the fixed end of the connection were calculated which was reached to 70%. However, in order to propose this kind of the connections as the semi-rigid connectors, there is a need for a acceptable regulation around the world which is expected to be accomplished by more studies on this subject.

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