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Analytical study of concrete-filled effect on the seismic behavior of restrained beam-column steel joints

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Horizontal reinforcement networks.

Abstract. Since placing continuity plates in panel zones of columns is difficult, including too much cutting and welding in connection areas, it also reduces the reliability of the connection. So, the continuity plates are removed from inside the column and replaced with internal elements such as horizontal reinforcement networks and external elements such as Trapezoidal stiffeners. In this study, through finite element modeling and geometric-material nonlinear analysis, under pushover and cyclic loading, we investigate loading. Results show that beam to box-column connections, with and without being in-filled with concrete, with arrangement stiffeners using concrete in the model with continuity plates, cause an increase of 0.12 percent in restraint, 4.98 percent in ductility and 96.92 percent in final resistance. Moreover, in the proposed model, the use of concrete leads to an increase of about 2 percent in restraint, and 52.51 percent in resistance, while ductility connection formation was reduced. Also, all parameters have shown a significant increase with binding reinforcement by horizontal reinforcement networks. Therefore, in the present study, the new proposed connection has satisfied all seismic parameters., which shows that it is a good alternative for continuity plates which are inside the column.

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1. Introduction

In steel construction, using columns with high moment inertia seems necessary when exerting loads on construction increase, because of stage and opening length increases. Usually, standard rolled sections are not responsible for this necessity, practically. Therefore, a continuous made section should be used in order to satisfy this necessity.

One of these sections is the box-column. These columns have symmetric sections and high moment inertia in two ways, while it has some difficulty of implementation. The main difficulty of these columns is in connection rigidity; for this, stiffeners must be used in the columns.

The rigidity of a connection is affected by the support rigidity. In the rigid connection of the beam to box-column, if the column wing is thin, there will be non-uniform deformation, which leads to tension distribution being expelled from the uniformity state along the weld and which makes a high tension focus. Stiffeners bring this tension distribution to a uniformity state and provide connection rigidity.

In this regard, many surveys have been done mostly by Shanmugam, Ting, and Lee [1-7]. In the research team's studies, external stiffeners of corner-

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stones, triangular continuous T-shaped, and continuity plates have been studied. The purpose of the present paper is to find a proper external stiffener as a continuity plate replacement, which could satisfy the basic factors of an efficient and rigid connection. Accordingly, edge and inter connections have been studied and surveyed. From the research team's studies, it has resulted that the connection with a T-shaped stiffener has the best function among other connections, and is a good substitute for the connection with inter continuity plates. Malek and Hajifathali [8] studied varieties of stiffeners by study and comparison of the I-beam connection with the box-column function in different states, i.e. in the presence or absence of continuity plates, with or without being in-filled with concrete, and also using encircled triangular plates with or without the welding of these plates to the corners of the columns. Research by Malek and Hajifathali [8] showed that the connection with a triangular external stiffener has the best function, in terms of stability, ductility, and energy absorbance, however, its function improved a little when it was filled with concrete. Moreover, existence of a triangular plate close to the connection caused the formation area of the plastic hinge to move away from the connected side and provide more safety for connections.

In the present study, we used trapezoid external stiffeners in order to support connection rigidity. Results have shown that these connections have satisfying functions according to the provisions of seismic criterion codes. To discover the effect of stiffener thickness and beam place on the connection function, four different state have been modeled and analysis determined by the limited component software, ANSYS. A load-displacement curve for each connection has been designed and parameters of final stability, restrained percentage and connection ductility have been compared and presented. Considering that the proposed connection has increased the beam's wing width around the panel zone and has made the tension distribution more constant around the panel zone, it has also moved the plastic hinge away from the column side and guided it to a safe and controlled place in the middle of the beam. This satisfied the ideal provisions of a weak beam of strong columns. Mirghaderi and his colleagues [9] tentatively studied the bending connection of an I-beam to a box-column using a band-pass plate. They suggested this connection for the purpose of removal of the continuity plates from inside the column, and to find a good substitute for it. In order to conduct the research more completely, they examined two models on the basis of loading cycles, and have studied and researched their seismic function. Although the goal was removal and replacement of the continuity plates by band-pass plates, they suggested an I-beam connection to the box column with band-pass plates, which continue from the beam to the inside of the column. After the experiment, they concluded that the plates transfer the cut and anchor to the column well, and properly provide a rigid connection benchmarks. On the one hand, because a gap has been made in the column wing plates at the beginning of construction, and the band-pass plates are replaced in the column, this connection, in addition to good function, has not created any difficulties relating to the continuity plates and could be a proper substitute for continuity plates in making a rigid connection. Sedighian Kashani and Aghakoochak [10] have investigated the I-beam connection to the box-column without internal continuity plates by implementing a tree column approach. In this paper, implementing an I-beam connection to a box column could be feasible by giving a new geometry to the connection, based on the tree column construction approach. To investigate the seismic function of the proposed connection, limited component modeling was used and the cross-shaped substructure of the monotonic and cyclic loading connection has been studied. Results show that the suggested connection provides the rigidity, bending resistance and ductility criterions which are considered in the AISC seismic code. The connection bears the loading to the end of the cycle which has a 4% stage angular deviation without significant stability decrease. In this analysis, the plastic-equivalent strain was calculated and controlled for controlling failure in the connection.

In this study, a new connection in steel buildings with columns box is presented. This connection is applicable for Hollow Steel Section (HSS) and Concrete Filled Steel Tubes (CFST) columns. The state in which trapezoid external stiffeners were used in the upside and downside wing balance of the beams around the column, and the situation in which horizontal reinforcement networks are used as internal stiffeners, have been presented and investigated.

For connection modeling and obtaining the load specification, displacement ANSYS software was used. In order to simulate the model's behavior of the real function, non-linear analysis was used. The procedure of using internal continuity plates as stiffeners was modeled and the analysis is determined by ANSYS software. A load-displacement diagram has also been drawn. Then, these plates are removed from the inside of the column and replaced by trapezoid external stiffeners, which are transferred to the column from outside in the beam wings balance. Also, horizontal reinforcement networks are placed in the column around the panel zone. A newly proposed connection, including trapezoid external stiffeners, along with horizontal reinforcement networks, and in-filled with the concrete of the column, have been modeled and analyzed. After analysis of the connection, the load-displacement diagram of each binding has been drawn and, accordingly, the connection rigidity, resistance and ductility were determined. It was then indicated which connection could satisfy the basic factors of a rigid connection and be a proper substitute for internal continuity plates.

2. Finite element models

2.1. Material properties

Steel and concrete are the materials used in the studied models. Steel has an elastic-plastic stress-strain curve. Considering that non-linear analysis of the materials is proposed to obtain more accurate answers, the steel function after yielding should be investigated. In the present study, two linear elastic-plastic curves were used to model the steel behavior. The selected steel is the type of construction mid steel, i.e. ST37. The steel elasticity module is 2×10^5 MPa, steel yielding stress is 240 MPa and the Poisson coefficient is 0.3. The bars used in some models have a diameter of 25 mm.

Since the concrete inside the column has practically become surrounded, we have tried to take this matter into account in criterion selection and the concrete behavioral stress-strain curve. The stability pressure of the concrete is 30 MPa and $\varepsilon_{cu} = 0.0035$. For steel modeling, different elements, such as SHELL and SOLID, which are surface elements, could be applied. In this survey, the SOLID186 element was used in the research procedure. For concrete modeling, a 3-dimensional, 8-node SOLID65 element, which has cracking capability under elastic stress and crumbling capacity under pressure stress, was applied. Moreover, it has the modeling capacity of creep and plastic deformations. For bar modeling, a Link180 element was used, which has truss behavior with tension and pressure capabilities. This element has two nodes, and each node has three degrees of freedom in x, y and z directions. Moreover, it has the modeling capability of creep and plastic deformations.

2.2. Boundary conditions

The models used in this study are inter connections, four 3 m beams have been connected to the box-column of 4 m from four directions. According to Figure 1, the end of each beam and the column foot are placed on 3-dimensional pin support. To avoid stress focus on the end of each beam and column foot, all the nodes should be coupled to each other in order to operate uniformly. The boundary conditions of this study are that all the transferring degrees of freedom have been, at some point, at the end of the beam or column foot.

2.3. Model loading

In this study, tree analyses have been done to study the accurate behavior of the connection, including monotonic static analysis, hysteresis and modal analysis. Modal analysis is given for the frequency behavior of the connection. Monotonic analysis was conducted in a manner of increasing and load control, however, the hysteresis analysis was done by regression and displacement control. A diagram of the time history for loading in this study is illustrated in Figure 2 on the basis of loading pattern SAC97 [11].

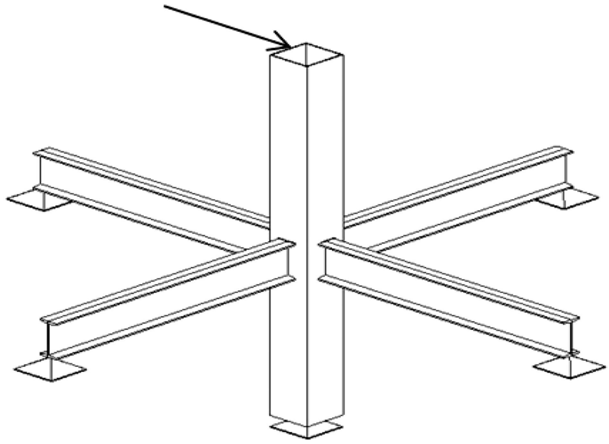


Figure 1. The general schema of the connections.

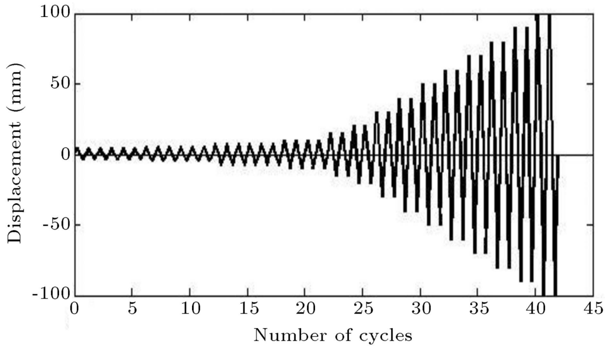


Figure 2. Time history of loading, diagram-SAC97 [11].

3. Models introduction

In this study, eleven models with specifications are listed in Table 1. In seven models, columns are filled with concrete but in other models, they are hollow. In all models, column is a square box, which is surrounded by I-beam of the four sides (see Figure 3).

4. Experimental verification

The experimental study shows high reliability but is cost and time consuming, and requires special equipment. Accordingly, the use of finite element software is considered for the study. The aim of the model in the software is to get the actual behavior of structural approximation to be acceptable. Thus, various factors, such as element type, mesh size, boundary condition, material behavior, and final behavior impact their

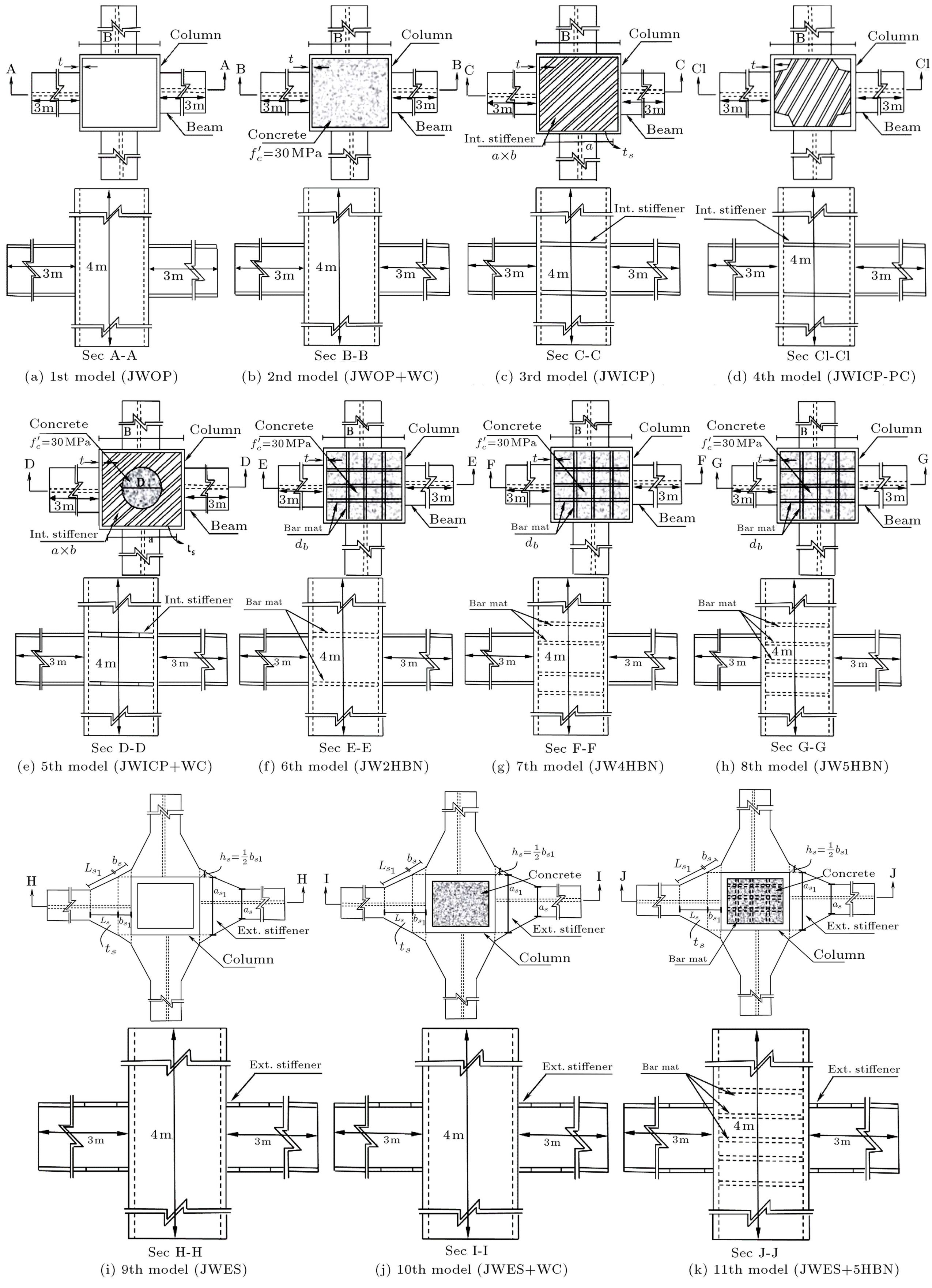
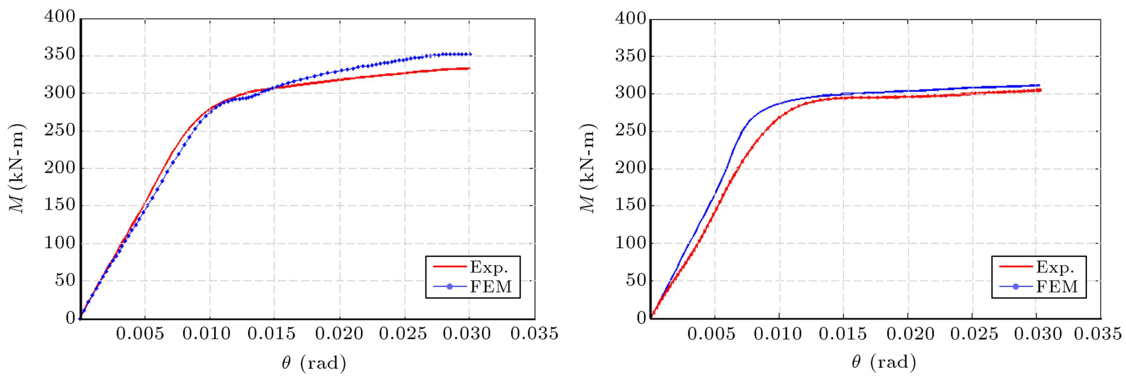


Figure 3. Details of models.

Table 1. Model introduction (sizes of models are in mm).

Names		JWOP	JWOP +WC	JWICP	JWICP -PC	JWICP +WC	JW2HBN	JW4HBN	JW5HBN	JWES	JWES +WC	JWES +5HBN
Box column $H = 4000$	$B \times t$	450×25	450×25	450×25	450×25	450×25	450×25	450×25	450×25	450×25	450×25	450×25
I-Beam $L = 3000$	$b_f \times t_f$	200×15	200×15	200×15	200×15	200×1 5	200×15	200×15	200×15	200×15	200×15	200×15
	$h \times t_w$	400×8	400×8	400×8	400×8	400×8	400×8	400×8	400×8	400×8	400×8	400×8
	d	430	430	430	430	430	430	430	430	430	430	430
Hollow/ filled		H	F	H	H	F	F	F	F	H	F	F
Bar mats		-	-	-	-	-	√	√	√	-	-	√
	d_b	-	-	-	-	-	25	25	25	-	-	25
Internal stiffener		-	-	√	√	√	-	-	-	-	-	-
	t_s	-	-	15	15	15	-	-	-	-	-	-
	$a \times b$	-	-	400×400	400×400	400×400	-	-	-	-	-	-
	D	-	-	-	-	210	-	-	-	-	-	-
External stiffener		-	-	-	-	-	-	-	-	√	√	√
	t_s	-	-	-	-	-	-	-	-	15	15	15
	b_s	-	-	-	-	-	-	-	-	212	212	212
	b_{s1}	-	-	-	-	-	-	-	-	150	150	150
	l_s	-	-	-	-	-	-	-	-	500	500	500
	l_{s1}	-	-	-	-	-	-	-	-	515.4	515.4	515.4
	a_s	-	-	-	-	-	-	-	-	200	200	200
	a_{s1}	-	-	-	-	-	-	-	-	450	450	450



(a) T-shape external stiffener (b) Continuity plates

Figure 4. Moment-rotation curve, experimental model and FEM.

model. So, the correct choice is to increase the accuracy of the solution. To review and verify the application of the model with ANSYS software must show that the results of the finite element analysis are compatible with experimental results.

In this study, two samples of the affirmative model provided by Shanmugam et al. [1,4] are used. A typical model with T-shape external stiffener and internal continuity plates has been modeled and analysed using ANSYS software and the results of the curve moment-rotation are presented. Finite element modeling results with experimental results available in the article by Shanmugam et al. are compared and the results prove the compatibility of the model. Comparison of the curve moment-rotation experiments and an analysis of these samples are presented in Figure 4.

5. Results analysis review

In this section, after obtaining the results of monotonic static analysis, regressive analysis, and modal analysis, the final results have been argued and studied. Parameters investigated here include final capacity, formation of initial stability, plastic hinge formation place, maximum stress, energy absorbance amount, and construction frequencies.

Results of the investigations show that the eleventh model (suggested model) has the best behav-

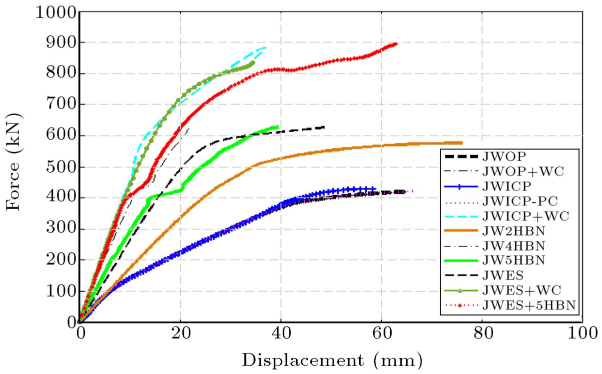


Figure 5. Comparison of force-displacement curves.

ior compared to other connections, and is a very good substitute for the connection with continuity plates considered in the regulations.

5.1. Results analysis review affected monotonic loading

From the force-displacement curve, initial rigidity, ductility coefficient and final resistance of the models are accounted for and are represented in Figure 5.

5.1.1. Connection comparison from the initial rigidity point view

From the restraint index of the first and second models, it is concluded that using in-filled concrete leads to an increase in the connection restraint index from 76.39 to 85.37, but could not reach minimum regulations in order to be classified as a rigid connection. Thus, it has been counted as semi-rigid. The fifth model was presented, and, as the third model rigidity criterion effects, was studied. The results indicate that the existence of concrete has no significant effect on the restraint index of this connection and is approximately equal to it. Both models, by obtaining a restraint index above 90%, are classified as rigid connections, according to the AISC code. For studying the continuity plate surface effects on connection rigidity, a fourth model was represented. Comparing it with the third model, it is resulted that by decreasing the continuity plate surface, the restraint index reduced from 93.37 to 91.23. It would, however, be classified as a rigid connection due to possessing a restraint index above 90%, according to the code.

However, the aim of this research is to find a good substitute for continuity plates which, in addition to satisfying code criteria for providing rigidity, should not have problems of difficult and unreliable construction of these connections. Accordingly, in this study, application of a horizontal reinforcement network along with beam wings in the column has been modeled and analyzed. Results of analysis show that this connection is classified as rigid by attaining a 92.01% restraint index. Since this connection was suggested as a substitute for the continuity plates, it could be a good substitute in respect of restraint. For investigating the effect of the horizontal reinforcement network number on the affinity index value of the connections, models with four networks (7th model) and five networks (8th model) have been modeled and analyzed. Results indicate the positive effect of network number on the connection's restraint.

Considering that the code's recommendation for fixing the beam connection to the box-column is the use of continuity plates in the beam wing balance inside the column, along with wings, and that the construction of these plates is very difficult and unreliable in the column, researchers suggested the use of an external stiffener to overcome this problem. These stiffeners could be a good substitute when the percentage of restraint is higher than 90%. In this survey, the modeled connection with continuity plates, assigned 93.37% affinity to itself, and the connection with an external stiffener acquired a 94.11% affinity index, which indicated that this connection is ideal regarding affinity. To investigate the effect of concrete on the connection restraint value with trapezoid external stiffeners of the column, the connection was constructed as CFT (10th model). Results indicate that the presence of in-filled concrete in the column relatively increases the connection restraint index to 95.75%. Therefore, the existence of concrete is not so appropriate for increasing the connection restraint.

In this paper, by integrating the 8th and 10th models, a new connection was suggested for further information. After modeling and analysis, a comparison was made between the results of this model and that of the others. The results show that the conjugate presence of concrete and five horizontal reinforcement networks caused the restraint to increase by 2.2%. By comparing the 10th and 11th models, it was concluded that the existence of horizontal reinforcement networks leads to an increase of 1% in restraint. On the other hand, comparing the 11th and 8th models would have shown that the existence of external stiffeners increases restraint by 2.1%, so, this connection would be desirable.

According to Table 2, the first and second models, with a restraint lower than 90%, were classified as semi-rigid connections, and the other connections, which acquired a restraint index of higher than 90%, were classified as rigid connections. By comparing the connections' restraint percentages to the reference model, it is concluded that by acquiring a higher restraint percentage, the 5th, 8th, and 9th to 11th models have better behavior and are a more appropriate substitute for continuity plates.

5.1.2. Ductility and maximum load of connections

In order to compare the connections from a ductility point of view, the ideal double line curve for that

Table 2. The indexes of connections restrain.

Rows	**Number of models (i)**	**Restrain index value (R%)**	$\left[\frac{R_{\max(i)}}{R_{\max(3)}} \times 100\right]$
1	First	76.39	81.81
2	Second	85.37	91.43
3	Third (base)	93.37	100
4	Fourth	91.23	97.70
5	Fifth	93.48	100.12
6	Sixth	92.01	98.54
7	Seventh	93.34	99.97
8	Eighth	94.28	100.94
9	Ninth	94.11	100.8
10	Tenth	95.75	102.55
11	Eleventh	96.18	103.01

connection has been drawn after the force-displacement curve of each connection, so that the bottom of the diagram of the force-displacement curve and the ideal curve were equal. It was also determined by the final displacement calculation and the connection ductility coefficient delivery (Eq. (1)) which is obtained by:

$$\mu = \frac{\Delta_{\max}}{\Delta y}. \tag{1}$$

The ductility parameter of connections is defined by Eq. (1).

According to Table 3, the suggested model obtains the highest ductility value, and the 5th and 9th models acquire a ductility coefficient of 6.11 and 5.57, respectively, after the 11th model, showing a better condition for ductility. Also, it could be concluded that in the 1st and 9th models, the existence of concrete reduces ductility, while, in the second model, it improves ductility.

Resistance is one of the main factors in investigating connection quality. In order to compare the connections from final resistance, the maximum tolerable force of each connection and the ratios of these quantities to the tolerable force of each connection, and the ratios of these quantities to the tolerable force of the reference model (3rd model) have been represented in Table 3.

By comparing the data of Table 3, it is concluded that only models without any plates and models with modified continuity plates acquire resistance lower than the reference model. It is noted that the suggested model, which obtained a resistance of 89.45 tons with an increase of 108.8% in resistance, functions the best between all others. It is resulted from comparing the first and second models that the existence of concrete leads to an increase of 33% in connection resistance. Moreover, by filling the column with concrete in the 3rd model, connection stability will increase 96.92%. Besides, increasing the number of horizontal reinforcement networks causes an increase in the final resistance of the connection.

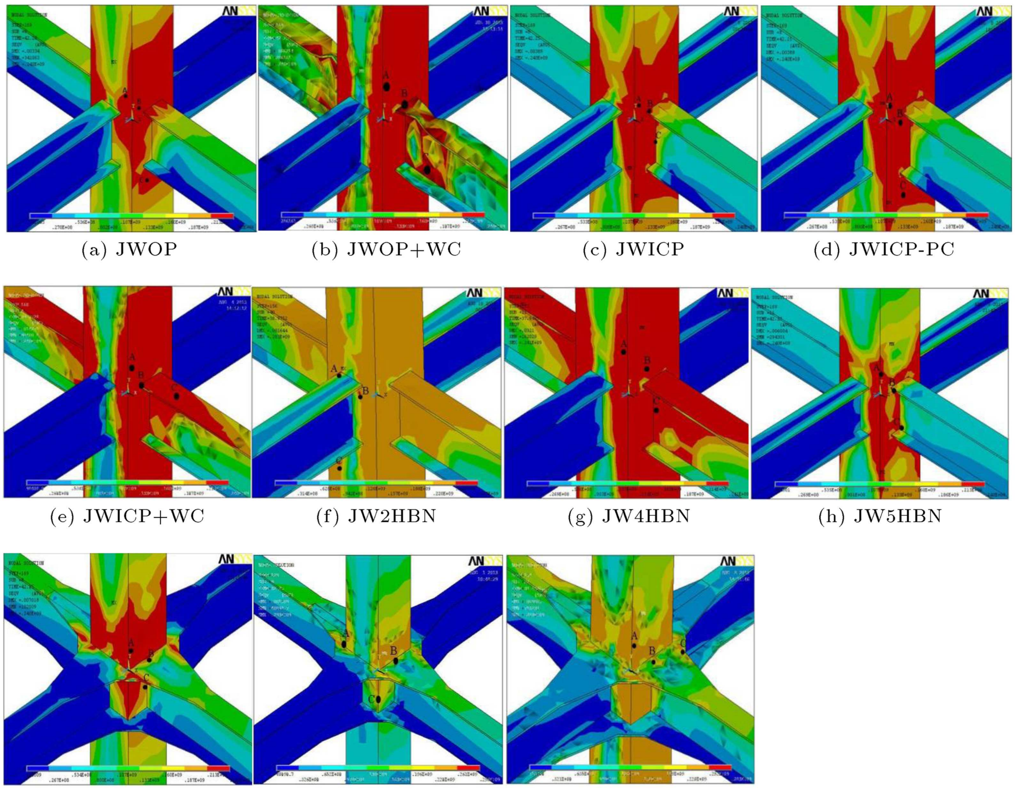
Comparing the 9th and 10th models demonstrated that the existence of concrete in a fixed connection by trapezoid external stiffeners leads to an increase of 30% in a connection resistance of about 5%.

5.1.3. Connection comparison from the plastic hinge place point of view

The place for plastic hinge forming varies for different connections. Results of the limited component analysis offer that, generally, in the connections, the plastic hinge is formed around the panel zone area. However, in connections whose beam wing width is larger than other points, due to the use of external stiffeners, and for stress focus, which has been made at the end of the

Table 3. Comparison of the ductility and maximum load coefficient of connections.

Rows	**Number of models (i)**	**Ductility index (μ)**	$\left[\frac{\mu_{\max(i)}}{\mu_{\max(3)}} \times 100\right]$	**Max. load ($P_{\max}(i)$)**	$\frac{P_{\max(i)}}{P_{\max(3)}} \times 100$
1	First	3.77	64.78	41.93	97.87
2	Second	3.66	62.88	55.77	130.18
3	Third (base)	5.82	100	42.84	100
4	Fourth	5.08	87.28	42.104	98.27
5	Fifth	6.11	104.98	84.36	196.92
6	Sixth	3.82	65.63	57.72	134.73
7	Seventh	4.01	68.90	62.18	145.14
8	Eighth	4.2	72.16	62.76	146.5
9	Ninth	5.57	95.7	62.59	146.09
10	Tenth	4.46	76.63	85.09	198.62
11	Eleventh	7.04	120.96	89.45	208.8



(a) JWOP (b) JWOP+WC (c) JWICP (d) JWICP-PC

(e) JWICP+WC (f) JW2HBN (g) JW4HBN (h) JW5HBN

(i) JWES (j) JWES+WC (k) JWES+5HBN

Figure 6. Von Mises stress distribution.

external stiffeners, the plastic hinge has retreated from the column side to the extent of the stiffener length and has completely formed in the column. This well provides the provisions of this idea: a powerless beam and a firm column. In addition, the investigations demonstrate that in fixed models with external stiffeners, firstly, the external stiffener becomes plastic at the connection side, and increases the force. According to Figure 6, the plasticity developed in the external stiffener and at the end of the stiffener has been transferred to the beam; the plastic hinge has been formed completely in the beam, as expected. The plastic hinge has retreated from the beam side to the same length as the external stiffener. This matter illustrates the proper function of a fixed column with a surrounded plate. Regarding its trapezoid form, it will direct the plastic hinge to a safe and controlled area in the beam, and meet well the regulation criteria. The models which have complete continuity plates in the column perform better than those without continuity plates, concerning the plastic hinge formation area. However, since accurate construction of these plates is very difficult in the column, the results of analysis might be different from reality.

5.1.4. Comparing the connections maximum stress

After the analyses have been done, the maximum generated stress in the connections is deduced and presented in Table 4. Also, for more accurate investigation of these values, their ratios to the reference condition are given.

It could be discovered from quality investigation of stress results that the existence of an external stiffener causes stress to become more moderate and its distribution to be more uniform. However, the inside of the column in-filled with concrete leads to a decrease in the maximum stress of the connections. By increasing rigidity around the panel zone, the 3rd and 4th models provide considerable tension in this area.

5.2. Investigating the analysis results and modeling affected by regressive loading

Since real earthquakes have regressive behavior, the cyclic behavior of the connections is the most important. As connections with a hysteresis curve are wider, they function more appropriately against cyclic forces. In this section, the hysteresis curves of the connections are represented (Figure 7(a)-(j)).

The results indicate that the 9th model, i.e. the connection with an external stiffener, and the 3rd model, i.e. the connection with continuity plates, have wider hysteresis curves and the best function of regressive behavior. On the other hand, the existence of concrete in the models causes the hysteresis curve to become thinner.

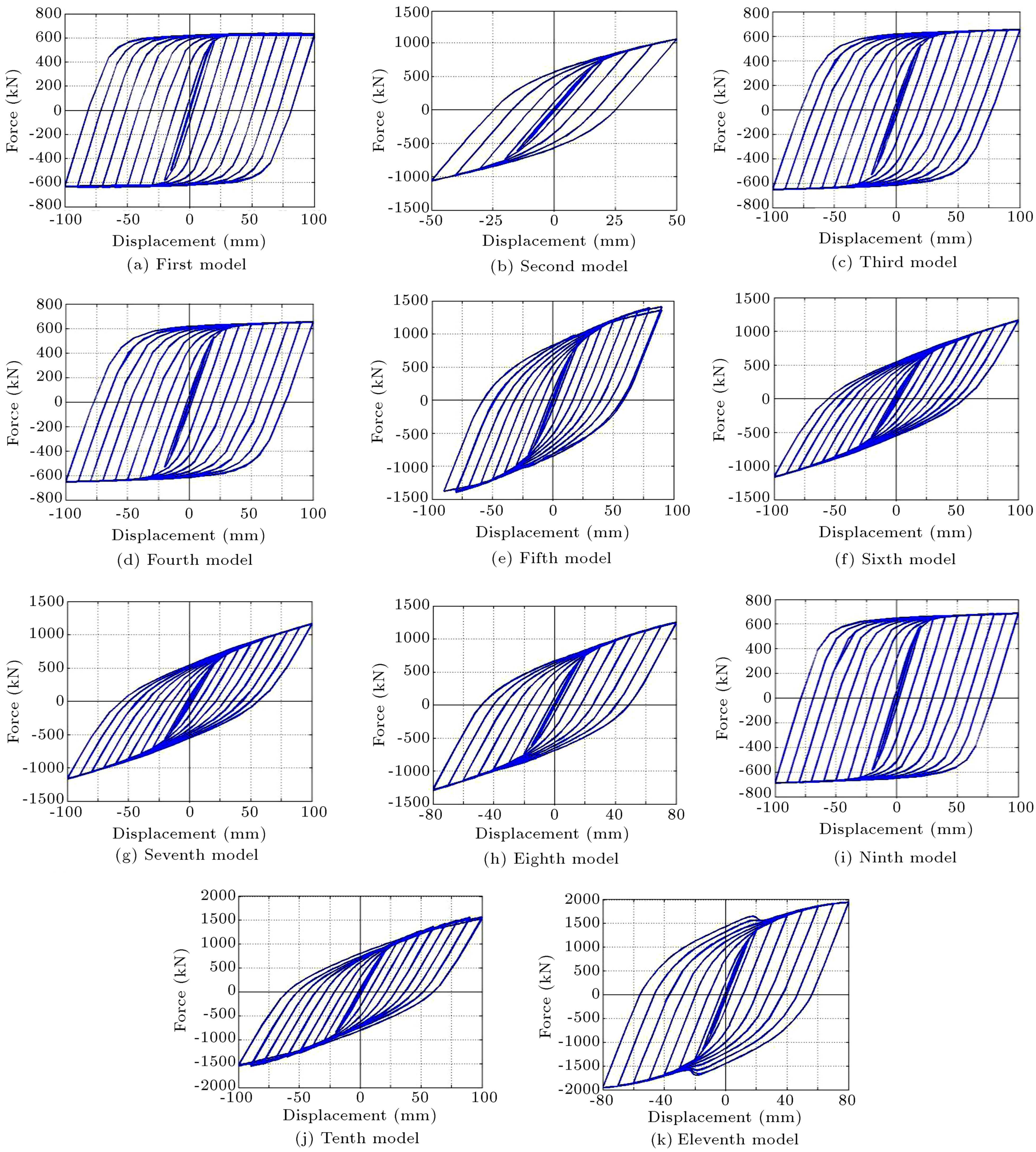


Figure 7. Models' hysteresis curves.

5.2.1. Connection comparison from the energy absorbance point of view

One of the parameters that indicate connection sufficiency is the energy absorbed by the connection. The higher this value is, the better the connection behavior. In Table 5, the values of maximum stress and the ratio of these values to the maximum stress of the reference model have been represented.

According to the above table, the energy absorbance values for the ninth and eleventh models were higher than the reference model because of the stiffeners existence. In the tenth model, despite the existence of a stiffener due to being in-filled with concrete in the column, the absorbed energy value is reduced.

5.3. Modal analysis of the connections

In order to investigate the connection's frequency behavior, a modal analysis was done on the connections, and its results are presented in Figure 8.

Table 4. The maximum stress value of the connection.

Rows	Number of models (i)	Location of the maximum stress	Maximum stress (MPa)	$\frac{\sigma_{\max(i)}}{\sigma_{\max(3)}} \times 100$
1	First	A (Figure 6(a))	415	96.5
2	Second	B (Figure 6(b))	285	66.28
3	Third (base)	B (Figure 6(c))	430	100
4	Fourth	B (Figure 6(d))	426	99
5	Fifth	C (Figure 6(e))	279	64.88
6	Sixth	C (Figure 6(f))	305	70.93
7	Seventh	A (Figure 6(g))	294	68.37
8	Eighth	A (Figure 6(h))	260	60.46
9	Ninth	C (Figure 6(i))	295	68.6
10	Tenth	B (Figure 6(j))	330	76.74
11	Eleventh	A (Figure 6(k))	364	84.65

Table 5. Absolute and relative values of models energy.

Rows	Connection energy $E_{(i)}(J)$	$\frac{E_{(i)}}{E_{(3)}} \times 100$
1	17597	69.69
2	13905.67	55.07
3	25249.19	100
4	18986.98	75.19
5	19220	76.12
6	14338.2	56.78
7	15875.72	62.88
8	16410.02	65
9	25859.69	118.26
10	19800	78.41
11	27619.14	109.39

Comparing the connection frequencies showed that, as the connection has higher rigidity, it would have greater frequency increases in upper moods.

6. Conclusions

In this paper, the behavior of connections stiffened using different methods has been investigated. So, it is recommended that when using the following results, caution has been served.

The investigated results of this study are as follows:

- Existence of continuity plates in a beam connection to an empty box-column causes the connection to form a resistance, and the restraint percentage to increase. Also, the use of an external stiffener instead of continuity plates leads to an improvement in connection behavior, in terms of resistance and restraint percentage. Regarding the width increasing around the panel zone areas, it forced the plastic hinge into the beam and provided the provisions of this idea: A powerless beam firm column;
- Increasing the number of horizontal reinforcement networks leads to an increase in the restrained final resistance and ductility of the connections;
- A column filled with concrete leads to an increased stability and restraint;

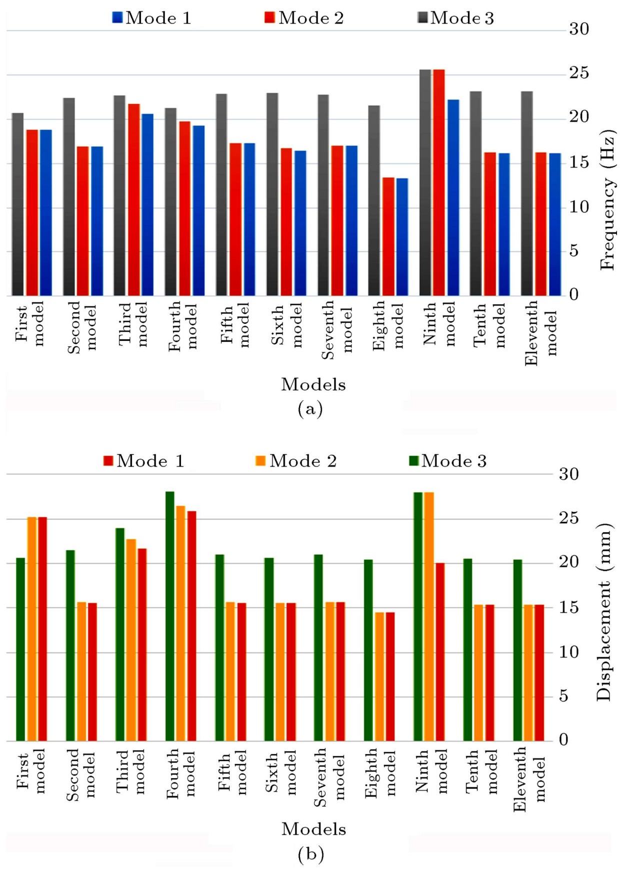


Figure 8. Bar graph of models: a) Frequency; and b) Displacement.

- Models with external stiffeners obtain the highest amount of restraint index;
- Among the studied models, the eleventh model, with a restraint index of 96.18%, has assigned the highest restraint percentage to itself. Concerning resistance, it has the best condition and is a good substitute for internal continuity plates;
- Considering connection ductility, the complete continuity plates acquired 5.82 and the fifth model 6.11 ductility coefficients, respectively, and the suggested model, with a 7.04 ductility coefficient, obtained the best behavior among the models;
- The wider hysteresis curve of the 9th and 3rd models indicate the proper behavior of these connections under cyclic forces. Furthermore, the frequency behavior of the 9th model is more appropriate than the others, and, regarding stress distribution, also has better behavior than the other models.

In general, the findings of the analyses show that using external stiffeners instead of continuity plates causes all parameters to increase and the connections to improve. The existence of concrete and reinforcement networks, simultaneously, in these connections causes them to be very good and safe.

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