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THE EFFECT OF STIFFENERS ON ASYMMETRIC (UPN) BEAMS UNDER ECCENTRIC LOADS

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ABSTRACT

Stiffeners are crucial in enhancing the resistance of steel elements to both point and distributed vertical loads. However, one of the main challenges is the vertical and horizontal deflection experienced by steel beams under asymmetric loading conditions. This study investigates, using IDEA StatiCa software, the effect of stiffeners on the performance of European UPN steel beams subjected to eccentric point loads. A total of 12 beam models stiffened and unstiffened were studied, varying in height and yield strength. Finite element analysis was conducted using the Component-Based Finite Element Method (CBFEM) to accurately capture stress distribution and deflection behavior. The results show that stiffeners significantly reduce both vertical and lateral deflections and improve torsional stability. Furthermore, stiffened and unstiffened beams reached yield strength at similar load levels, but the presence of stiffeners limited post-yield deformations. The findings align with previous studies and confirm the value of stiffeners in enhancing the structural performance of asymmetric beams. This highlights the practical importance of stiffeners in UPN steel beam design, especially under eccentric loading where stability and local deformation are critical concerns.

Keywords: Stiffeners, Asymmetrical section, Eccentric load, Steel beam.

1 INTRODUCTION

Steel structure consists of a connection between a beam and a column. The beam is responsible of handling the vertical loads from the slabs. Therefore, the beam is subjected to bending moments and shear force. The bending moments is produced due the beam being subjected to point and distributed loads based on the way of loading. And these moments cause a deformation in the beam.

And the steel structures have many advantages that make them more attractive compared to concrete structures. One of the most beneficial characteristics is the speed of its implementation where many stories could be constructed within short time [1]. Moreover, the use of steel elements enables longer spans while reducing their dimensions compared to concrete elements [2], [3]. Ease of maintenance is another characteristic that makes it desirable in the construction sector [4], [5]. On the other hand, some characteristics are still critical and need to be addressed, i.e., compressed steel elements might have less bearing capacity compared to concrete elements in tension due to lateral torsion [6].

Due of the way of loading or the loading direction or the initial imperfections it obtained lateral torsion in the beam. This torsion may lead to the beam going out of service in an early stage of the loading phase [7], [8], [9], [10], [11], [12].

The problem of this deformed shape can be overcomed through the lateral support of the section [13], [14], [15]. In another way, stiffeners can be relied upon to increase the bearing capacity of the section to a certain extent and prevent the deflection, whether in the compressed flange of beams that are subject to bending or in columns. Therefore, they are used to raise the efficiency of the section and prevent it from lateral deformation if lateral support is not available.

Hence, we see the importance of stiffeners in steel elements in general and in their compressed parts in particular.

Similar to UPN beams subjected to eccentric loads, castellated beams also exhibit critical failure mechanisms such as lateral-torsional buckling, web-post buckling, and Vierendeel mechanisms. Kaveh and Shokohi [16] emphasized that providing lateral supports is essential to prevent these failures, a concept that aligns with the objective of using stiffeners in the present study. Furthermore, previous research has demonstrated that structural modifications, such as web expansion through castellated and cellular designs, significantly enhance the load-bearing efficiency and stiffness of steel beams without substantially increasing their weight, highlighting the broader importance of geometric optimization in structural performance improvement [17]. Also, some studies have shown that modifications to beam webs, such as the use of different opening shapes in castellated beams, can significantly influence bending resistance and vibration characteristics [18].

In general, local deformation can happen under point load which stiffeners can prevent it efficiently [19], [20], [21], [22]. The other one is lateral torsion which happens in asymmetrical section shape or in case of load eccentricity [23], [24], [25].

In this study stiffeners have been used to connects between the web, the top flange and the bottom flange with Continuous fillet weld on (UPN) beam as asymmetrical section and preview the influence of stiffeners existing.

This study focuses on the issue of vertical and horizontal deflections, including lateral torsion, in asymmetric UPN steel beams under eccentric point loads. While stiffeners are known to improve resistance to vertical loads and local deformations, their specific impact on mitigating both vertical and horizontal deflections and lateral torsion in UPN sections with eccentric loads needs further examination. This research analytically investigates the benefits of stiffeners in such UPN beams using IDEA Staticas Software, comparing stiffened and unstiffened beams. This is important for ensuring stability and preventing failure due to lateral torsion and excessive deflections in these specific scenarios. Distinct from existing literature, this work provides analytical insights into the influence of stiffeners on local deformations and overall structural behavior of asymmetric UPN sections under eccentric point loads by utilizing a finite element method-based software (IDEA Staticas), offering a targeted contribution to the understanding of stiffener applications in complex loading situations.

2 FINITE ELEMENT MODELLING

2.1 Specimen Details

12 beams categorized in two groups based on the beam stiffness statue were modelled and analyzed. All the beams shared the same span of 5 m. The specimens are divided into two groups. Group A contains six unstiffened beams. Group B contains six stiffened beams; each group contain a total six of beams: three (UPN 300) and three (UPN 400). UPN 300 beam dimensions and details shown in figure 1and UPN 400 beam dimensions and details shown in figure 2. with three different yield strengths 235,275 and 355. Table 1 provides the abbreviations and descriptions of the studied beams.

To investigate the effect of stiffeners on the studied beams, a detailed analysis was conducted using IDEA StatiCa software, which employs the Component-Based Finite Element Method (CBFEM). CBFEM combines conventional finite element concepts with engineering theory to simulate the behavior of steel connections and components under complex stress conditions accurately and reliably. The finite element model utilized 3D 8-node hexahedral (brick) elements with linear interpolation to capture stress distributions in steel members, welds, and stiffeners. Each node included three translational degrees of freedom (DOFs) based on standard linear elasticity theory under small-strain assumptions. The analysis assumed linear elastic material behavior up to yield, without considering geometric nonlinearity, contact effects, or initial imperfections. Welds were modeled as ideal continuous fillet welds without defects.

Table 1. Details of the specimens.

Group	Type	Height (m)	Yield Strength (MPa)	Stiffened Statues	Specimen Identification
A	(UPN) European Normal Channels	300	235	Unstiffened	UST-P-UPN-300-235
			275		UST-P-UPN-300-275
			355		UST-P-UPN-300-355
		400	235		UST-P-UPN-400-235
			275		UST-P-UPN-400-275
			355		UST-P-UPN-400-355
B		300	235	Stiffened	ST-P-UPN-300-235
			275		ST-P-UPN-300-275
			355		ST-P-UPN-300-355
		400	235		ST-P-UPN-400-235
			375		ST-P-UPN-400-275
			355		ST-P-UPN-400-355

2.2 Modelling and Properties

The studied beams were designed based on the European steel code (Eurocode 3) and for the dimensional properties of the (UPN 300, UPN 400) steel beams studied, the dimension is shown in the figures 1. Mechanical Material properties of the steel beams studied, is shown in the table 2.

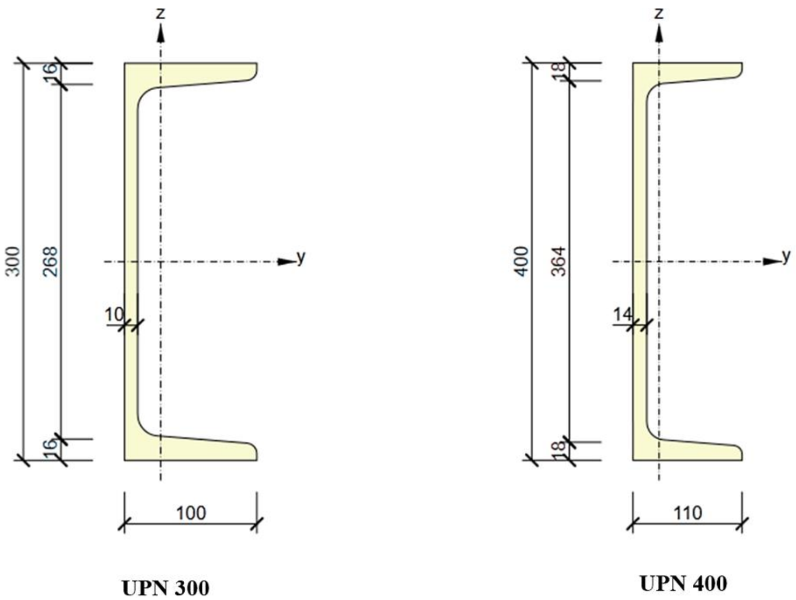


Figure 1. UPN 300 and 400 dimensional Properties.

Table 2. Mechanical and Material properties.

Material	m (kg/m^3)	E (MPa)	ν (-)	α (1e-6/k)	λ (W/(m.k))	c (kj/(kg.k))	*fu* (MPa)	*fy* (MPa)
S 235	7850	210000	0.3	12	50	0.49	293.8	235
S 275							430	275
S 355							490	355

Regarding the S235 fu value, it should also be noted that it is the program's default setting and it was directly taken from the material properties defined in IDEA StatiCa software's default steel database. UPN is the short name for European normal channel sections. The use of UPN beams characterized by high design flexibility and by fast and cost-effective construction. The applied loads are point loads and they are symmetrically positioned on the beam with a one-meter spacing between the axes of the load. Note that the total length of the beam is 5 m. And to study the effect of the stiffeners on the beam to resist torsion the load was applied on the last 50 mm of the top flange (placing of the applied load is shown in figure 2). The 1-meter spacing between the two-point loads was chosen to replicate a realistic condition often seen in practice, such as machine legs resting on a steel beam or a beam-to-beam support situation. This spacing offers a practical example without focusing on a specific case. Stiffeners were added at the load points to compare the beam's behavior in supported vs. unsupported conditions. This approach follows common engineering practices and is consistent with design guidance from sources like Eurocode 3.

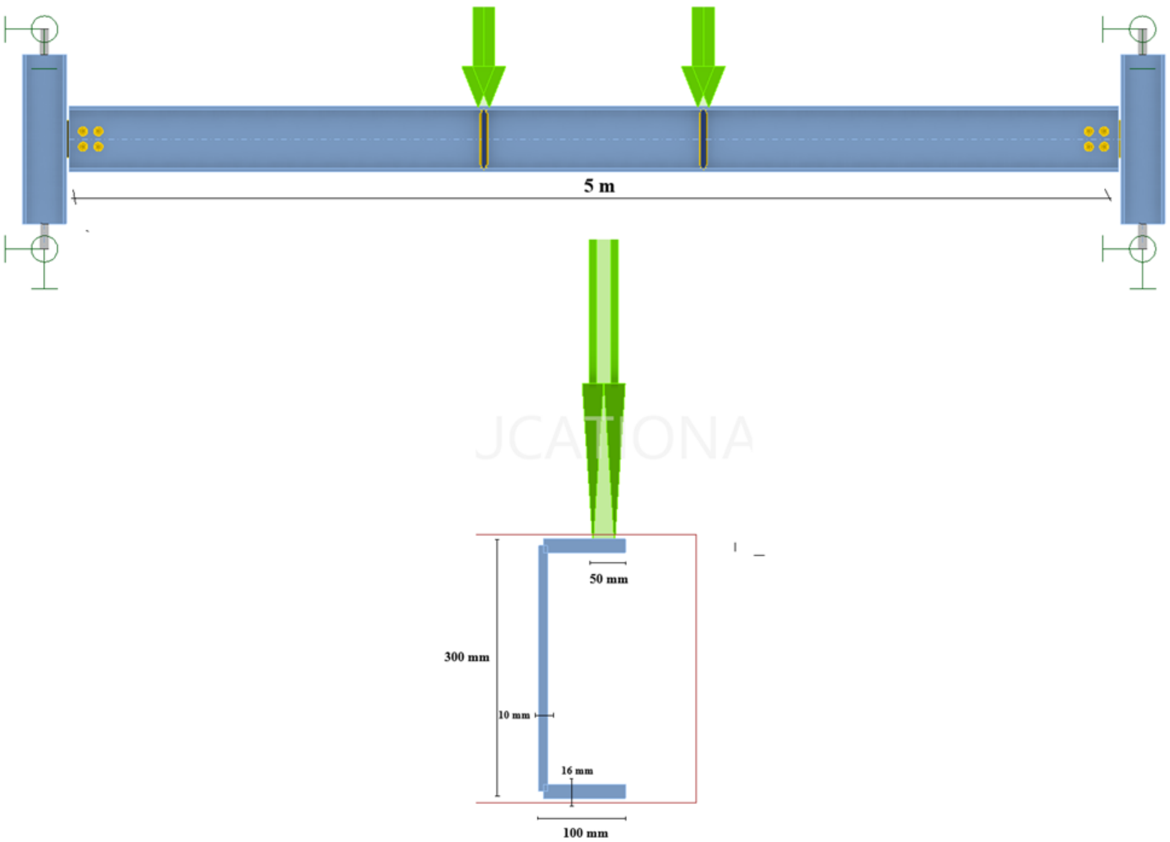
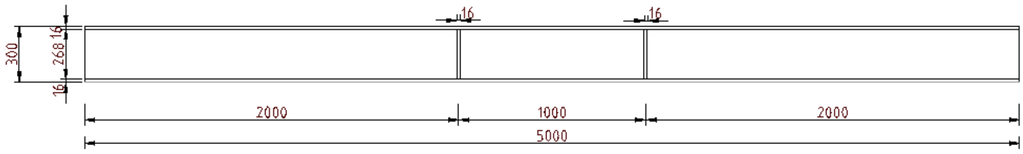
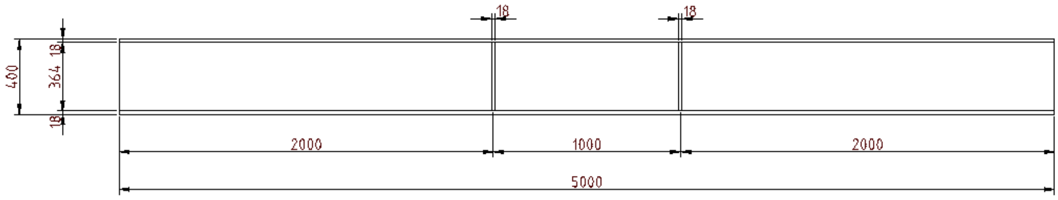


Figure 2. 3D Model for point load on UPN 300 beam.

The number of the stiffeners is the same of the applied loads which is 2 and they were placed under the loading points and the loads are symmetrically positioned on the beam with a one-meter spacing between the axes of the load. And the stiffeners always have the same mechanical properties of beams. Figure 3 shows the placing of the stiffeners on the beams and the dimensions.



UPN 300



UPN 400

Figure 3. placing of the stiffeners on the UPN beam and the dimensions.

In general, the thickness of the stiffeners is the same as the thickness of the top flange and the width of the stiffeners is equal to the distance between the web and the end of the flanges for each beam and the thickness of the welds is 0.7 of the thickness of the web. In the study, the stiffeners were connected using fillet welds, which are commonly used in practical steel construction. And The weld thickness is 0.7 times the web thickness, in compliance with EN 1993-1-8. These welds were modeled explicitly in IDEA StatiCa, which simulates welds using special nonlinear elements that capture force transfer between connected plates.

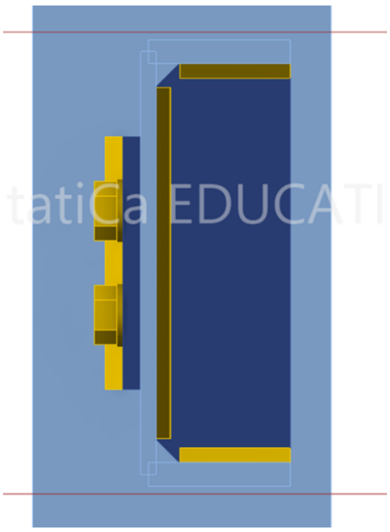


Figure 4. Cross-Section for stiffeners and Weld on UPN beam.

The connection type that is being used in all the cases is simple support and it is shown in figure 5.

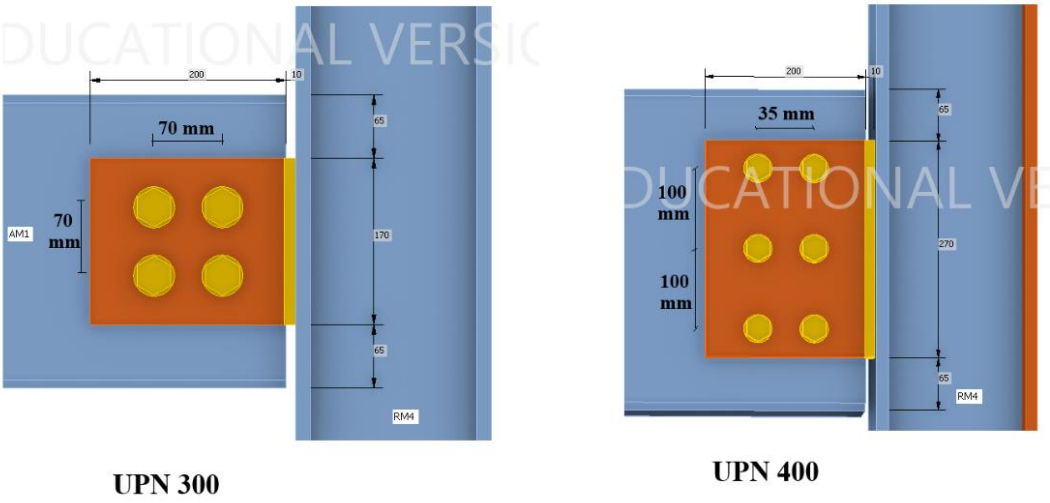


Figure 5. simple support Connection type for UPN beam.

2.3 Mesh

Mesh generation was carried out using IDEA StatiCa's automatic meshing settings, which refine the mesh based on geometric complexity and stress concentrations. The element size varied from 10 mm to 25 mm, with finer meshes near load application areas, stiffeners, and welds. Manual meshing was initially tested, and results were found to be very close to those from automatic meshing; thus, the automatic settings were adopted to save time and resources without compromising accuracy.

3 NUMERICAL RESULT

All the models in this paper have been done using IDEA Statica Software. and the objective of the paper is to study the effect of the stiffeners on the UPN beams when the eccentric loads are applied. The UPN section is asymmetrical with respect to the axis of the vertical element suffers from the problem of lateral torsion even if vertical loads are applied due to the mentioned asymmetry. And this section has horizontal deflection under vertical load and the stiffeners must have a positive role in the beam performance. The numerical study has two groups based on the height of the beam and each group have 3 cases and 6 models with a total number of 12 model. the cases will be shown below:

Case: P-UPN-300-235:

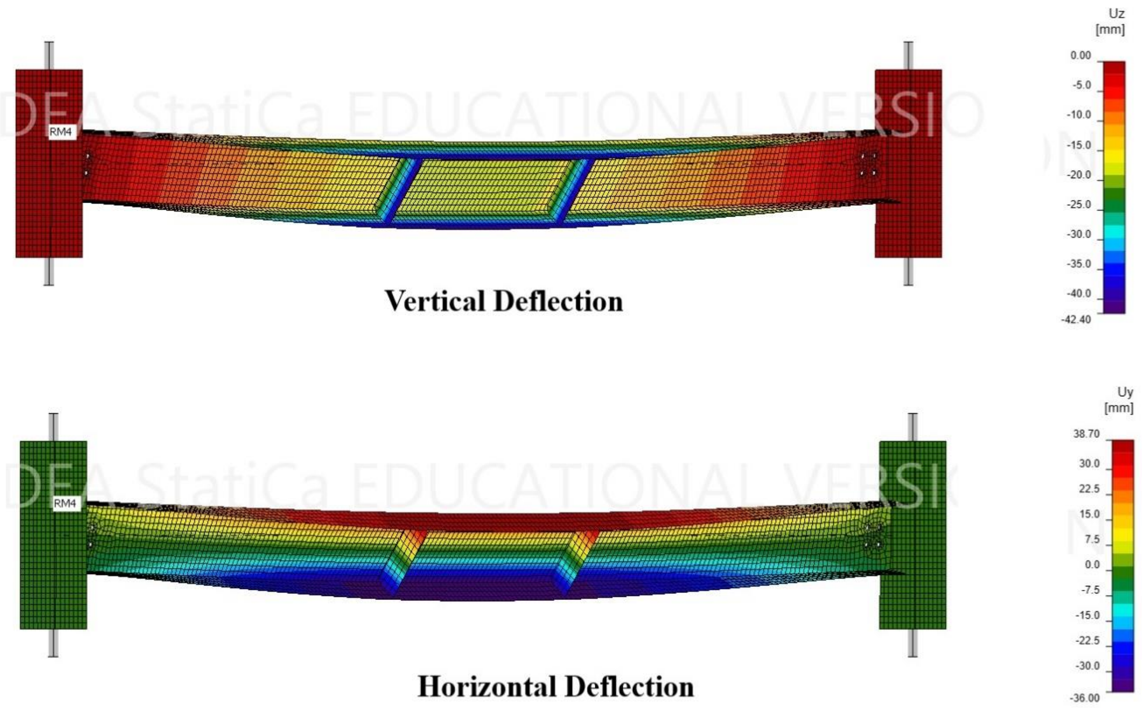


Figure 6. Deflections for Case (P-UPN-300-235) at Load P=40 kN.

The applied loads, the deflections and the equivalent Stress for the case (P-UPN-300-235) are showed in the table below:

Table 3. Results of case (P-UPN-300-235).

Unstiffened						Stiffened					
Load (kN)	Deflection		Stress б (MPa)			Load (kN)	Deflection		Stress б (MPa)		
	Uz (mm)	Uy (mm)	Top Flange	Web	Bottom Flange		Uz (mm)	Uy (mm)	Top Flange	Web	Bottom Flange
0	0	0	0	0	0	0	0	0	0	0	0
10	10.4	9.1	87.6	137.6	75.2	10	10.1	8.9	72.8	137.3	75
20	20.8	18.3	175.3	235	150.6	20	20.1	17.8	145.7	235	150.1
30	31.5	27.7	235	235.3	226.7	30	30.4	27.1	219.3	235.3	226
40	44.3	40.1	235.2	236.1	235.1	40	42.4	38.6	235.1	236.1	235.1
50	73.2	69.6	235.8	238.1	235.2	50	63.9	61.2	235.2	238	235.2
54	134.2	106.9	237.2	241	235.7	54	90.8	89.1	235.5	239.6	235.4
55	201.3	197.7	238.7	244.5	236.4	55	106.9	105.9	235.7	240.7	235.6

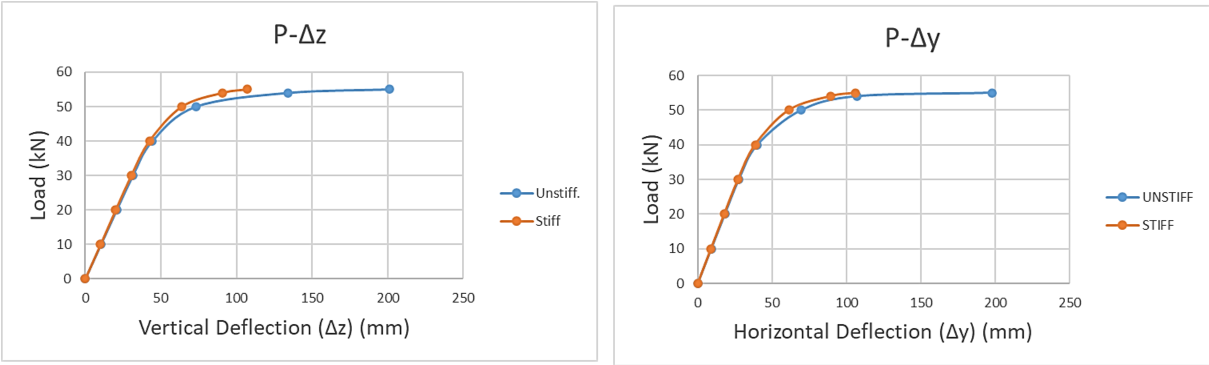


Figure 7. P-Δ Graphs for Case (P-UPN-300-235).

From Table 3, it can be seen that in the case (P-UPN-300-235), both the unstiffened and stiffened models reached the yield strength at the same load 20kN.Additionally, at the load 55kN, the vertical deflection for the unstiffened model was 201.3mm, while for the stiffened model it was 106.9mm, so there is a decrease by 47%. Likewise, the horizontal deflection at the load 55kN for the unstiffened model was 197.7mm, and for the stiffened model, it was 105.9mm, so there is a decrease by 46%. Moreover, the ratio of elastic to plastic deflection for the vertical deflection in the unstiffened beam was 10%, while for the stiffened beam, it increased to 19%, so there an increase by 9%. For the horizontal deflection, the ratio of elastic to plastic deflection was 9% for the unstiffened beam and 17% for the stiffened beam, so there an increase by 7%. This confirms that the stiffeners positively impact the beam's deflection.

Case: P-UPN-300-275

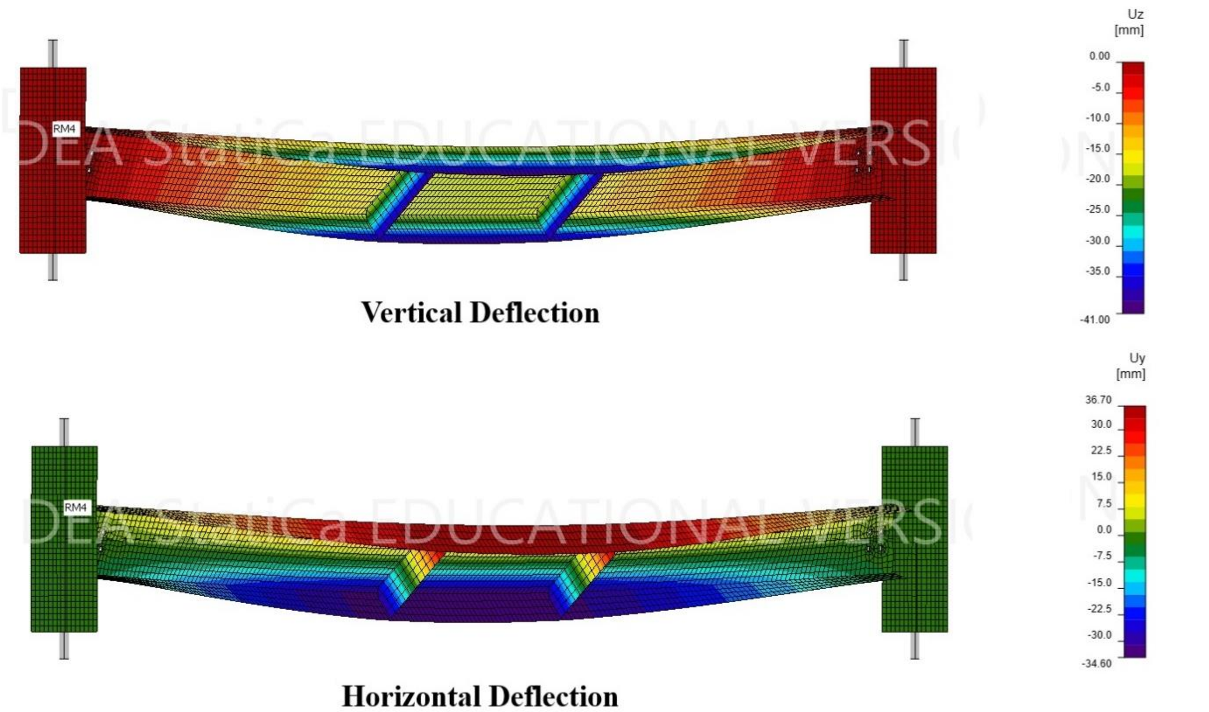
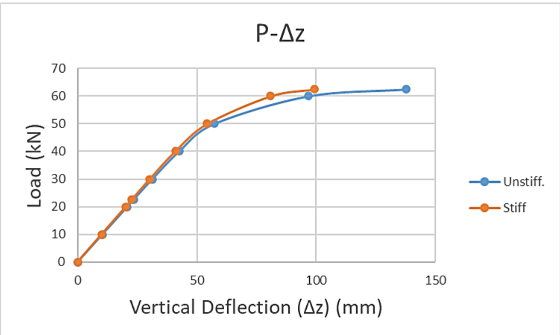


Figure 8. Deflections for Case (P-UPN-300-275) at Load P=40 kN.

The applied loads, the deflections and the equivalent Stress for the case (P-UPN-300-275) are showed in the table below:

Table 4. Results of case (P-UPN-300-275).

Unstiffened						Stiffened					
Load (kN)	Deflection		Stress б (MPa)			Load (kN)	Deflection		Stress б (MPa)		
	Uz (mm)	Uy (mm)	Top Flange	Web	Bottom Flange		Uz (mm)	Uy (mm)	Top Flange	Web	Bottom Flange
0	0	0	0	0	0	0	0	0	0	0	0
10	10.4	9.1	87.6	137.9	75.1	10	10	8.9	72.7	137.6	74.9
20	20.8	18.2	175.1	259.2	150.2	20	20.1	17.8	145.3	258.9	149.8
22.5	23.4	20.5	197	275	169	22.6	22.7	20.1	164.3	275	169.3
30	31.3	27.5	262.8	275.2	225.6	30	30.2	26.8	218.3	275.2	225
40	42.5	37.7	275.1	275.6	275	40	40.9	36.7	275	275.6	275
50	57.3	52.5	275.3	276.8	275.1	50	54.3	50	275.1	276.8	275.1
60	96.7	92.6	276.2	279.1	275.3	60	80.9	78	275.3	278.9	275.3
62.5	137.8	134.7	277.1	282	275.7	62.5	99.3	97.6	275.5	280.5	275.4



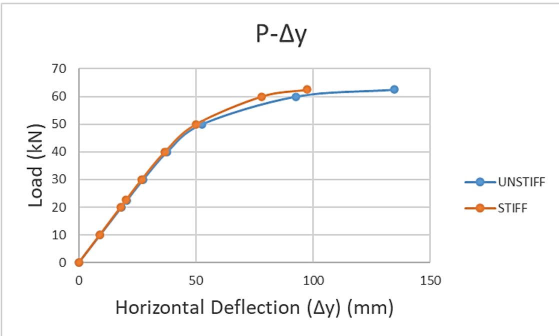


Figure 9. P-Δ Graphs for Case (P-UPN-300-275).

From Table 4, it can be seen that in the case (P-UPN-300-275), the unstiffened model reached the yield strength at the load 22.5kN and stiffened models reached the yield strength at the load 22.6kN. So, both the models reached the yield strength at the same load. Additionally, at the load 62.5kN, the vertical deflection for the unstiffened model was 137.8mm, while for the stiffened model it was 99.3mm, so there is a decrease by 28%. Likewise, the horizontal deflection at the load 62.5kN for the unstiffened model was 134.7mm, and for the stiffened model, it was 97.6mm, so there is a decrease by 28%. Moreover, the ratio of elastic to plastic deflection for the vertical deflection in the unstiffened beam was 17%, while for the stiffened beam, it increased to 23%, so there an increase by 6%. For the horizontal deflection, the ratio of elastic to plastic deflection was 15% for the unstiffened beam and 21% for the stiffened beam, so there an increase by 6%. This confirms that the stiffeners positively impact the beam's deflection.

Case: P-UPN-300-355

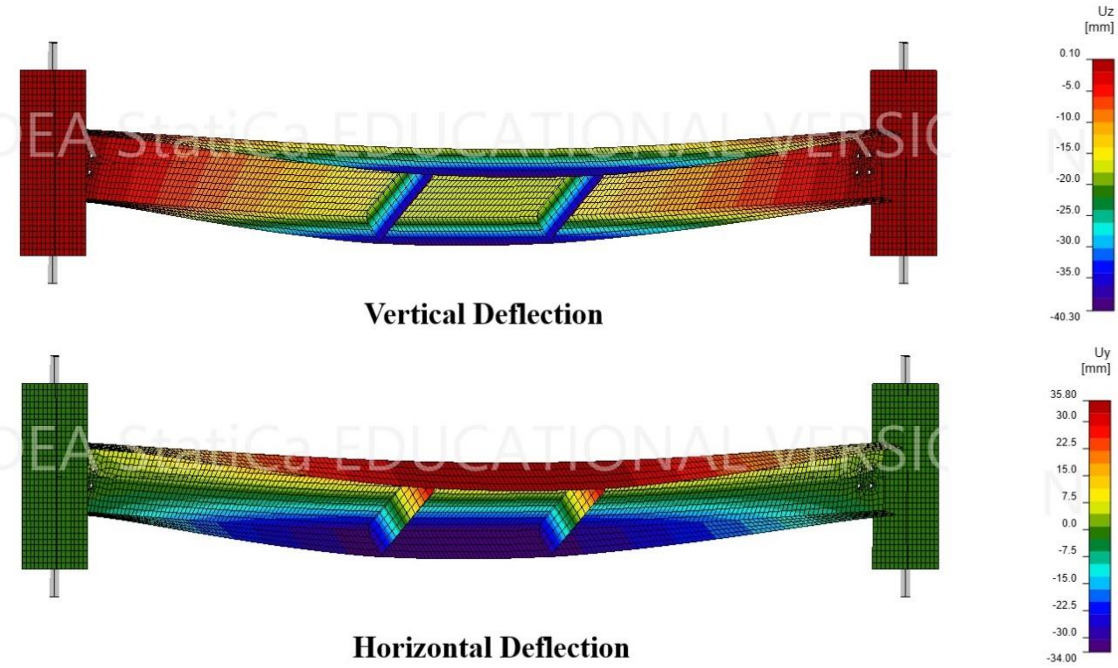


Figure 10. Deflections for Case (P-UPN-300-355) at Load P=40 kN.

The applied loads, the deflections and the equivalent Stress for the case (P-UPN-300-355) are showed in the table below:

Table 5. Results of case (P-UPN-300-355).

Unstiffened						Stiffened					
	Deflection		Stress б (MPa)				Deflection		Stress б (MPa)		
Load (kN)	Uz (mm)	Uy (mm)	Top Flange	Web	Bottom Flange	Load (kN)	Uz (mm)	Uy (mm)	Top Flange	Web	Bottom Flange
0	0	0	0	0	0	0	0	0	0	0	0
10	10.4	9.1	87.5	138.1	75	10	10	8.9	72.6	137.8	74.7
20	20.7	18.2	175	276.3	149.9	20	20	17.8	145.1	275.7	149.5
29	30.1	26.4	253.5	355	217.2	29	29.1	25.8	210.8	355	217.2
30	31.1	27.3	262.6	355.1	255	30	30.1	26.7	217.8	355.1	224.4
40	41.7	36.6	349.2	355.3	300.5	40	40.3	35.8	290.8	355.3	299.6
50	52.8	46.7	355.1	355.7	355	50	50.9	45.5	355	355.7	355
60	66	59.7	355.2	356.6	355.1	60	63.2	57.5	355.1	356.6	355.1
70	87	81.3	355.7	358.3	355.2	70	80.4	75.3	355.2	358.2	355.2
76	114.5	109.9	356.3	360.8	355.4	76	98.9	95.4	355.3	360.3	355.3

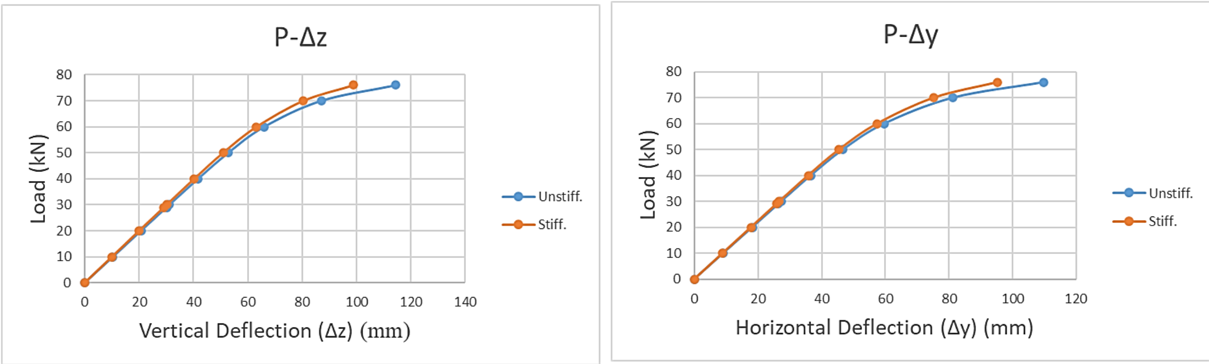


Figure 11. P-Δ Graphs for Case (P-UPN-300-355).

From Table 5, it can be seen that in the case (P-UPN-300-355), both the unstiffened and stiffened models reached the yield strength at the same load 29kN. Additionally, at the load 76kN, the vertical deflection for the unstiffened model was 114.5mm, while for the stiffened model it was 98.9mm, so there is a decrease by 14%. Likewise, the horizontal deflection at the load 76kN for the unstiffened model was 109.9mm, and for the stiffened model, it was 95.4mm, so there is a decrease by 13%. Moreover, the ratio of elastic to plastic deflection for the vertical deflection in the unstiffened beam was 26%, while for the stiffened beam, it increased to 29%, so there an increase by 3%. For the horizontal deflection, the ratio of elastic to plastic deflection was 24% for the unstiffened beam and 27% for the stiffened beam, so there an increase by 3%. This confirms that the stiffeners positively impact the beam's deflection.

Case: P-UPN-400-235

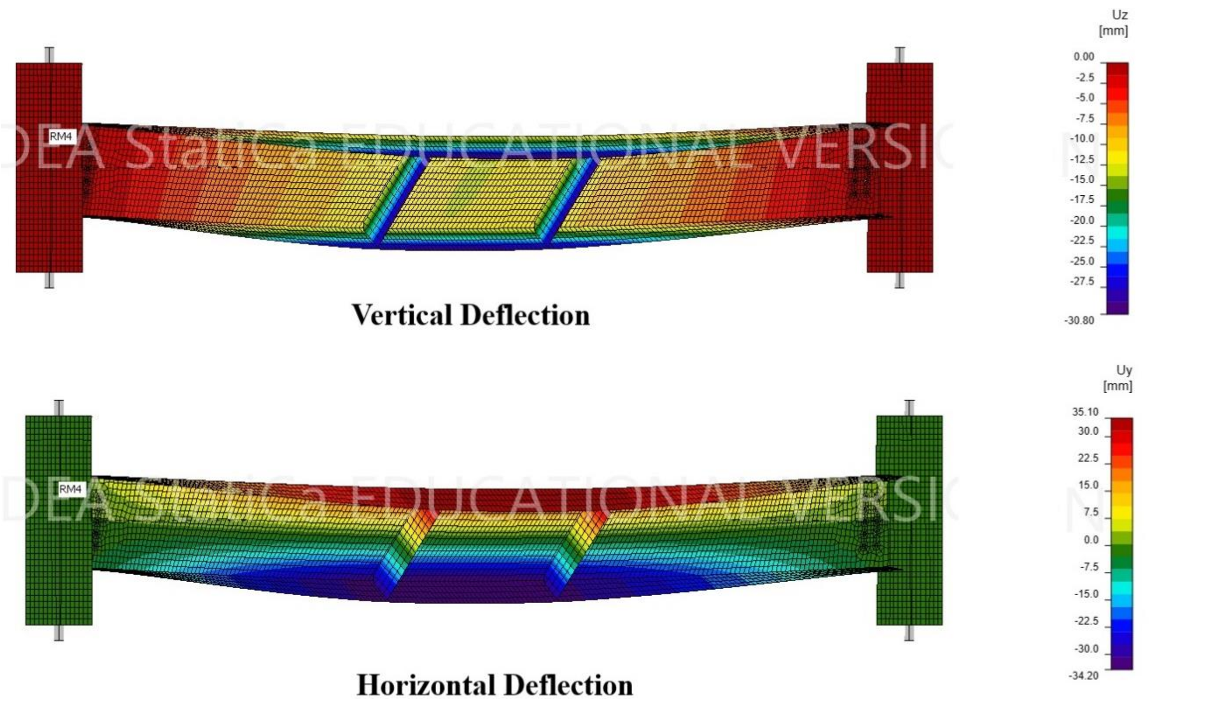
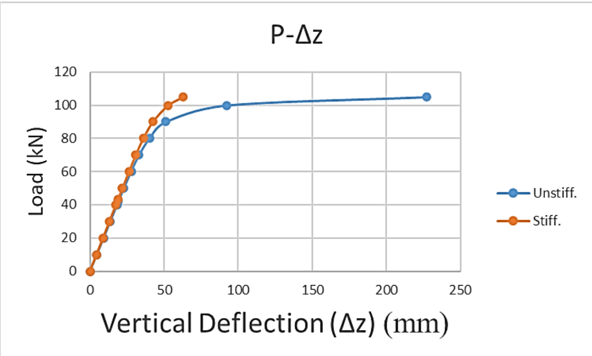


Figure 12. Deflections for Case (P-UPN-400-235) at Load P=70 kN.

The applied loads, the deflections and the equivalent Stress for the case (P-UPN-400-235) are showed in the table below:

Table 6. Results of case (P-UPN-400-235).

Unstiffened						Stiffened					
Load (kN)	Deflection		Stress б (MPa)			Load (kN)	Deflection		Stress б (MPa)		
	Uz (mm)	Uy (mm)	Top Flange	Web	Bottom Flange		Uz (mm)	Uy (mm)	Top Flange	Web	Bottom Flange
0	0	0	0	0	0	0	0	0	0	0	0
10	4.6	5	61.8	64.3	35.8	10	4.4	4.9	35.2	63.9	35.9
20	9.2	10.1	123.6	128.6	71.7	20	8.7	9.9	70.4	127.8	71.7
30	13.7	15.1	185.3	192.9	107.5	30	13.1	14.8	105.6	191.7	107.6
40	18.3	20.2	230.2	228.8	143.4	40	17.4	19.8	140.8	228.1	143.4
42	19.2	21.2	235	233	150.5	43.1	18.8	21.3	151.8	235	154.6
50	22.9	25.3	235.1	235.1	179.4	50	21.8	24.7	176.1	235.1	179.4
60	27.8	30.7	235.1	235.3	216.1	60	26.3	29.8	211.6	235.2	215.7
70	33.1	36.7	235.5	235.5	235	70	30.8	35	220.4	235.5	235
80	40.2	44.5	236	236	235.1	80	35.9	40.9	235.1	235.8	235.1
90	51.3	55.9	237.1	237.2	235.1	90	42.3	48.3	235.1	236.3	235.1
100	92.3	89.3	242.6	244.4	235.6	100	52.6	60.2	235.3	237	235.3
105	227.1	198.3	260.1	267	237.2	105	62.9	71.9	235.5	237.6	235.5



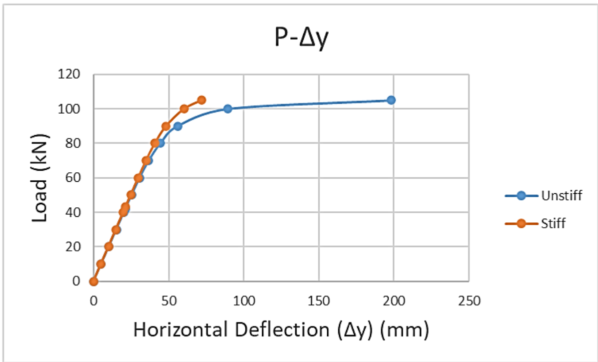


Figure 13. P-Δ Graphs for Case (P-UPN-400-235).

From Table 6, it can be seen that in the case (P-UPN-400-235), the unstiffened model reached the yield strength at the load 42kN and stiffened models reached the yield strength at the load 43.1kN. So, there is an increasing percentage by (3%). Additionally, at the load 105kN, the vertical deflection for the unstiffened model was 227mm, while for the stiffened model it was 62.9mm, so there is a decrease by 72%. Likewise, the horizontal deflection at the load 105kN for the unstiffened model was 198.3mm, and for the stiffened model, it was 71.9mm, so there is a decrease by 64%. Moreover, the ratio of elastic to plastic deflection for the vertical deflection in the unstiffened beam was 8%, while for the stiffened beam, it increased to 30%, so there an increase by 22%. For the horizontal deflection, the ratio of elastic to plastic deflection was 11% for the unstiffened beam and 30% for the stiffened beam, so there an increase by 19%. This confirms that the stiffeners positively impact the beam's deflection.

Case: P-UPN400-275

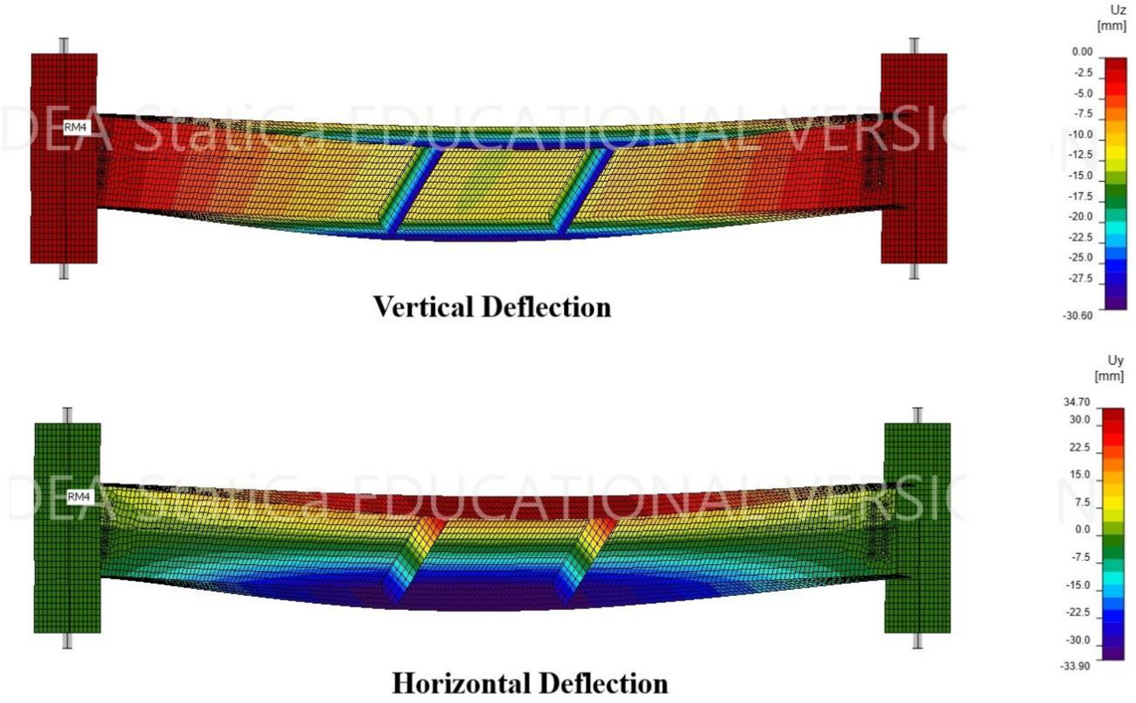


Figure 14. Deflections for Case (P-UPN-400-275) at Load P=70 kN.

The applied loads, the deflections and the equivalent Stress for the case (P-UPN-400-275) are showed in the table below:

Table 7. Results of case (P-UPN-400-275).

Unstiffened						**Stiffened**					
Load (kN)	**Deflection**		**Stress б (MPa)**			**Load (kN)**	**Deflection**		**Stress б (MPa)**		
	Uz (mm)	**Uy (mm)**	**Top Flange**	**Web**	**Bottom Flange**		**Uz (mm)**	**Uy (mm)**	**Top Flange**	**Web**	**Bottom Flange**
0	0	0	0	0	0	0	0	0	0	0	0
10	4.6	5	61.8	64.3	35.7	10	4.3	4.9	35.1	63.9	35.8
20	9.1	10.1	123.6	128.7	71.5	20	8.7	9.9	70.3	127.9	71.5
30	13.7	15.1	185.4	193	107.2	30	13	14.8	105.4	191.8	107.3
40	18.3	20.2	247.2	247.8	143	40	17.4	19.7	140.5	247.1	143.1
49.2	22.5	24.8	275	273.6	175.9	49.2	21.4	24.3	172.9	273.2	176
50	22.8	25.2	275	274.8	178.8	50	21.8	24.7	175.7	274.4	178.9
50.4	23.1	25.4	275	275.1	180.4	50.4	21.9	24.9	177.2	275	180.5
60	27.5	30.4	275.1	275.2	214.8	60	26.1	29.6	210.9	275.2	214.9
70	32.3	35.7	275.3	275.3	251.5	70	30.6	34.7	246.3	275.3	251.1
80	37.6	41.6	275.5	275.5	275	80	35.1	39.9	254.9	275.5	275
90	44.1	48.8	275.9	276	275.1	90	40	45.6	273.4	275.8	275
100	53	58.4	276.8	276.8	275.1	100	45.7	52.2	275.1	276.2	275.1
110	69.9	74.2	278.6	279	275.2	110	53.3	60.9	275.2	276.8	275.2
120	151.1	136.4	290.2	294.5	276.1	120	66.6	76.2	275.4	277.1	275.4

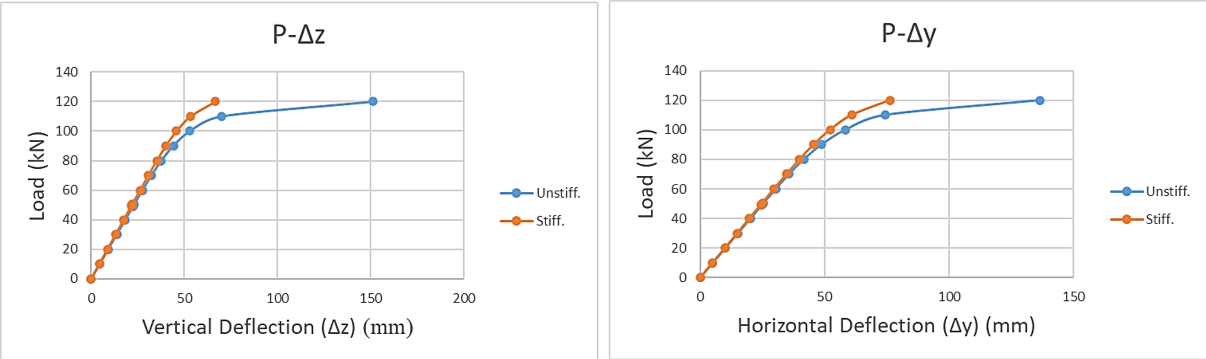


Figure 15. P-Δ Graphs for Case (P-UPN-400-275).

From Table 7, it can be seen that in the case (P-UPN-400-275), the unstiffened model reached the yield strength at the load 49.2kN and stiffened models reached the yield strength at the load 50.4kN. So, there is an increasing percentage by (2.5%). Additionally, at the load 120kN, the vertical deflection for the unstiffened model was 151.1mm, while for the stiffened model it was 66.6mm, so there is a decrease by 56%. Likewise, the horizontal deflection at the load 120kN for the unstiffened model was 136.4mm, and for the stiffened model, it was 76.2mm, so there is a decrease by 44%. Moreover, the ratio of elastic to plastic deflection for the vertical deflection in the unstiffened beam was 15%, while for the stiffened beam, it increased to 33%, so there an increase by 18%. For the horizontal deflection, the ratio of elastic to plastic deflection was 18% for the unstiffened beam and 33% for the stiffened beam, so there an increase by 15%. This confirms that the stiffeners positively impact the beam's deflection

Case: P-UPN-400-355

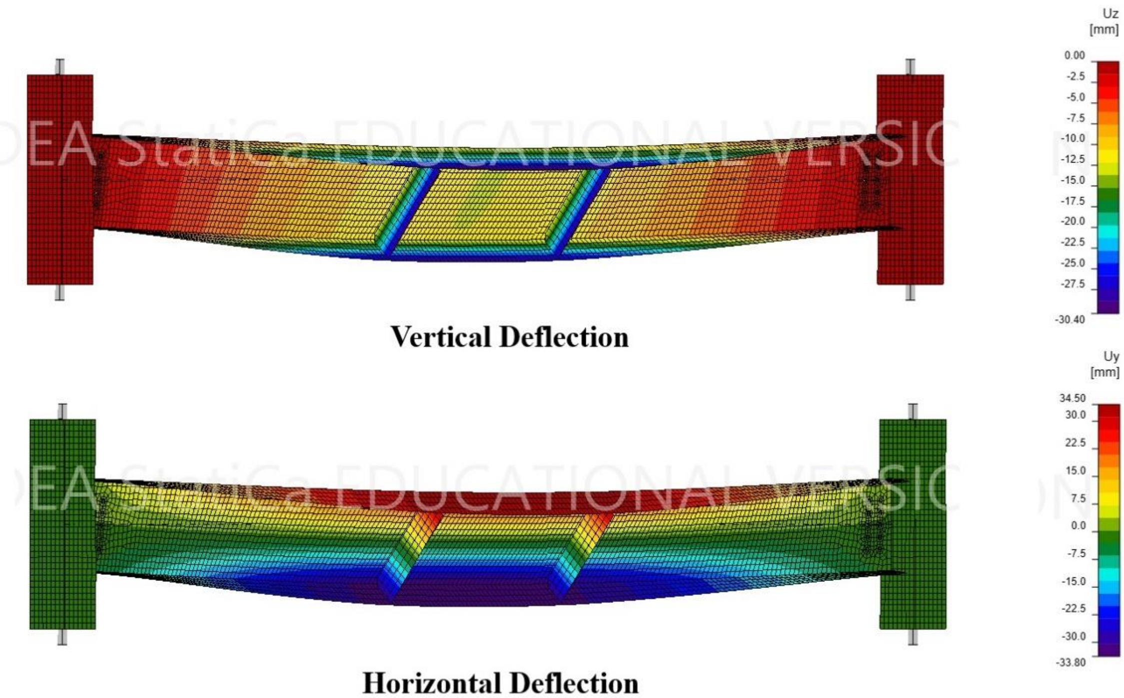


Figure 16. Deflections for Case (P-UPN-400-355) at Load P=70 kN.

The applied loads, the deflections and the equivalent Stress for the case (P-UPN-400-355) are showed in the table below:

Table 8. Results of case (P-UPN-400-355).

Unstiffened						Stiffened					
Load (kN)	Deflection		Stress б (MPa)			Load (kN)	Deflection		Stress б (MPa)		
	Uz (mm)	Uy (mm)	Top Flange	Web	Bottom Flange		Uz (mm)	Uy (mm)	Top Flange	Web	Bottom Flange
0	0	0	0	0	0	0	0	0	0	0	0
10	4.6	5	61.8	64.4	35.7	10	4.3	4.9	35.1	64	35.7
20	9.1	10.1	123.6	128.7	71.4	20	8.7	9.9	70.2	127.9	71.4
30	13.7	15.1	185.5	193.1	107.1	30	13	14.8	105.2	191.9	107.1
40	18.2	20.1	247.3	257.4	142.8	40	17.4	19.7	140.3	255.8	142.9
50	22.8	25.2	309.1	315.2	178.5	50	21.7	24.6	175.4	314.3	178.6
60	27.4	30.2	346.6	344.5	214.2	60	26.1	29.6	210.5	343.4	214.4
63.4	31.9	28.9	355	353.1	226.4	65.1	28.3	32.1	228.4	355	232.6
70	32	35.3	355.1	355.1	250	70	30.4	34.5	245.7	355.1	250.2
80	36.6	40.5	355.2	355.2	286.2	80	34.8	39.5	281	355.2	286.2
90	41.5	45.9	355.4	355.4	322.9	90	39.3	44.6	316.4	355.4	322.5
100	46.6	51.6	355.6	355.6	355	100	43.8	49.7	323.9	355.6	319.6
110	52.6	58.2	355.9	356	355	110	48.5	55.2	340.2	355.8	355
120	59.8	66.3	356.4	356.5	355.1	120	53.6	61.1	355.1	356.1	355.1
130	69.4	76.5	357.3	357.4	355.1	130	59.7	68.1	355.2	356.6	355.1
140	85.4	91.6	359	359.4	355.3	140	67.1	76.6	355.2	357.2	355.2
150	131.9	129.5	365.2	367.5	355.8	150	78.1	89.3	355.4	358	355.4
155	206	185.8	375.8	381.6	356.6	155	86.9	99.4	355.6	358.7	355.6

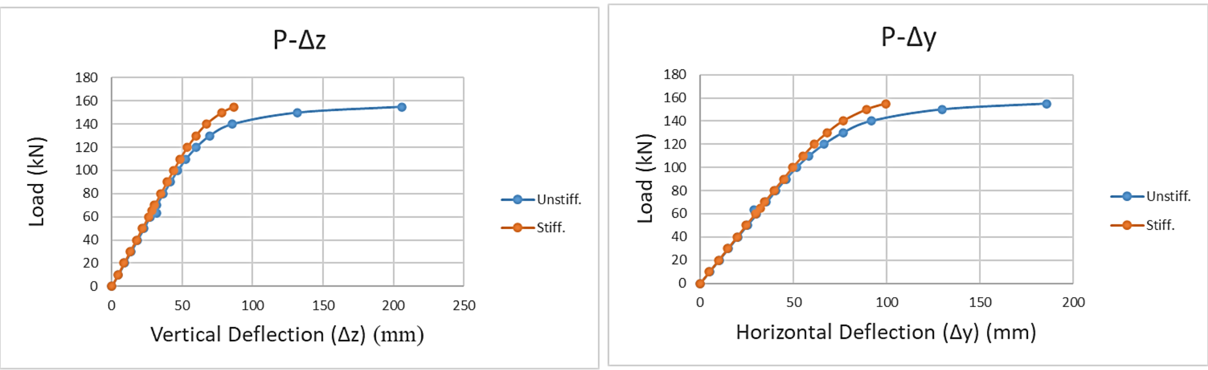


Figure 17. P-Δ Graphs for Case (P-UPN-400-355).

From Table 8, it can be seen that in the case (P-UPN-400-355), the unstiffened model reached the yield strength at the load 63.4kN and stiffened models reached the yield strength at the load 65.1kN. So, there is an increasing percentage by (3%). Additionally, at the load 155kN, the vertical deflection for the unstiffened model was 206mm, while for the stiffened model it was 86.9mm, so there is a decrease by 58%. Likewise, the horizontal deflection at the load 155kN for the unstiffened model was 185.8mm, and for the stiffened model, it was 99.4mm, so there is a decrease by 47%. Moreover, the ratio of elastic to plastic deflection for the vertical deflection in the unstiffened beam was 15%, while for the stiffened beam, it increased to 33%, so there an increase by 18%. For the horizontal deflection, the ratio of elastic to plastic deflection was 16% for the unstiffened beam and 32% for the stiffened beam, so there an increase by 16%. This confirms that the stiffeners positively impact the beam's deflection.

Based on the numerical results, it can be seen that the normal stress in the web is greater than in the flanges because the web directly resists the majority of the vertical load applied to the beam. As a result, stress tends to concentrate more in the web, leading to higher normal stress values than those observed in the flanges.

4 CONCLUSION

In this paper a numerical study was conducted using Idea Statica program to study the effect of the stiffeners on steel beams for asymmetrical section shape while Load Eccentricity is applied. A total of 6 cases was studied, a comparison between the stiffened and unstiffened beam was done to see the effect of the stiffeners. And the following conclusions was found:

- When group A and B are compared it can be seen that stiffened beams have proved to yield better displacement values compared to unstiffened ones.
- There is a similarity in elastic phase for the values of displacement between the two groups (stiffened and unstiffened).
- It can be seen that both group A and group B reach the yield strength at same loads but the effect of stiffeners was shown in minimizing the values of both vertical and horizontal deflections.
- Minimizing the values of vertical and horizontal deflections was shown even more when the height increase was applied.
- It can be stated that the use of stiffeners in case of point loads is vital, because the steel beams have a local deforming in top flange in the areas of applied load.
- In general, stiffeners have a positive role in supporting the performance of the beam, and they also have a role in preventing the local deformation under the influence of point loads, in addition it also reduces the lateral torsion.

This study confirms that stiffeners significantly improve the beam performance under eccentric loading, similar to how strategic modifications in castellated beams, as discussed by Kaveh and Shokohi, mitigate critical failure modes through lateral support. (16). Also The findings regarding the enhancement of UPN beam resistance through stiffeners are consistent with the broader understanding that local stiffening strategies can significantly delay buckling and improve load-bearing capacity, as demonstrated in previous studies [27].

From a practical perspective, this study demonstrates that incorporating stiffeners into UPN steel beams is a simple yet highly effective method for enhancing load resistance and limiting deflections—especially under eccentric loading conditions. Designers working with asymmetric profiles can consider stiffeners not only for strength but also for improving torsional behavior and serviceability performance without excessive material cost.

For future research, experimental studies are recommended to validate these numerical findings under real-world loading scenarios. And investigations into different stiffener configurations, materials, would also offer valuable insights.

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

Artificial Intelligence (AI) Contribution Statement

This manuscript was entirely written, edited, analyzed, and prepared without the assistance of any artificial intelligence (AI) tools. All content, including text, data analysis, and figures, was solely generated by the authors.

Contributions of the Authors

Ahmad Kakhia: Formal analysis, Methodology, Software, Validation, Writing – original draft, Writing – review and editing,

Esra Eylem Karataş: Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review and editing.

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