Experimental Investigation of Moment-Rotation Curves of End-Plate Connection using Sinusoidal Beam

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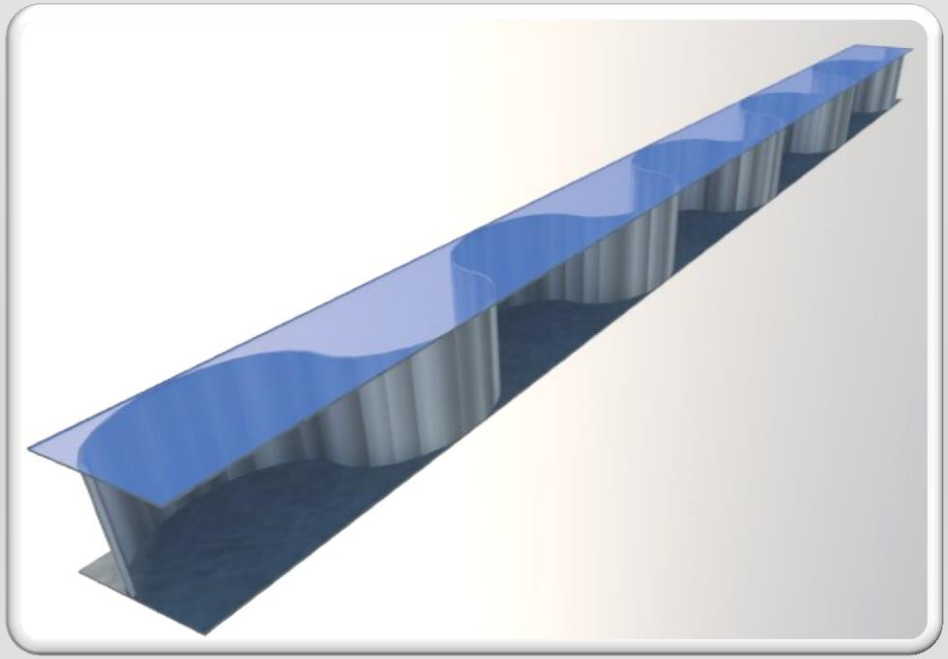


Steel Structures 2015-Dubai
16-18 November 2015

Abstract

- In this study, a new beam model called sinusoidal beam is discussed based on experimental investigation.

- The presentation exhibits the moment-rotation curves of fixed end-plate connection made from sinusoidal beams and evaluation the structural performance of sinusoidal beams.

Details

- End-plate connections are used in beam-to-column joints
- Connection dimensions are selected from the research of Coelho et al.
- This study aims to investigate the effect of the sinus angles in the web of I-beam with end-plate connection to the moment-rotation curves.
- Accordingly, moment-rotation curves are drawn for four end-plate optimum connections.

Details

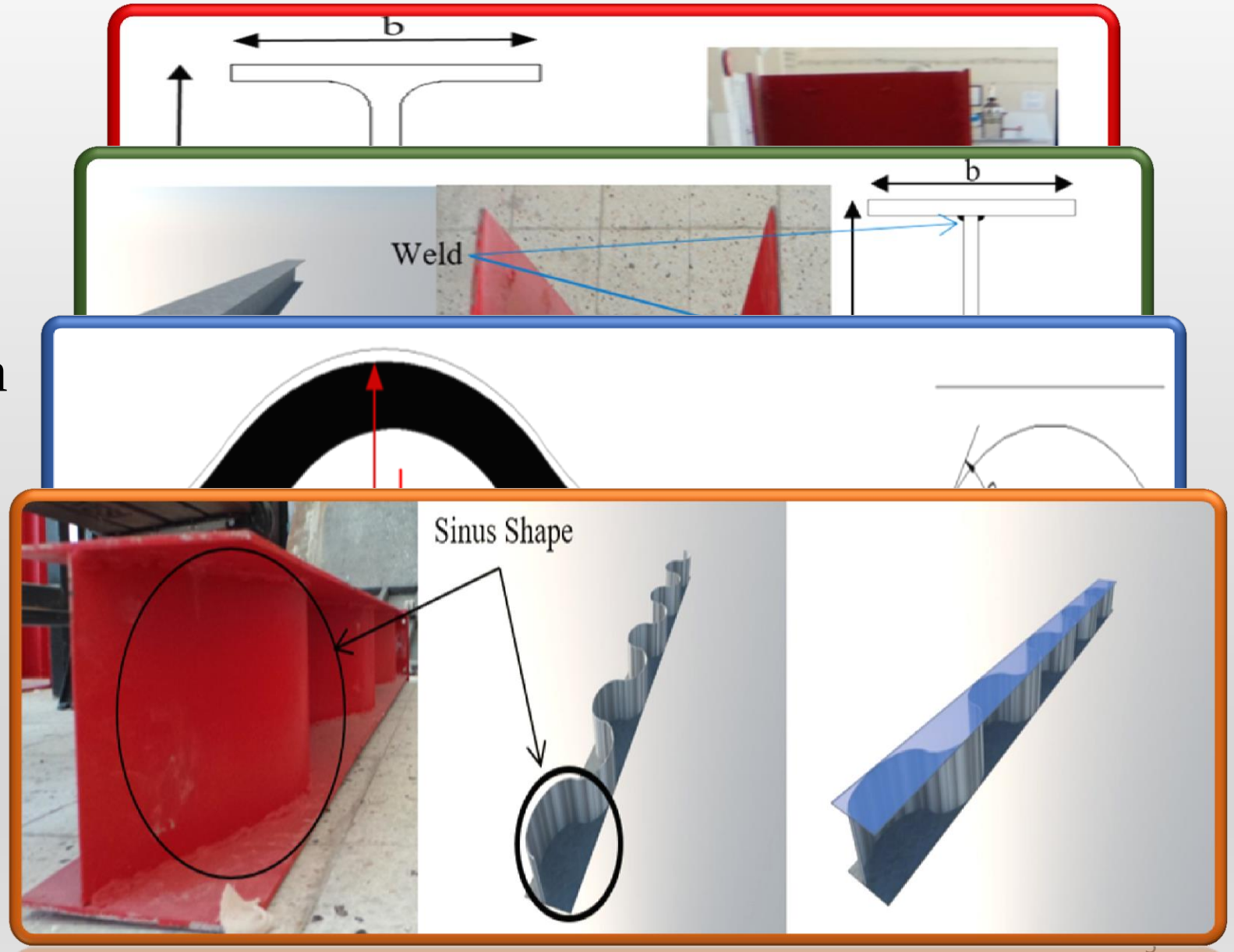
- The purpose of these experiments is to understand the effects of sinus beam connections on the end-plates.

- Among these four models,
  - two models using sinus beams,
  - one manufactured model,
  - one IPE beam model are prepared.

- The moment-rotation curves are compared and the effects of sinus beams are examined at end-plate connections

Test specimens

- Standart IPE profile
- Manufactured beam
- Sinusoidal angle/ Sinus shape



Sinusoidal Sheet Manufacturing System

- The web and flange of the sinusoidal beam have 2.5-mm and 4-mm thicknesses, respectively.
- Sheets with dimensions of 1500 × 6000 mm were first prepared
- These sheets were divided into ten and eighteen parts for the web and flange, respectively, using a cutting device.
- The cylindrical device works with three cylinders. To run 30°- and 70°-angles, the upper cylinder and two lower cylinders were made with diameters of 269.1 mm and 238.85 mm, respectively.

Sinusoidal Sheets

- After making the cylinders, the sheets were made into a sinusoidal shape inside this device. These sinusoidal sheets are shown in the Figure (right)

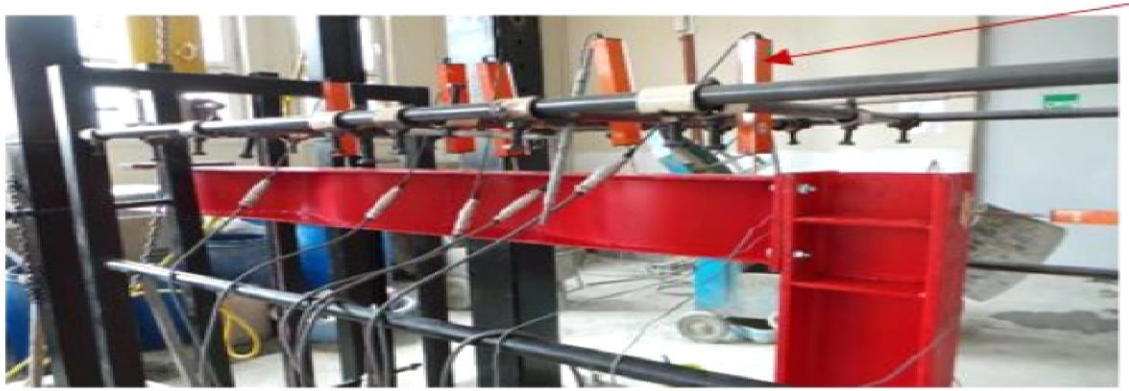
- To realize all planned lengths, because the sheet length was 1500 mm, sheets were welded by using arc welding with a continuous 45° fillet weld.

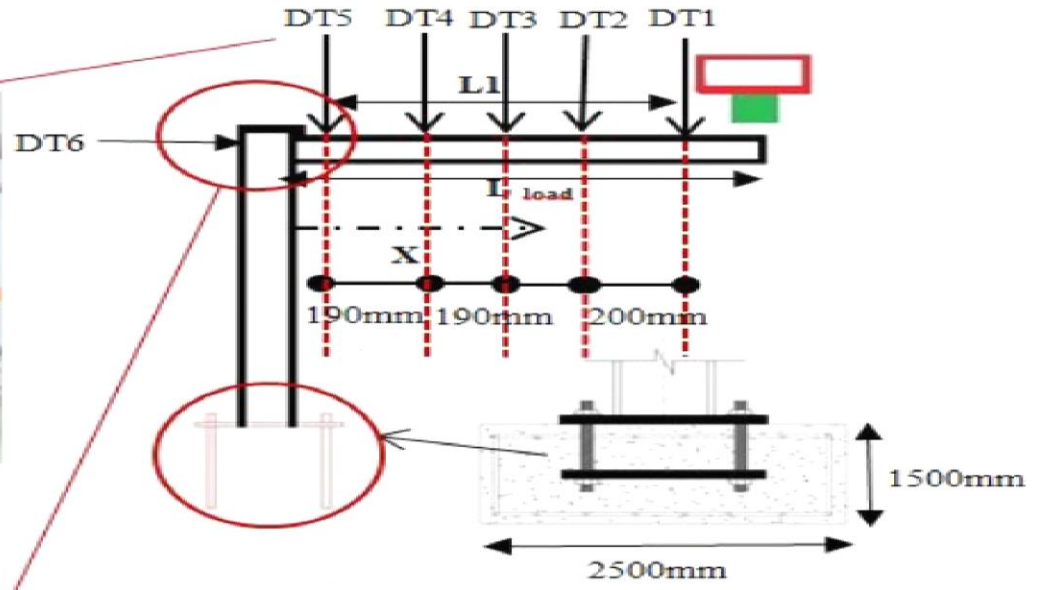
The details of the beams

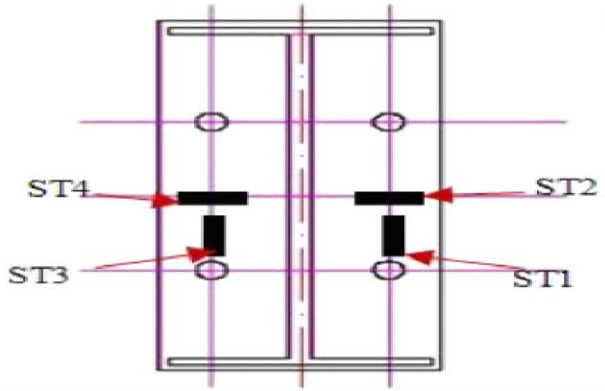
Name of model	h (mm)	b (mm)	t (mm)	s (mm)	L (mm)	Weight (kg/m)	t_p (mm)
Manufactured	160	150	4	2.5	-	15.68	8
Sinusoidal 30°					85.8	12.7	8
Sinusoidal 70°					200.2	16.57	8
IPE160	160	82	7.4	5	-	15.8	8

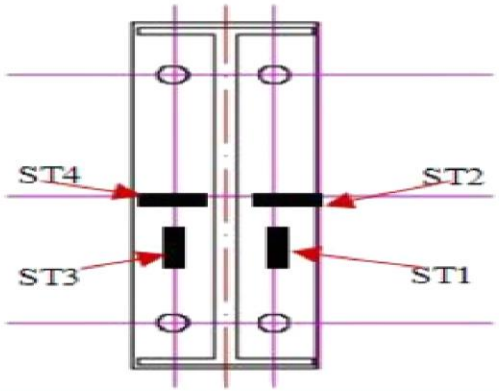
t_p: thickness of end-plate

Test instrumentation





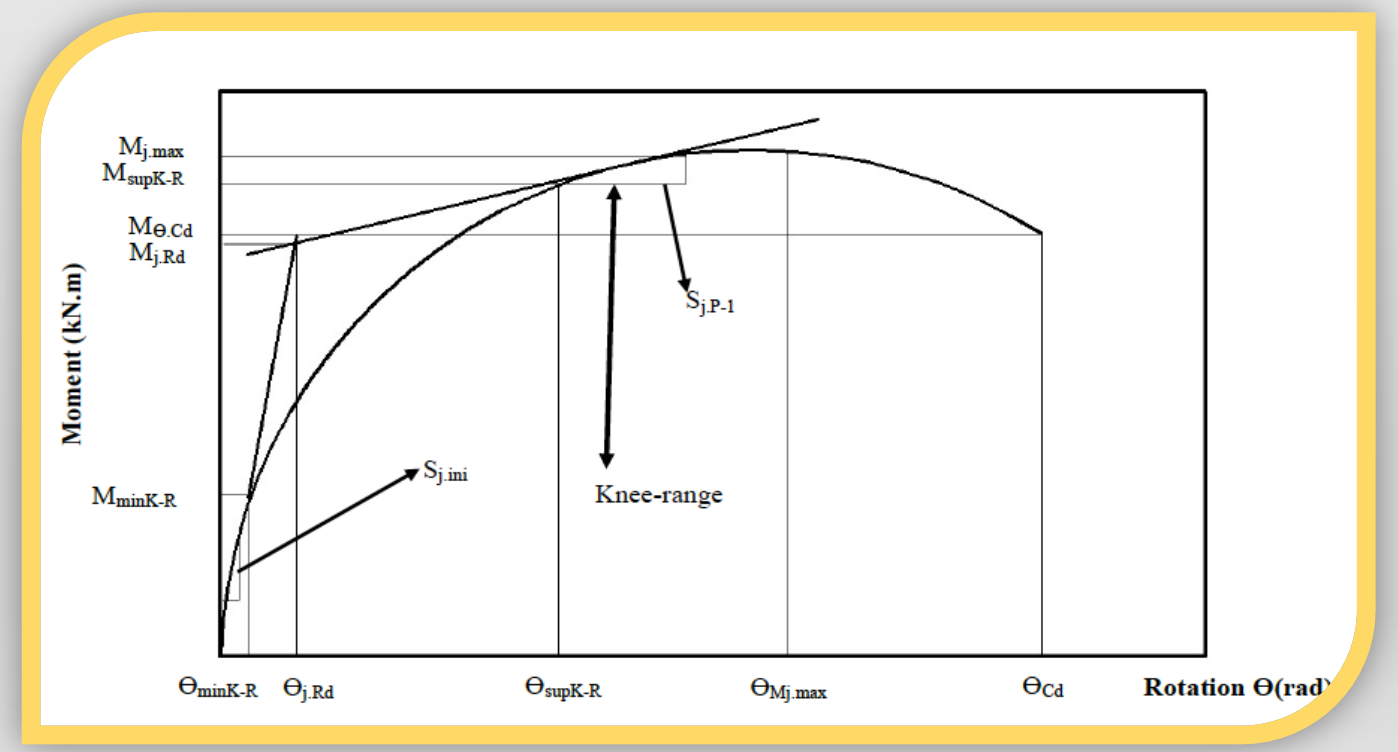




Moment-rotation curve characteristics

- The moment-rotation curve shows the behavior of the moment connections that describe the relationship between the applied moment (M) and the corresponding rotation (Θ) between the members.

- The M–Θ curve of the connection may be characterized by using the aforementioned relationships. The main features of this curve are moment resistance, rotational stiffness, and rotation capacity.



- The rotation and the bending moment (M) are predicted by using displacements of the beam as well as multiplication of the distance between the load application point and beam end bolted to the column (L_{load}), respectively:

$$M=PL_{load} \quad (1)$$

- The rotational deformation of the joint (Θ) is equal to the connection rotation. The beam rotation is approximately given by

$$\Theta=\frac{\arctan(\delta DT1-\delta DT5-\delta b.el(DT1))}{L1} \quad (2)$$

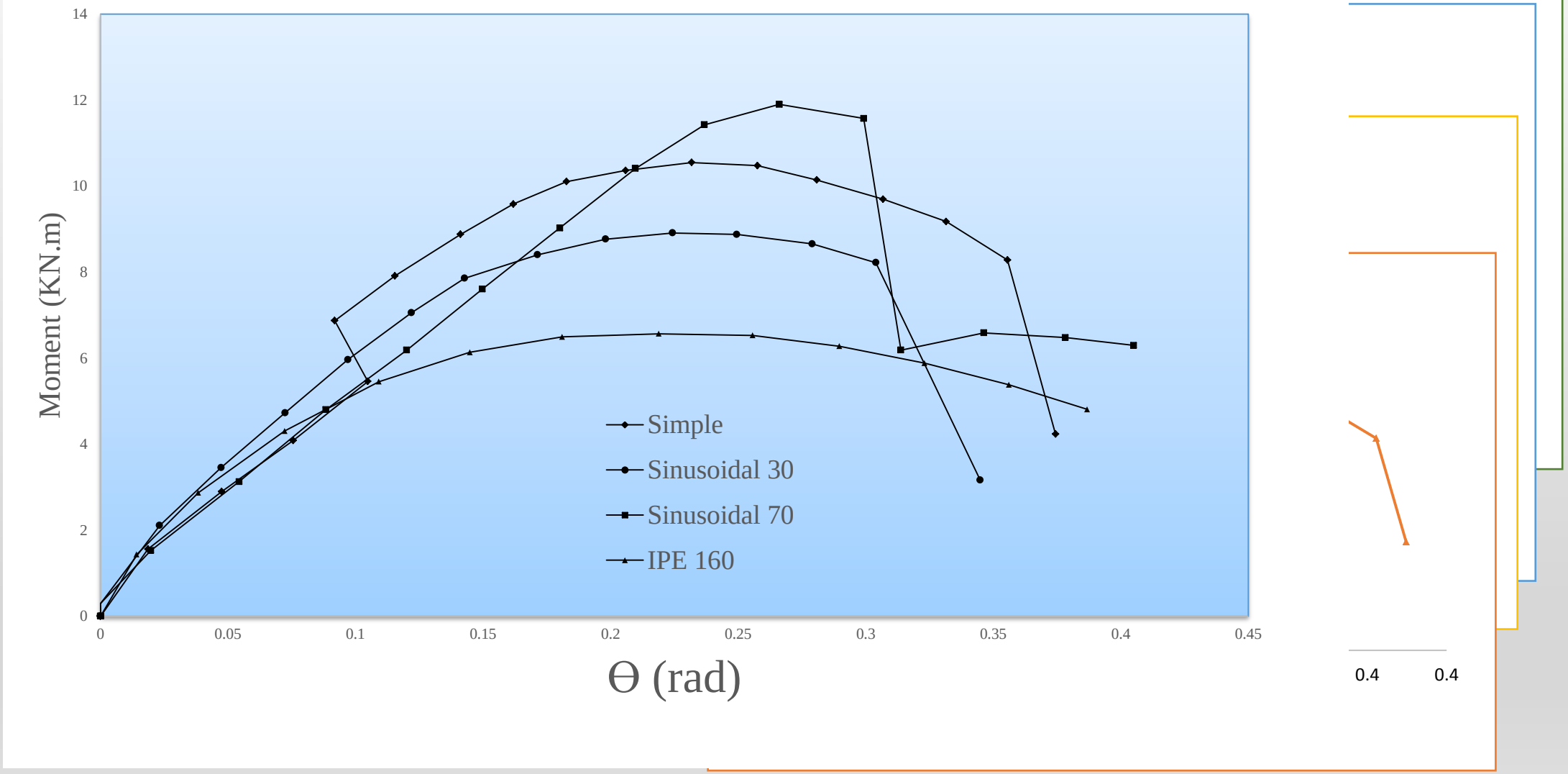
$$\delta_{b.\,el(DTi)} = \left(-\frac{P}{EI}\right)\left(\left(\frac{X^3{}_{DTi}}{6}\right)-\left(\frac{L_{load}X^2{}_{DTi}}{2}\right)\right) \quad (3)$$

Test results

- The table is obtained from the moment-rotation curves of the tested systems.

Specimens	Resistance (KN.m)				Stiffness (KN m/rad)			Rotation (rad)				
	KR (knee-range)	$M_{j.Rd}$	$M_{j.\ max}$	$M_{\Theta Cd}$	$S_{j.ini}$	$S_{j.p-l}$	$S_{j.ini}/S_{j.p-l}$	$\Theta_{M.Rd}$	$\Theta_{Min.K.R}$	$\Theta_{Msup.k.R}$	$\Theta_{Mj.max}$	Θ_{Cd}
Manufactured	1.56-9.58	8.88	10.55	8.28	1.60	0.36	4.44	0.14	0.02	0.16	0.23	0.36
Sinusoidal 30˚	3.45-7.86	7.06	8.91	8.22	1.73	0.45	3.84	0.09	0.05	0.14	0.25	0.30
Sinusoidal 70°	4.8-11.43	9.03	11.90	11.57	1.21	0.59	2.05	0.18	0.09	0.24	0.27	0.30
IPE 160	2.87-6.14	5.45	6.57	4.573	3.09	0.43	7.18	0.08	0.04	0.15	0.22	0.39

Moment-Rotation Curves

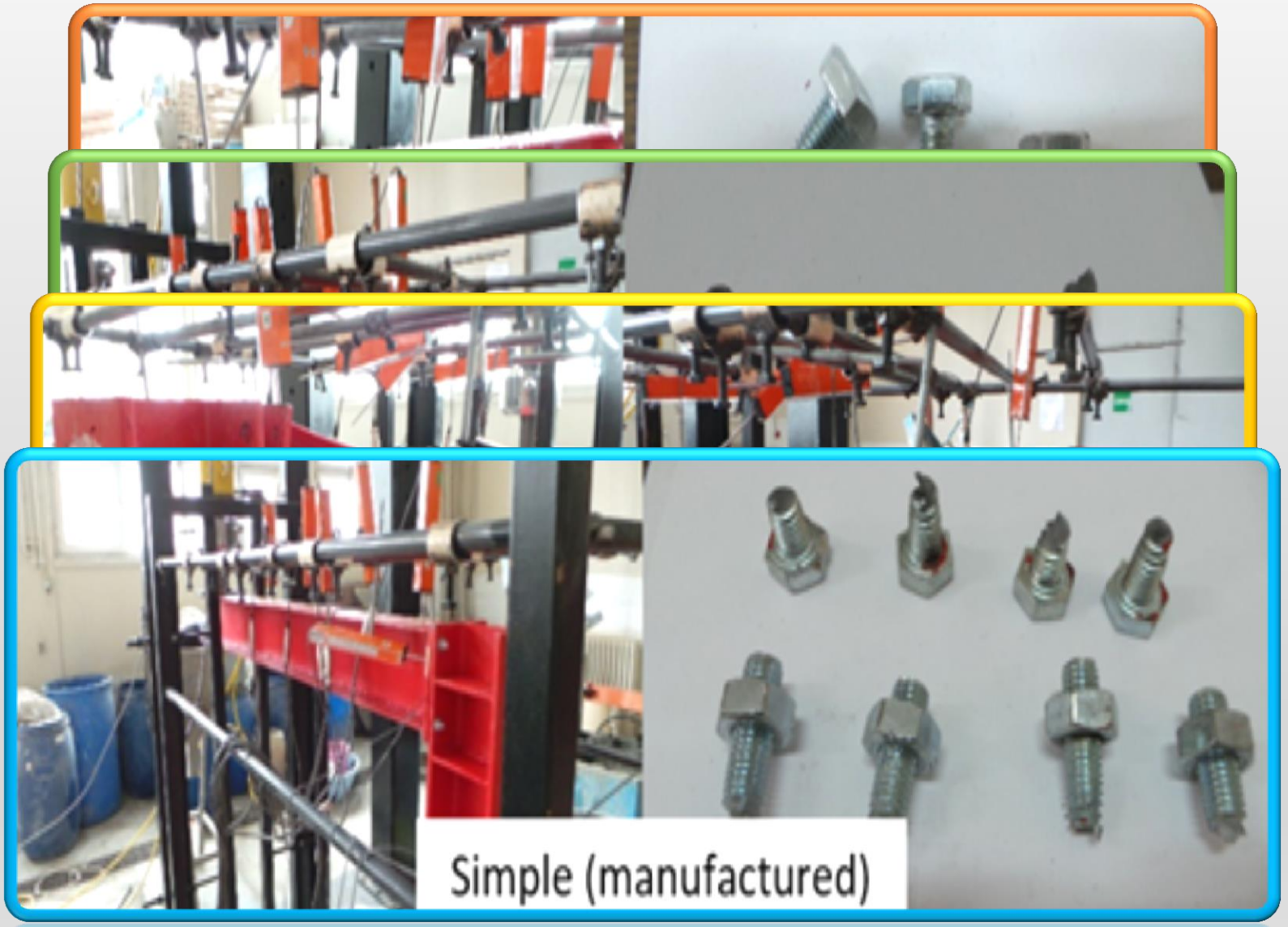


Test results

Experiment	$\Theta_{MR.d}$ (rad)	$\Theta_{Mj.max}$ (rad)	$\Theta_{C.d}$ (rad)	$\Psi_j = \frac{\Theta Cd}{\Theta MRd}$	$\Psi_{j.max.load} = \frac{\Theta Mj.max}{\Theta MRd}$	Energy Dissipated (kNmrad)
Simple	0.14	0.23	0.36	2.57	1.64	1.90
Sinusoidal 30˚	0.09	0.25	0.30	3.33	2.77	1.34
Sinusoidal 70°	0.18	0.27	0.30	1.66	1.5	1.79
IPE 160	0.08	0.22	0.39	4.87	2.75	1.28

Test specimens

- Standart IPE profile
- Sinusoidal 30º
- Sinusoidal 70º
- Manufactured beam



Conclusion

The purpose of these experiments is to understand the effects of sinus-type beam composites on end-plates and to provide data necessary to improve Eurocode 3

- The knee-range is observed for the manufactured model. The knee-range values of the manufactured model are higher than for other models. Therefore, the knee-range is increased with the increasing sinus degree of the web from 30° to 70°

- The plastic flexural resistance, maximum bending moment, and bending moment capacity are increased with the increasing sinus degree of the web. Therefore, the rotation plastic flexural resistance is increased with the increasing sinus degree of the web.

- The rate of rise of the initial stiffness to the post-limit stiffness values of the I profile is higher than in the sinus and manufactured models. The rotation at the maximum bending moment and the rotation plastic flexural resistance is increased with the increasing sinus degree of the web.

- The Ψ_j and $\Psi_{j.max.load}$ values of the sinusoidal 30° model are higher than for the manufactured and sinusoidal 70° manufactured models. Moreover, it is observed that Ψj in the IPE160 model is greater than in the manufactured, sinusoidal 30°, and sinusoidal 70° specimens.
- The $\Psi_{j.maxload}$ values of the IPE160 beam are greater than those of the sinusoidal 70° and manufactured models.
- The energy dissipation capacity values of the manufactured model are higher than for other models. Moreover, energy dissipation capacity values of the sinusoidal 70° model are higher than for the sinusoidal 30° and IPE160 models.
- Therefore, despite the fact that the ductility of a sinus beam joint is lower than for other models, the energy dissipated in sinus models is greater than in other models.

- As a result, the sinus models are better than other models for use in industry.

- All of the bolts used in the models show similar failure patterns with 45° angles. However, the number of broken bolts is four, except for the sinusoidal 70° models, which have three broken bolts.

- The failures of the bolts were obtained from the top down, as expected.

Thanks for your attention

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