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EXPERIMENTAL STUDY OF BEAMS WITH EMBOSSED WEB

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In order to reduce the weight and the material cost in the steel structures, a study on the slender sectional design has been continuously carried out. Steel beams with corrugated web have been widely used in the steel structures. The welding part between the corrugated web and the flange, however, is not straight, which makes the production costs increased. In order to compensate for this drawback, steel beam with an intaglio and embossed web (IEB) was invented by Innovation & Smart Heavy Industry Co., Ltd., South Korea. Plain plate is pressed to keep the upper and lower boundary of the web straight. This makes it possible to weld the flange and the embossed web by the automatic welding machine. In this study, four types of specimens were tested for comparison with plain H-shaped steel beam. Experimental results showed that the maximum load of the IEB specimens is about 1.3 times larger than that of the H-shaped steel beams. This is because the tension field action of embossed web significantly increased the post-buckling strength.

Keywords: Corrugated web, Tension field action, Post-buckling strength, Intaglio and embossed web.

1 INTRODUCTION

Steel is one of the representative materials that have grown along with the development of the construction industry. Among them, H-shaped steel composed of flange and web has excellent performance in a cross section and is widely used as structural steel for construction. When H-beams are used as flexural members, the flanges resist most of the bending moments and the webs resist most of the shear forces caused by the load. However, it is possible to waste material by selecting a large member during the structural design process. In order to reduce the weight and the material cost in the steel structures, a study on the slender sectional design has been continuously carried out by Kim *et al*. (2012), Lee *et al*. (2012), Hong (2015), Driver *et al*. (2006) and Elgaaly *et al*. (1996). Steel beams with corrugated web have been widely used in the steel structures. The welding part between the corrugated web and the flange, however, is not straight, which makes the production costs increased. In order to compensate for this drawback, steel beam with an intaglio and embossed web (IEB) was invented by Innovation & Smart Heavy Industry Co., Ltd., South Korea. Plain plate is pressed to keep the upper and lower boundary of the web straight. This makes it possible to weld the flange and the embossed web by the automatic welding machine. For practical application of IEB, a comparative experiment with general H - beam was carried out for various member lengths. In this paper, it is aimed to confirm the structural performance, identify the main behavior characteristics and the maximum load, and confirm the possibility of use as an economical structural member.

2 EXPERIMENT PLAN

Table 1 shows the list of specimens. The web height is 400 mm and the thickness of the web is 2.3 mm. Experimental parameters were divided into two types according to the web type: IEB with embossed web and H-beam with flat web. The span length is 4,320 mm and 7,560 mm.

Table 1. Specimen list.

No.	Specimens name	Web type	Specifications	Span (mm)
1	IEB-4	Embossed	H-400×195×2.3×12	4,320
2	IEB-7	Embossed	H-400×195×2.3×12	7,560
3	H-4	Flat	H-400×195×2.3×12	4,320
4	H-7	Flat	H-400×195×2.3×12	7,560

In this study, four types of specimens were tested for comparison between general H beam and IEB. The welded H-beams were produced by cutting and welding the steel sheets. The steel plates used for the test specimens were SM490 (flange) and SS400 (web). In the case of IEB, the web and the flange were assembled by welding after press-forming in an embossing shape.

Figure 1 and Figure 2 show the specimen details. The size of the embossing is 95 mm in width and nine mm in depth, and the interval between the embossing is 20 mm. Stiffeners are reinforced at the point of force and reaction force for the local buckling of the flange due to the concentrated load. For flat web specimens, the shape except for webs is the same as for IEB specimens.

In order to secure a pure flexural section, a force jig (1,080 mm) was installed as shown in Figure 3 and four point loading test was carried out. Based on the theoretical calculations, we set 4,320 mm as the span length to confirm the shear failure and 7,560 mm as the span length to induce flexural failure.

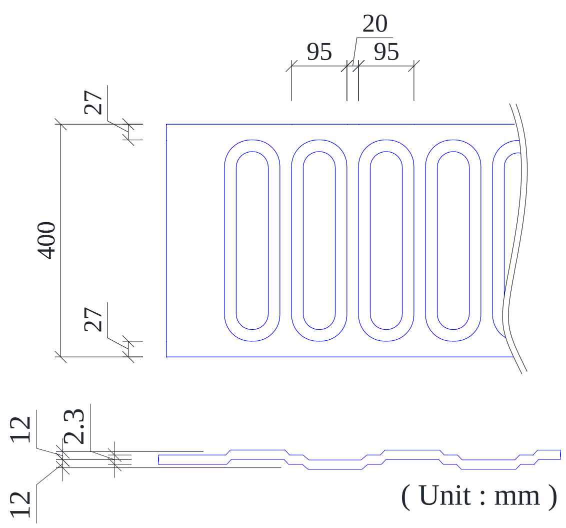

Figure 1. Embossed web detail.

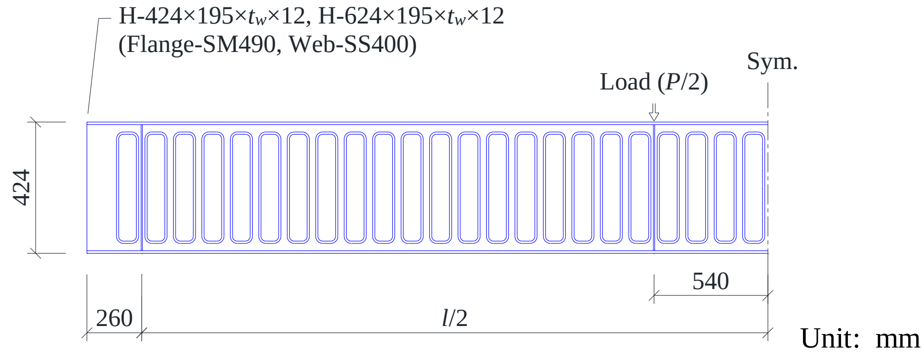

Figure 2. Elevation of IEB specimen (l = 4,320 mm and 7,560 mm).

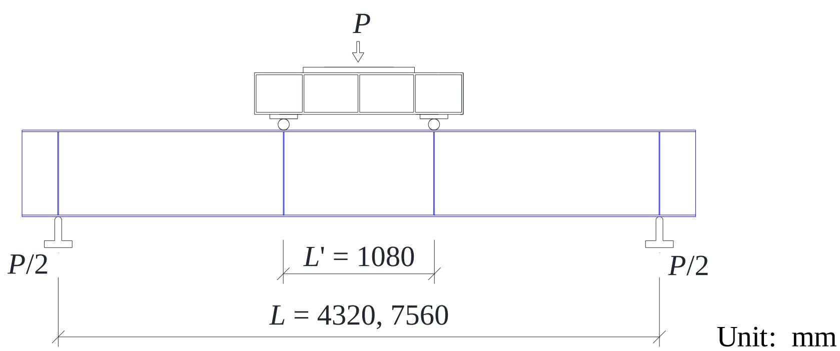

Figure 3. Specimen installation.

3 EXPERIMENT

Figure 4 shows the installation status of the specimen. On the structural frame (pedestal), the lateral supports were installed by calculating the unsupported length of the beam that can give sufficient strength to the specimen by avoiding elastic lateral buckling. Teflon was attached to the friction surface to minimize the effect of frictional force generated when the specimen contacted with the lateral support during the test. As shown in Figure 4, the two-point force is applied to the center of the member using a hinge. The progress of the experiment was controlled by the displacement control until the collapse and deformation of specimens.

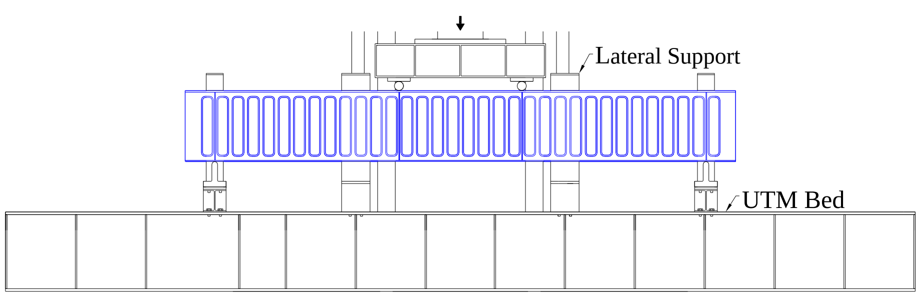

Figure 4. Specimen setup.

4 EXPERIMENT RESULT

Table 2 shows the experimental results of each specimen. P_{max} represents the maximum load. Local buckling of web occurred in IEB specimens and global buckling of web occurred in H specimens.

Table 2. Maximum load and failure mode.

No.	Specimens name	P_{max} (kN)	Failure mode
1	IEB-4	263.1	Local buckling of web
2	IEB-7	248.2	Local buckling of web
3	H-4	188.8	Global buckling of web
4	H-7	181.9	Global buckling of web

4.1 Experiment Result of IEB

Figure 5 shows the load-deflection curve for IEB specimens. The maximum load of the specimens with span lengths of 4,320 mm and 7,560 mm were 263.1 kN and 248.2 kN, respectively. The deflections at the maximum load of IEB-4 and IEB-7 were 35.4 mm and 101.8 mm. After reaching the maximum load, strength of the specimens was reduced rapidly as shown on the Figure 5. It can be said that the elastic buckling occurred in the embossing. The shear load of the IEB-4 was 70.2% (263.1 kN to 184.6 kN) of the maximum load, and the IEB-7 was 68.2% (248.2 kN to 169.4 kN) respectively. In general, the intermediate stiffeners of the corrugated webs or plate girders play a role in significantly increasing the post-buckling strength of the web through tension field action, and the embossing of this specimen seems to have same effect. Figure 6 shows the IEB-7 specimen after the experiment. There is the trace of the tension field action on the left web. After the maximum load, wrinkles occurred in the web at an angle of about 45° for each embossing from the center to the reaction force point, and a wavy curve in Figure 5 appeared after the maximum load.

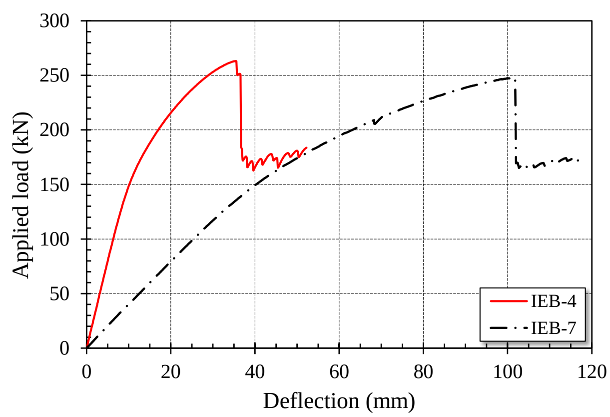

Figure 5. Load-deflection curve of IEB-4 and IEB-7 at the center the specimens.

Figure 6. Final transformation of IEB-7.

4.2 Experimental Result of H

Figure 7 shows the load-deflection curve for each H specimens. The maximum load of the specimens with span lengths of 4,320 mm and 7,560 mm were 188.8 kN and 181.9 kN, respectively. The deflection at the maximum load of H-4 and H-7 were 12.6 mm and 48.6 mm. In case of H specimens with flat web, unlike the IEB specimen, in which several wrinkles were formed sequentially due to tension field action caused by embossed web, only one wrinkle occurred on the web and the strength was decreased. Figure 8 shows the H-7 specimen after the experiment. Only one global buckling has occurred in the web on the right side.

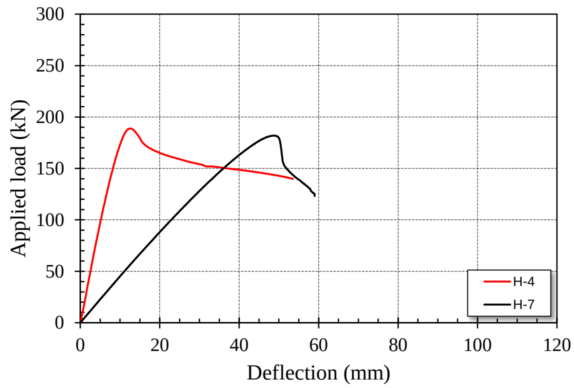

Figure 7. Load-deflection curve of H-4 and H-7 at the center the specimens.

Figure 8. Final transformation of H-7.

4.3 Comparison of Experimental Results (IEB vs H)

Figure 9 and Table 3 show the comparison of the test specimens. As shown in the table, the maximum load of IEB specimen is about 40% higher than the maximum load of H specimen.

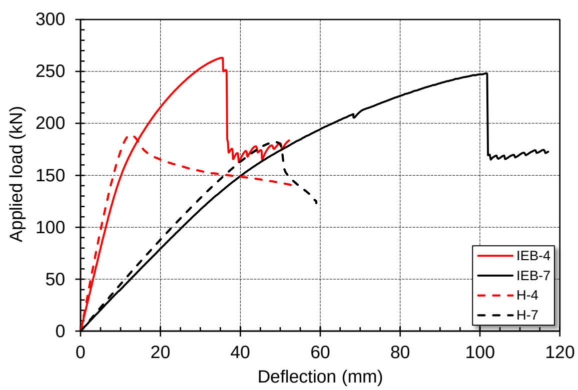

Figure 9. Load-deflection curve of IEB and H.

Table 3. Comparison of maximum load.

Figuration(mm)			**Experiment result(kN)**		**P_{max} comparison (IEB / H)**
			IEB	**H**	
H	***t_w***	***L***	***P_{max}***	***P_{max}***	
400	2.3	4320	263.1	188.8	1.39
		7560	248.2	181.9	1.36

5 CONCLUSION

The purpose of this study is to determine whether the IEB is suitable as an economical structural member by grasping the main behavior characteristics and the maximum load. It seems that the embossing of this specimen plays a role in significantly increasing the post-buckling strength of the web through the tension field action. However, in order to be applied to actual field, more experiments should be performed by adding variables. Based on this, a design formula applicable to actual situation would be presented finally.

Acknowledgements

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