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Experimental Study on Finding Reliable Connectors for Infill-frame Connection in Infilled Steel Frame

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ABSTRACT: During earthquakes, infill walls are imposed to in-plane (IP) and out-of-plane (OOP) seismic loads. After some in-plane seismic vibrations, the worst case for out-of-plane stability of the infill appears when there is the least integrity in the frame-to-wall connections. Using some kind of reliable connectors for frame-to-wall connection is an innovative method to improve their IP and OOP seismic behavior. Noting that the literature on infilled frames has not focused on this subject yet, the present research was carried out with the purpose of introducing a kind of reliable and efficient frame-to-wall connector and to study its effects on IP and OOP behavior of the infilled frames and the infills. Four half-scale single-story single-bay specimens, including one bare frame, an infill wall and two infilled steel frames having walls of autoclave-cured aerated concrete (AAC) blocks, were tested under IP and OOP cyclic displacement controlled loading. The specimens were tested to investigate their failure modes, strength, stiffness degradation, damage evolution in frame and infill, cracking patterns of infill, energy dissipation capacity and out-of-plane displacement of infills. The experimental results revealed that the V-type connectors showed good and reliable interaction as far as the safety issues were concerned. Therefore, such types of fasteners can be used as kinds of promising reliable frame-to-wall connectors for AAC infill panels.

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1- Introduction

Unreasonable infill walls-to-frame connection type constitutes one of the reasons for the failure of the infill walls in addition to the quality of the latter. Presentation of details of an appropriate and reliable infill-frame connection can obviate a part of the existing weakness of the infill walls to be used in buildings. The very few studies conducted in this area have investigated the effect of connection types on the in-plane behavior of the infilled frames only [1]. Indeed, the previous damage caused by in-plane loading seriously decreases the out-of-plane resistance and stability of the infills.

Investigation of the effect of in-plane interactions on the out-of-plane response of the thin unreinforced masonry (URM) infills [2], Experimental results of reinforced concrete frames with masonry infills under combined in-plane and out-of-plane seismic loading [3], experimental investigation on the influence of the aspect ratio (w/h ratio) on the in-plane/out-of-plane interaction for masonry infills in RC frames are among the latest research conducted in this arena but, the role of infill-frame connection type on in-plane/out-of-plane behavior of infills.

The present study was carried out aiming to investigate the effect of the infill-frame connection type on the behavior of the steel infills in order to find a type of safe and efficient connector. For this purpose, two specimens, CINF-0 and CINF-V were first exposed to the cyclic in-plane loading with controlled displacement up to 4% drift. Then, the in-plane loading was stopped and, when the infill returned to its normal position, the infill for the mentioned specimen (without previous damage) was tested under out-of-plane loading protocol. The BF (Bare Frame) control specimens and WNPD (with no previous damage) specimens were tested to compare the in-plane and out-of-plane experimental results, respectively. The objective was to find a reliable infill-frame connection type.

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2- Methodology

The experiments were carried out in the Iran Road, Housing & Urban Development Research Center. The specimen infills were autoclave-cured aerated concrete (AAC) blocks. The blocks were attached to each other using thin steel plates and iron pins were used in even rows. For the purpose of this research, polyurethane glue was used for connecting the blocks in horizontal and vertical bed-joints.

In CINF-0 and WNPD the AAC blocks were connected to the beam and column of the infill (Figure 1a). In CINF-V, V-shaped steel connectors were used to connect the infill to the frame at one-third of the height of the infill from top and bottom. In this specimen, the infill was surrounded by 2L40×4. The out-of-plane stability of the infill wall was provided by a number of steel plates welded to the column and beam flanges from both sides and in contact with the confining angle as lateral support (Figure 1b). Table 1 presents the details of the specimens. The amplitude, number of cycles and extent of loading were set according to FEMA 461 [4]. The out-of-plane loading protocol on the center of the wall was set according to the approach employed by the researchers [5].

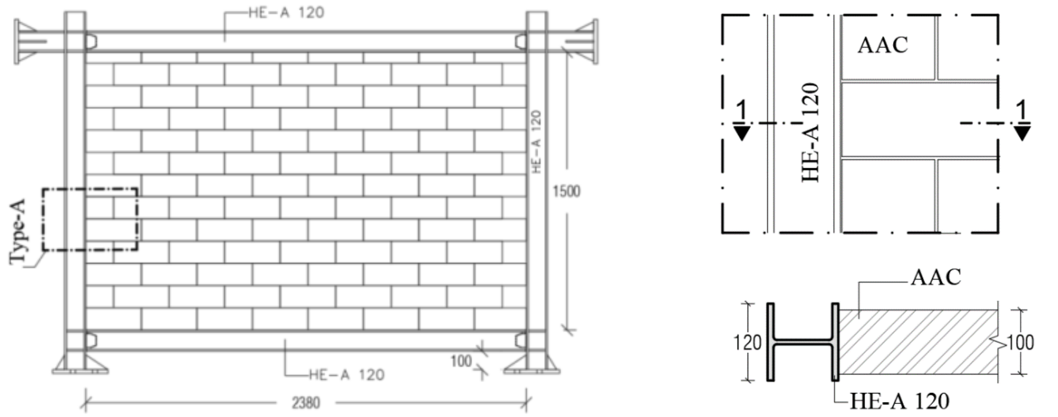
3- Results and Discussion

The ratio of the strength of the tested specimens to that of BF and CINF-0 for relative slides of the story as 0.8%, 2.5% and 3.5% are provided in Table 2. The details provided by Table 2 reveal that the CINF-0 shows the highest strength increase equal to 87% at drift of 0.8% compared to specimen BF. This rate declined at 2.5% drift due to the evolution of damage in the wall and reached 32%. Noting the extent of

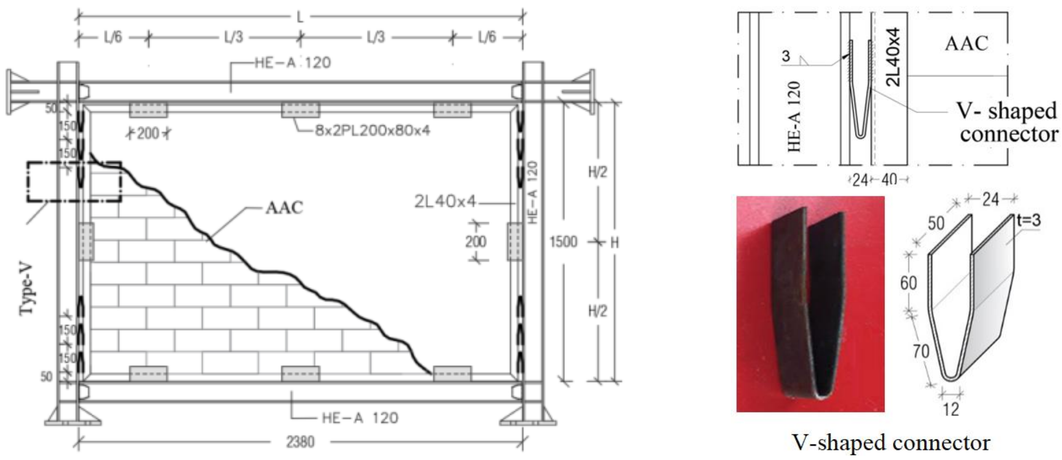
Table 1. Information of the test specimens

Specimen	Wall type	Wall thickness (mm)	Mortar and glue	Wall connection type	Connector type	IP test	OOP test	
							(a)	(b)
BF	-	-	-	-	-	Yes	No	No
WNPD	block	100	Polyurethane	Infill	Type -A	No	Yes	No
CINF-0	block	100	Polyurethane	Infill	Type -A	Yes	No	Yes
CINF-V	block	100	Polyurethane	Infill	Type -V	Yes	No	Yes

(a) With no previous IP damage; (b) With previous IP damage



(a) WNPD and CINF-0



(b) CINF-V

Fig. 1. Detailed dimensions and configurations of specimens (unit: mm)

Table 2. Comparing the ratio of IP strength in the infilled frames to that of BF and CINF-0

Specimen	Loading direction	0.8% drift			2.5% drift			3.5% drift		
		P(kN)	Ratio (a)	Ratio (b)	P(kN)	Ratio (a)	Ratio (b)	P(kN)	Ratio (a)	Ratio (b)
BF	Average	31.4	1.00	0.53	78.3	1.00	0.76	87.9	1.00	0.74
CINF-0	+	58.8			104.6			120.2		
	-	58.9	1.87	1.00	101.9	1.32	1.00	117.0	1.35	1.00
	Average	58.85			103.2			118.6		
CINF-V	+	39.9			97.8			123.7		
	-	37.2	1.23	0.66	97.1	1.24	0.94	122.6	1.40	1.04
	Average	38.6			97.5			123.2		

(a) Bare frame, (b) CINF-0

the damages imposed on infills, the strength increase for CINF-0 will not be usable at the performance levels of Immediate Occupancy (IO) and Life Safety (LS) [6] when earthquakes happen.

The CINF-V increased the infill strength of the infilled frame for 23% compared to that of BF specimen at drift of 23%. This increase continued as displacement increased such that at 3.5% drift, without observing any damage in the infill wall, the strength increase in this specimen compared to BF reached 40%.

The ratio of OOP strength in infilled specimens to that of WNPD are provided in "Figure 2" the results show that the previous damage caused by in-plane loading led to decrease in out-of-plane strength of the specimens but, the least out-of-plane strength decrease is recorded for CINF-V. In this specimen, the performance of V-shaped connectors results in improvement of out-of-plane behavior of the related infills.

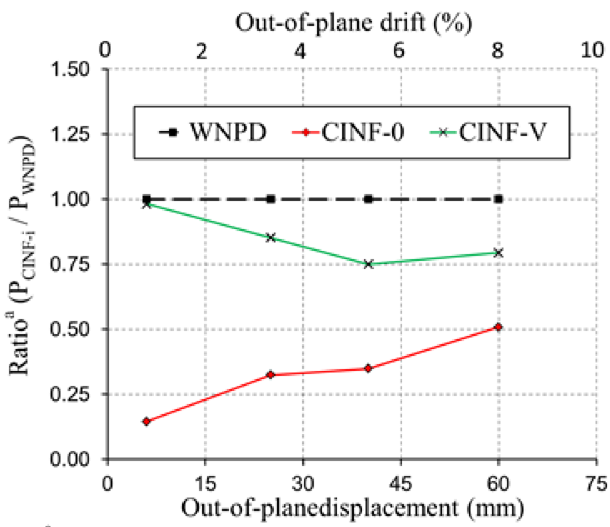


Fig. 2.Comparing the out-of-plane strength of the infilled specimens with that of WNPD

Comparison of the initial stiffness of the specimens and ratio of stiffness degradation of the specimens at 0.8%, 2.5% and 3.5% drifts with that of specimen BF revealed that the initial stiffness increase ratio for CINF-V to specimen BF was 15% while the initial stiffness for CINF-0 was 3.02 times as much as the BF stiffness. The ratio of stiffness of CINF-V to that of BF at drift of 2.5% was 0.94. In other words, for this specimen, not only the initial stiffness increase is not notable but the frame stiffness degradation is compensated by the infill remaining safe at LS level (at 2.5% drift).

4- Conclusions

As the most important finding of this research, it can be put forward that using of appropriate and reliable Infill-frame Connection Type has positive effects in prevention of unfavorable effects of infill-frame interactions in infilled frames. According to the experimental results, V-shaped connectors showed good and reliable cooperative behavior as far as safety was concerned. The results of the experiments revealed that using these types of connectors causes the infills to remain safe up to LS (2.5% drift) level [6], the strength of the unfilled frames to increase, the stiffness degradation and strength decrease after drift of 2.5% to be compensated and the out-of-plane stability of the infills to be sufficiently provided. Therefore, V-shaped connectors can be presented as reliable and efficient Infill-frame Connection Type.

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