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Effect of cyclic loading protocols on the performance of perforated plate fuses in mass timber seismic force Resisting Systems

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ABSTRACT

Keywords: Seismic fuse, Perforated plate, Cyclic loading protocol, Mass timber seismic force resisting systems, ductile connections.

INTRODUCTION

The full-length papers or extended abstracts should be submitted through the online submission system (Submission Portal) **before April 10, 2023** (or according to the deadline indicated at the CCEE-PCEE 2023 website: http://ccee-pcee.ca/). Documents received after the deadline will not be included in the proceedings. Papers will be peer-reviewed and will be **included only if at least one of the authors is registered to the conference not later than April 10, 2023**.

The suggested length of the full paper is **8 (eight) pages** and should not exceed **12 (twelve) pages**, including figures, tables, acknowledgments, and references. The extended abstract should be at least 4 pages. The document should comply with this template, including page size (Letter type), margins (19mm or 3/4in all around), given styles and given sizes of fonts for the all sections. The authors should use this template for the writing of the paper and should print it into a pdf file for submission named by using the Last Name of the corresponding author of the accepted abstract and the Paper ID (XXX) (e.g. CCEE-PCEE 2023_ LastName_XXX.pdf). The size of the final PDF should not exceed **15 MB**.

HEADING 1 STYLE

EXPERIMENTAL PROGRAM

- 16 Tests (4M / 12C):
  - 3 Protocols (ASTM E2126 Method B & C, FEMA 461)
  - 4 Parameters (# of Rows, Diameter, Shape, Stagger)

Figure 1.Test setup and instrumentation.

Test specimens

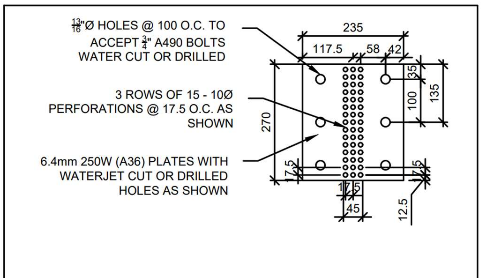
The specimens consist of 1/4 in (6.4 mm) thick and 235 mm wide plates (length varied slightly), made of ASTM A36 steel material with waterjet cut or drilled six 13/16in holes at 100 center to center, considered to accept 3/4in ASTM A490 bolts. The size of perforations is shown in Figures1 (a) to (e).

Table 1: Testing Matrix.

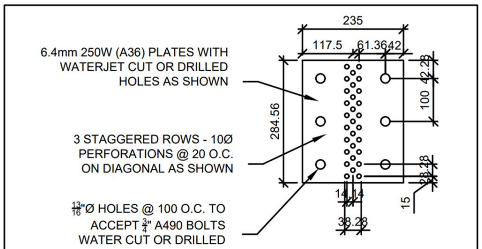
Test Label	Configuration	Loading Protocol	Plate		Perforation			
			Length (mm)	Thickness (mm)	No. of Rows	Size (mm)	End Distance (mm)	Link Size (mm)
10-17.5-M	Regular	Monotonic	270	6.4	3	10	7.5	7.5
10-17.5-B		Method B*	270	6.4	3	10	7.5	7.5
10-17.5-B2		Method B	270	6.4	3	10	7.5	7.5
10-17.5-C		Method C	270	6.4	3	10	7.5	7.5
10-17.5-C2		Method C	270	6.4	3	10	7.5	7.5
10-17.5-F		Fema 461	270	6.4	3	10	7.5	7.5
10-17.5-F2		Fema 461	270	6.4	3	10	7.5	7.5
10-20S-C	Stagger	Method C	284.6	6.4	3	10	10	18.3
10-20S-B		Method B	284.6	6.4	3	10	10	18.3
10E-17.5-M	Ellipse	Monotonic	270	6.4	3	10 x 14	7.5	7.5
10E-17.5-B		Method B	270	6.4	3	10 x 14	7.5	7.5
10E-17.5-B2		Method B	270	6.4	3	10 x 14	7.5	7.5
10E-17.5-C		Method C	270	6.4	3	10 x 14	7.5	7.5
10E-17.5-C2		Method C	270	6.4	3	10 x 14	7.5	7.5
10E-17.5-C3		Method C	270	6.4	3	10 x 14	7.5	7.5
10E-17.5-F		Fema 461	270	6.4	3	10 x 14	7.5	7.5
10E-17.5-F2		Fema 461	270	6.4	3	10 x 14	7.5	7.5
10E-17.5-F3		Fema 461	270	6.4	3	10 x 14	7.5	7.5
10SL-17.5-M	Slot	Monotonic	270	6.4	3	10 x 15	7.5	7.5
10SL-17.5-B		Method B	270	6.4	3	10 x 15	7.5	7.5
10SL-17.5-B2		Method B	270	6.4	3	10 x 15	7.5	7.5
10SL-17.5-C		Method C	270	6.4	3	10 x 15	7.5	7.5
10SL-17.5-C2		Method C	270	6.4	3	10 x 15	7.5	7.5
10SL-17.5-F		Fema 461	270	6.4	3	10 x 15	7.5	7.5
10SL-17.5-F2		Fema 461	270	6.4	3	10 x 15	7.5	7.5

15-25-M	Larger Diameter	Monotonic	285	6.4	3	15	10	10
15-25-B		Method B	285	6.4	3	15	10	10
15-25-C		Method C	285	6.4	3	15	10	10

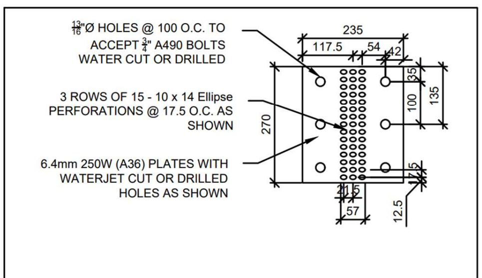
8 for the 10-3-17.5-6.4R (10mm diameter) Price including mat $74.00 Each
6 for 15-3-25-6.4R (15mm diameter) Price including mat $74.00 Each
6 for 10SL-3-17.5-6.4R (Slot) Price including mat $83.00 Each
8 for 10E-3-17.5-6.4R (Ellipse) Price including mat $80.50 Each
4 for 10-3S-20-6.4R (Stagger) Price including mat $60.00 Each
3 Coupons $10.00 Each



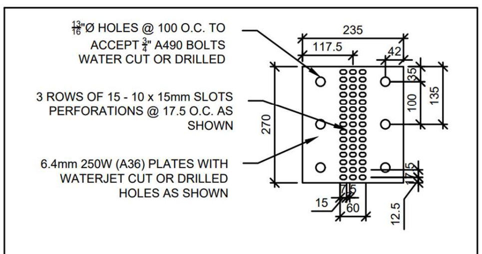
SERIES 10-3-17.5-6.4: PLATE W/ 3 ROWS @ 17.5 O.C.



SERIES 10-3S-20-6.4: PLATE W/ 3 STAGGERED ROWS @ 20 O.C.



SERIES 10E-3-17.5-6.4: PLATE W/ 3 ROWS @ 17.5 O.C.



SERIES 10SL-3-17.5-6.4: PLATE W/ 3 ROWS @ 17.5 O.C.

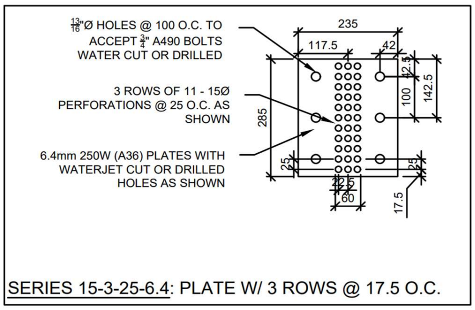
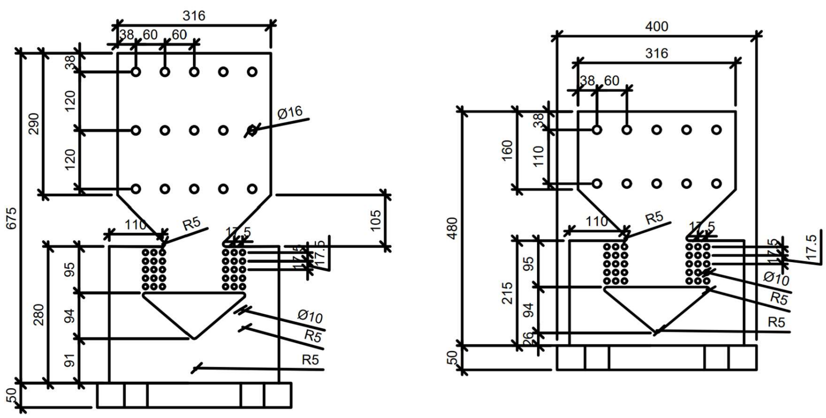


Figure 2.Test specimens: Phase 1B .



(a) (b)

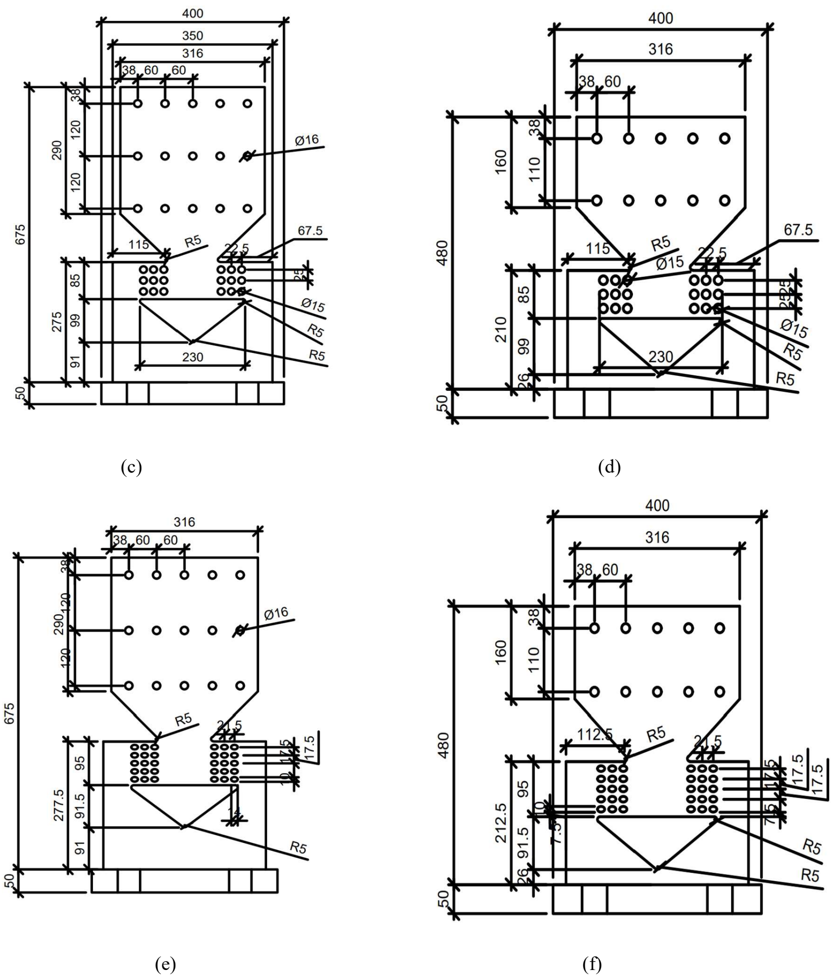
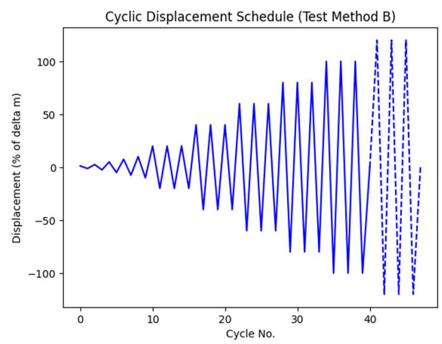


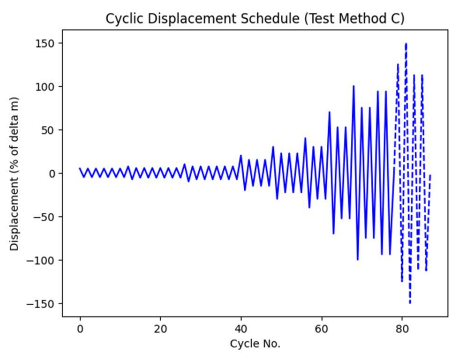
Figure 3.Test specimen: phase 2.

Load protocols

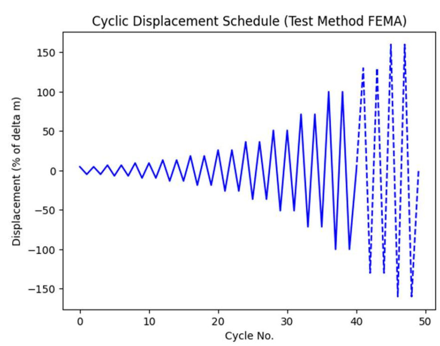
Three loading protocols are considered in thi study, FEMA 461, ASTM Method B, and Method C.



(a)



(b)

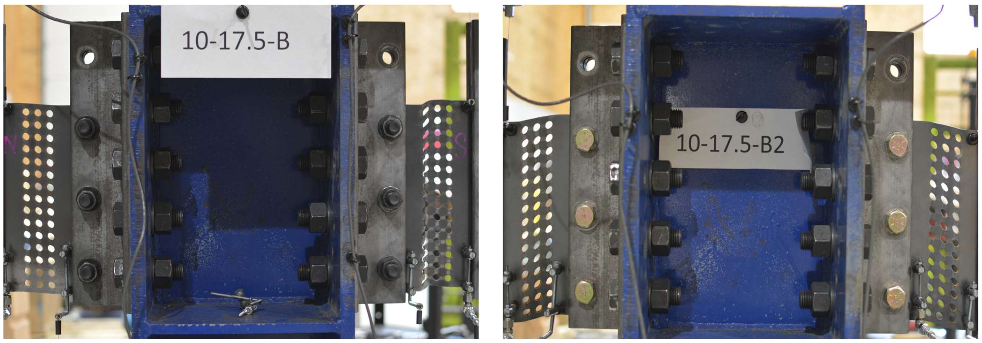


(c)

Figure 4.Testing protocols: phase 1B.

TEST RESULTS

Phase 1B:



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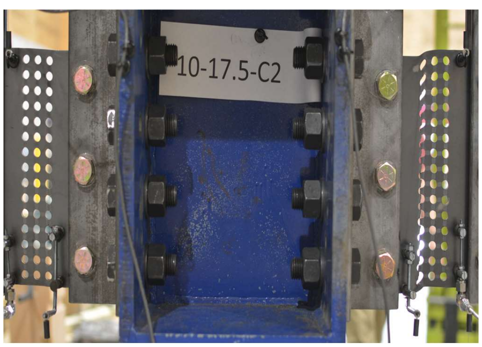

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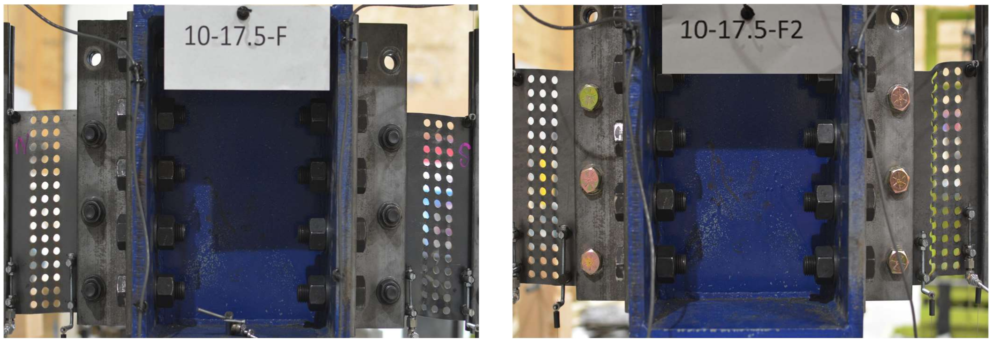

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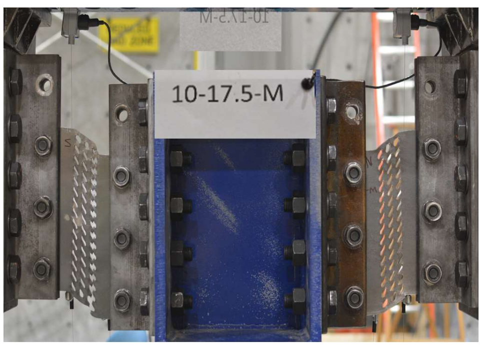
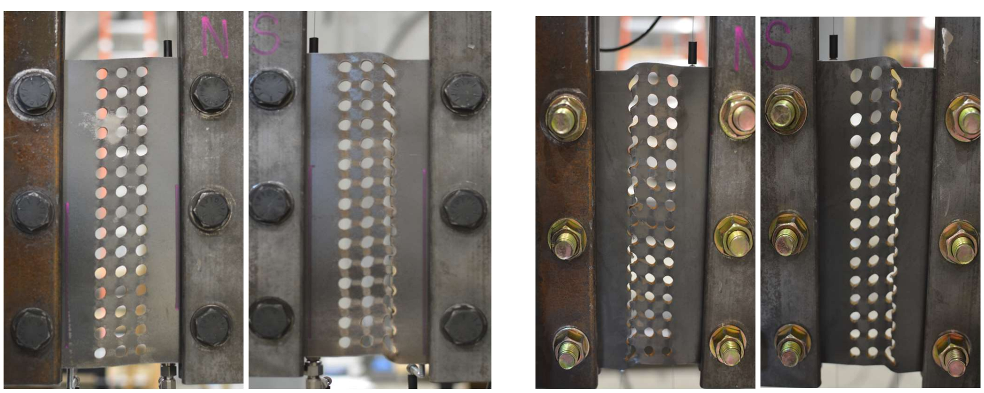


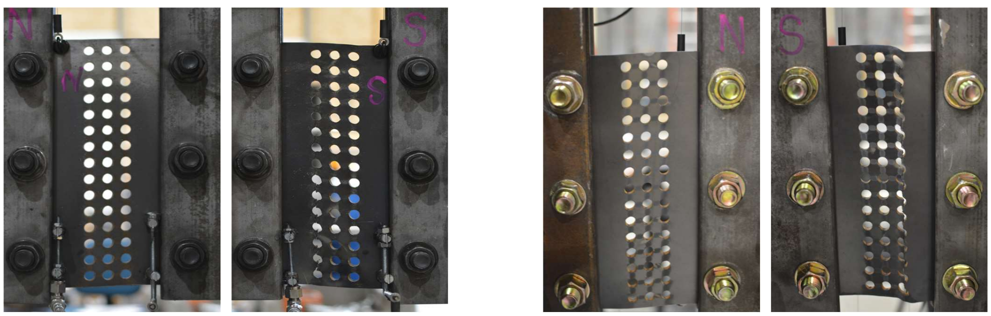
(d)

Figure 5. Deformed shapes and failure modes of specimens 10-17.5 for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C, (c) FEMA 461(d) monotonic loading



(a)

(b)



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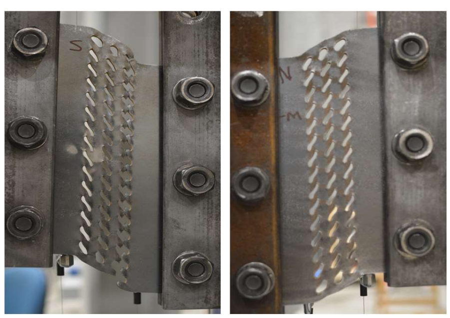
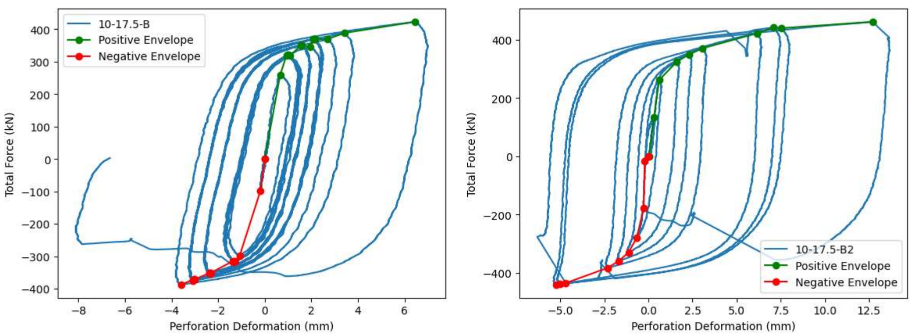
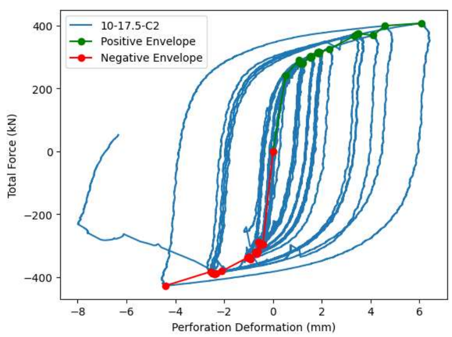


(d)

Figure 6. Deformed shapes and failure modes of specimens 10-17.5 for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C, (c) FEMA 461(d) monotonic loading (Magnified view)



(a)



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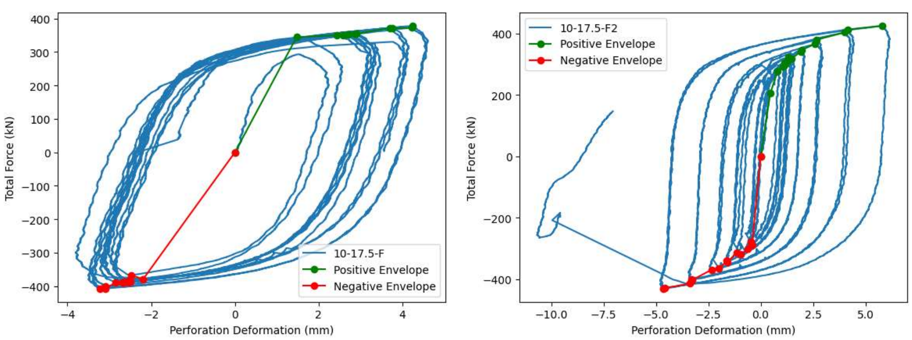


(c)

Figure 7. Total force versus perforation deformation of specimens 10-17.5 for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C, (c) FEMA 461

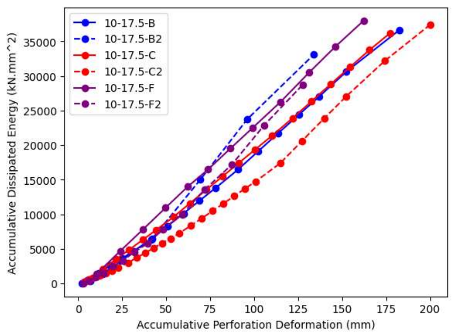
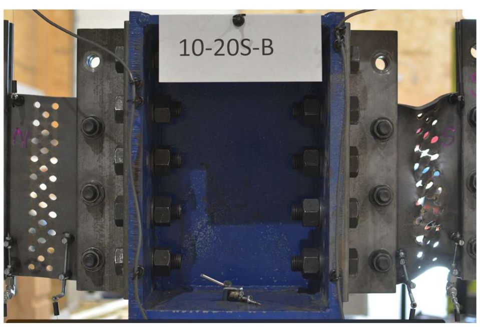
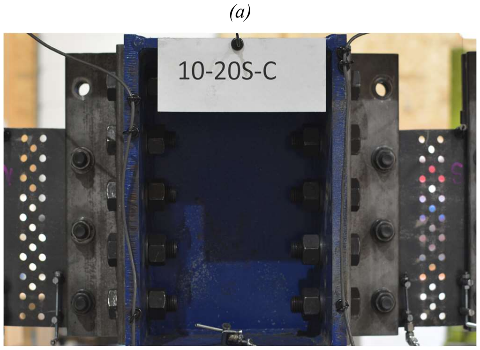


Figure 8. Accumulative dissipated energy versus accumulative perforation deformation of specimens 10-17.5 for loading protocols

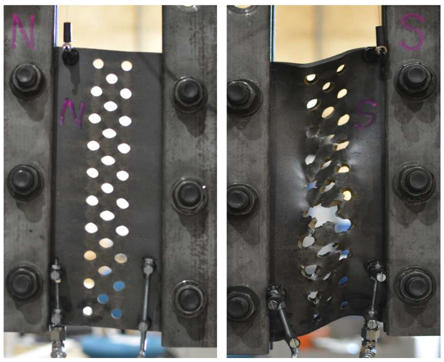


(a)

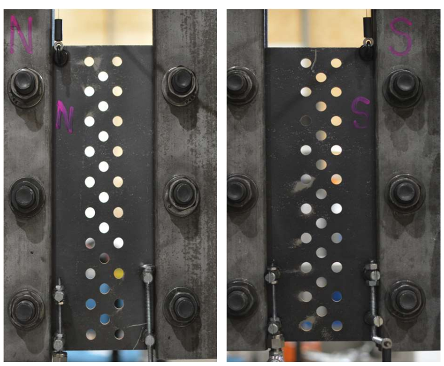


(b)

Figure 9. Deformed shapes and failure modes of specimens 10-20S for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C

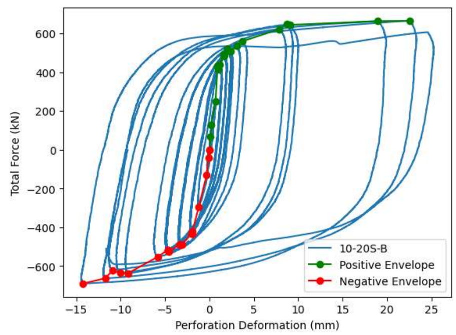


(a)

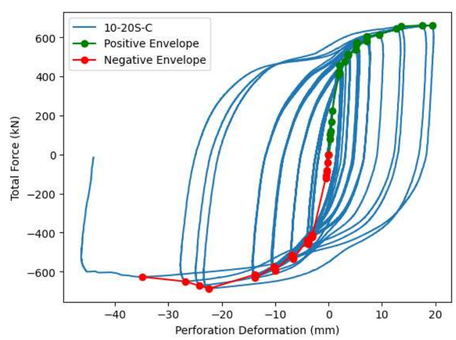


(b)

Figure 10. Deformed shapes and failure modes of specimens 10-20S for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C (Magnified view)



(a)



(b)

Figure 11. Total force versus perforation deformation curves for specimens 10-20S for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C

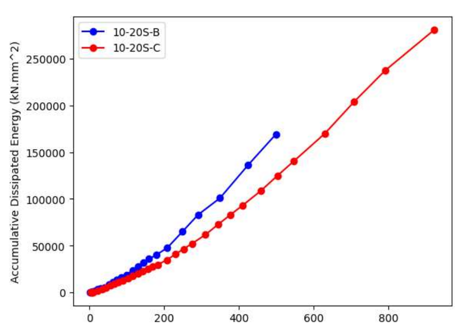
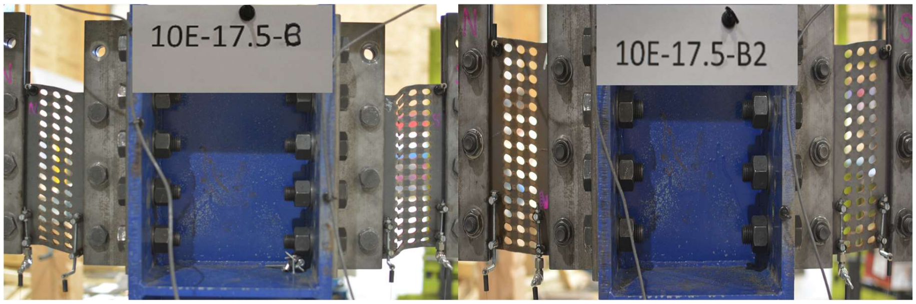
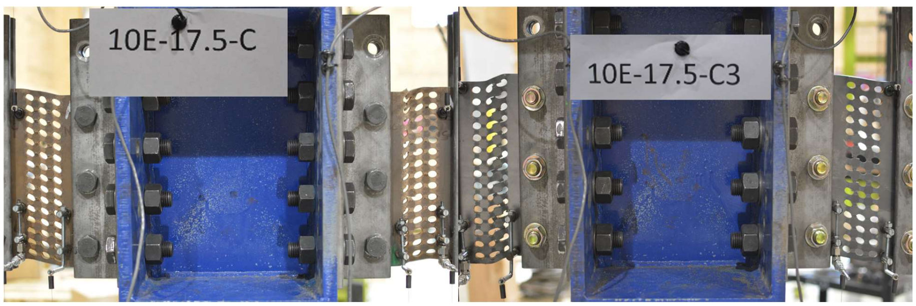


Figure 12. Accumulative dissipated energy versus accumulative perforation deformation of specimens 10-20S for loading protocols



(a)



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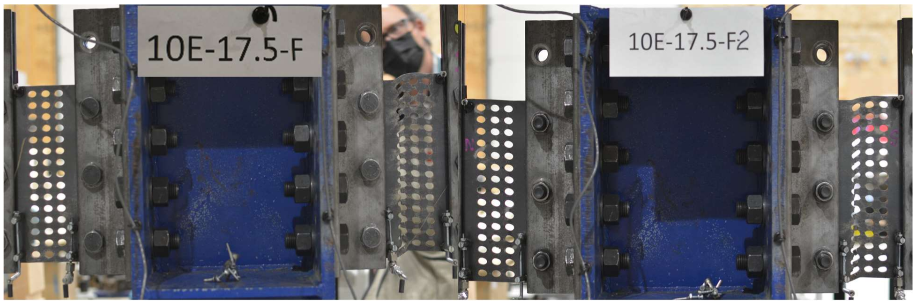

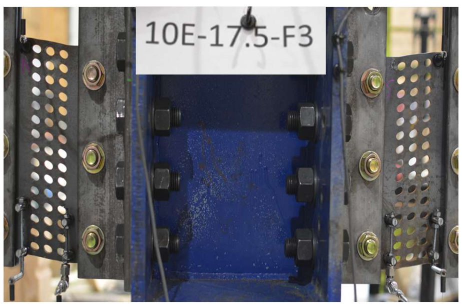

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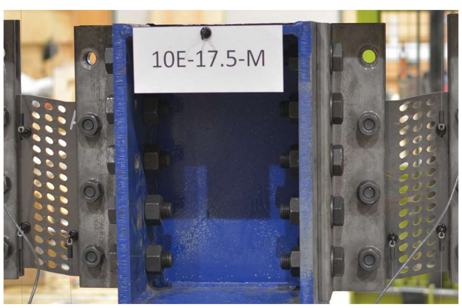
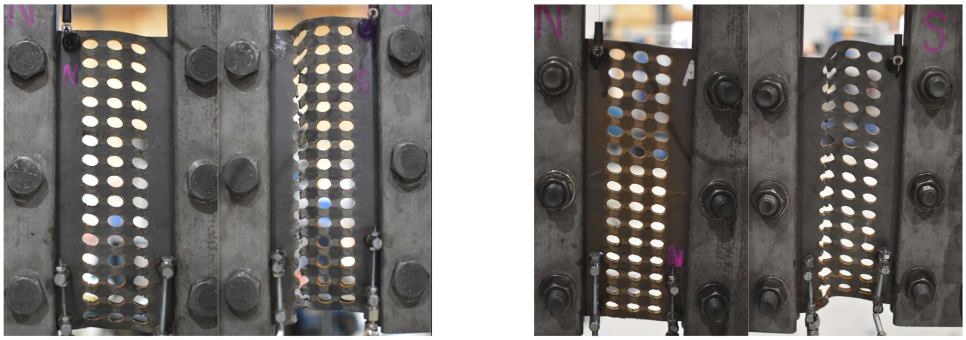
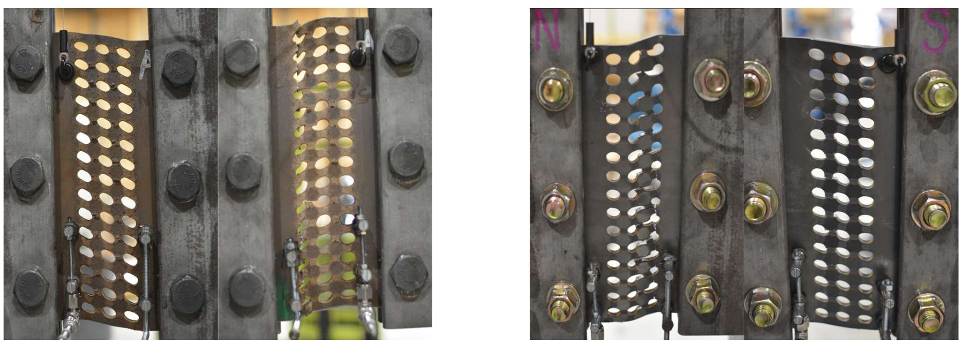


(d)

Figure 13. Deformed shapes and failure modes of specimens 10E-17.5 for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C, (c) FEMA 461(d) monotonic loading



(a)



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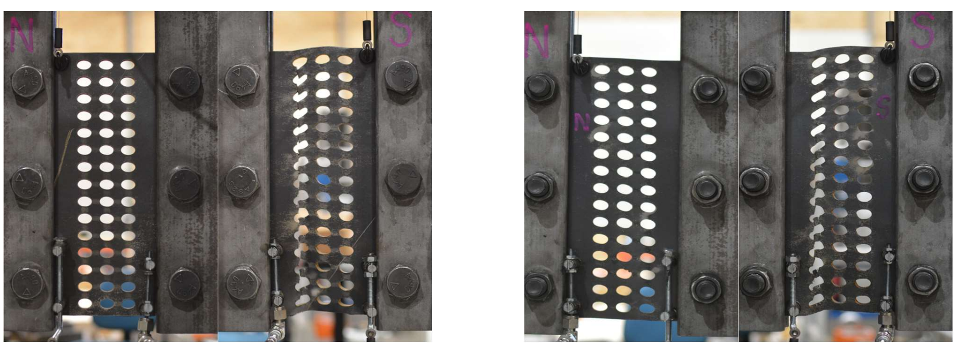

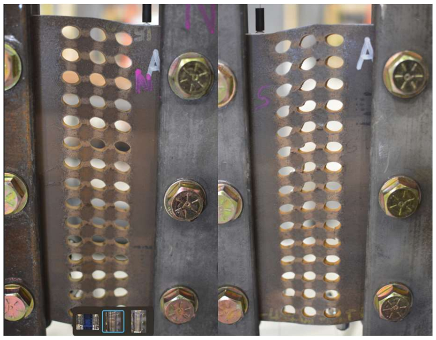

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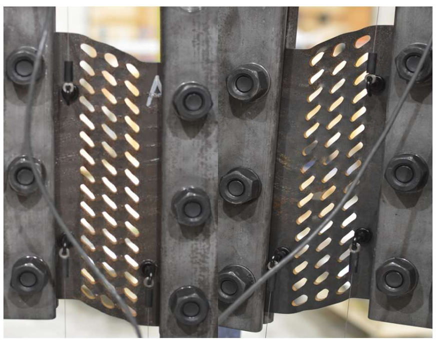
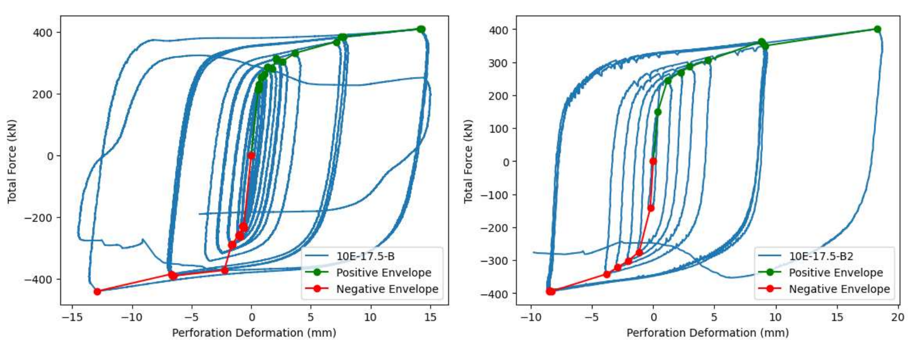
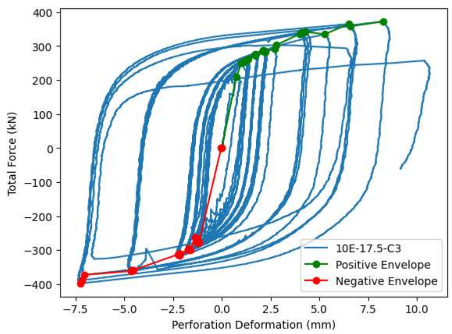


(d)

Figure 14. Deformed shapes and failure modes of specimens 10E-17.5 for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C, (c) FEMA 461(d) monotonic loading (Magnified view)



(a)



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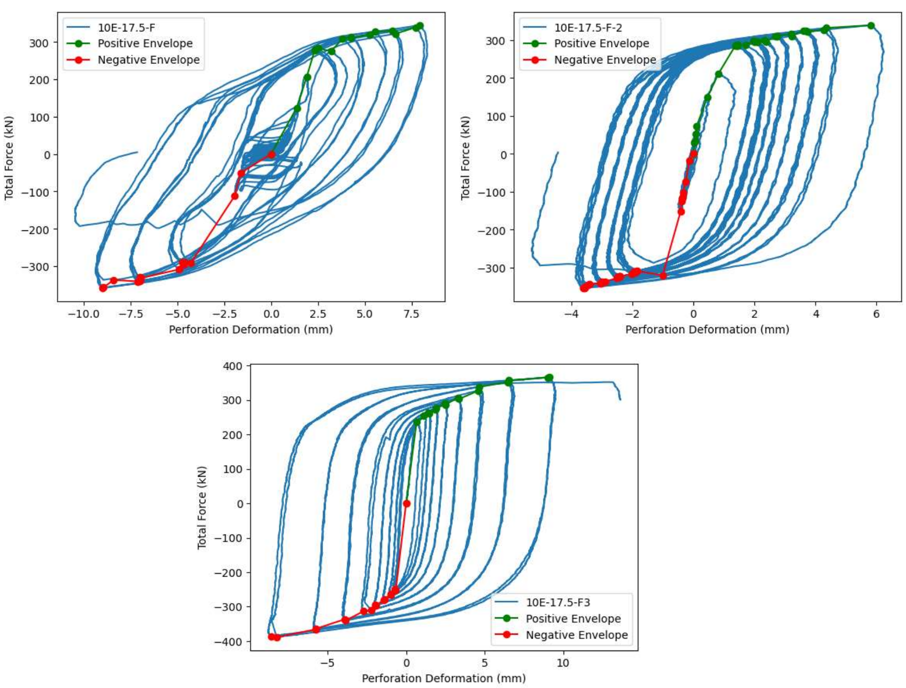


(c)

Figure 15. Total force versus perforation deformation curves of specimens 10E-17.5 for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C, (c) FEMA 461

Commented [HD1]: How about 10E-17.5-C?

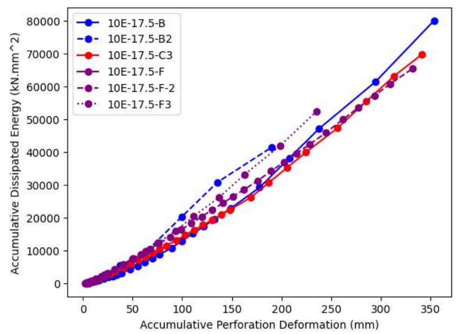
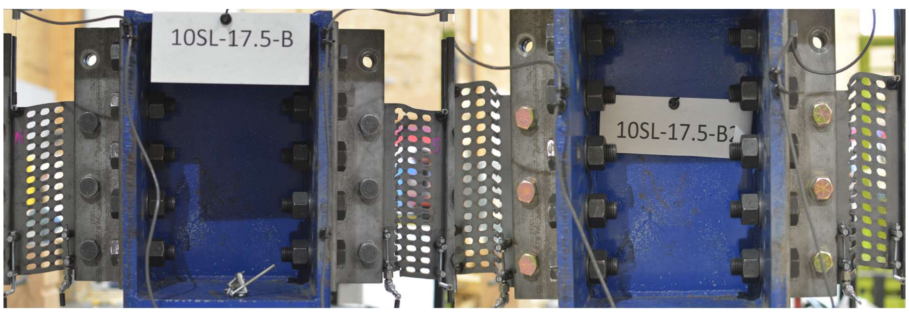
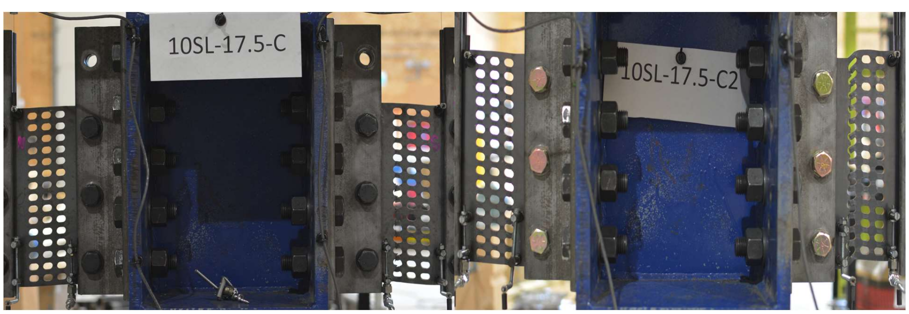


Figure 16. Accumulative dissipated energy versus accumulative perforation deformation of specimens 10E-17.5 for loading protocols



(a)



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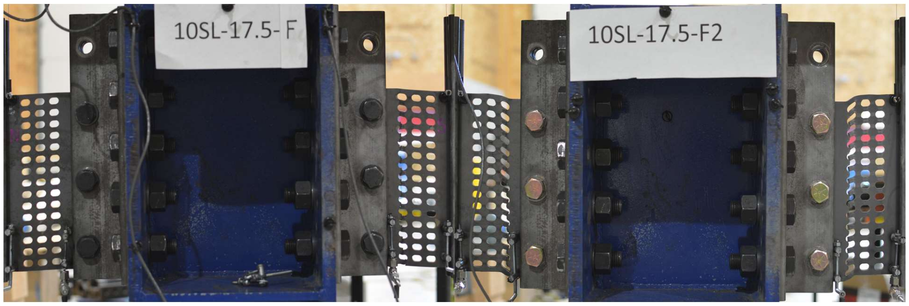

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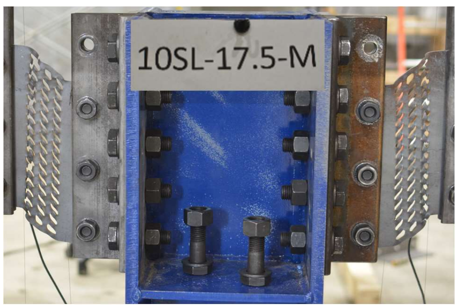
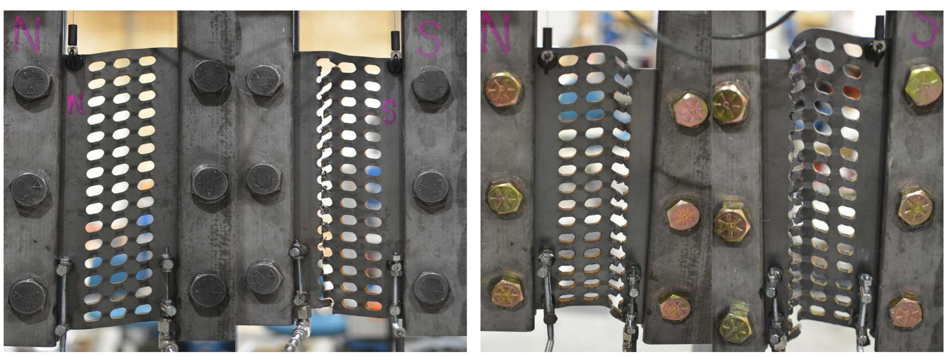
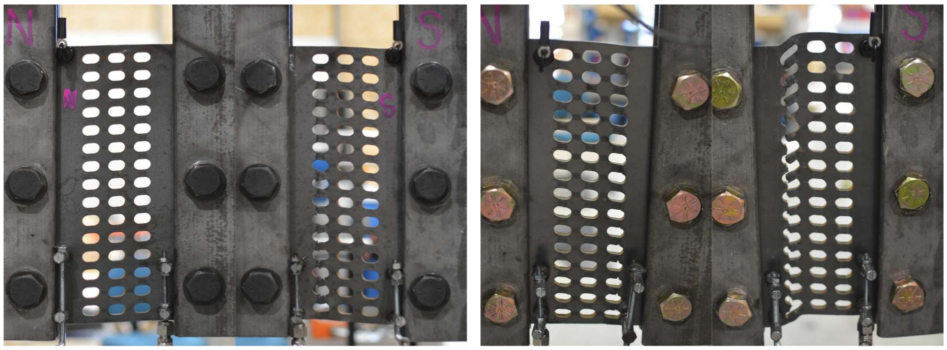


(d)

Figure 17. Deformed shapes and failure modes of specimens 10SL-17.5 for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C, (c) FEMA 461 (d) monotonic loading



(a)



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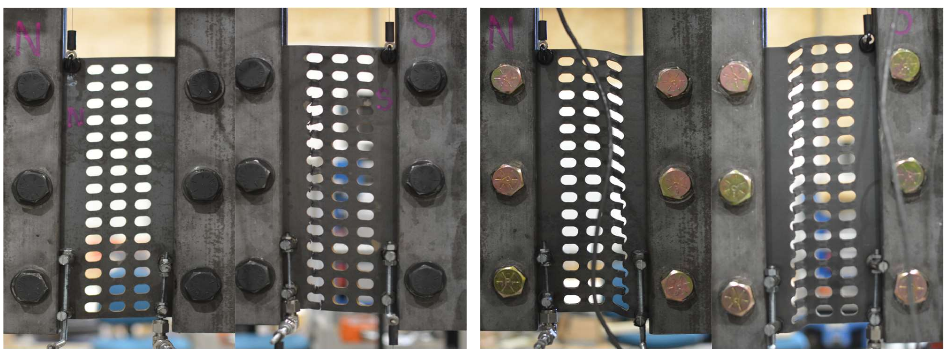
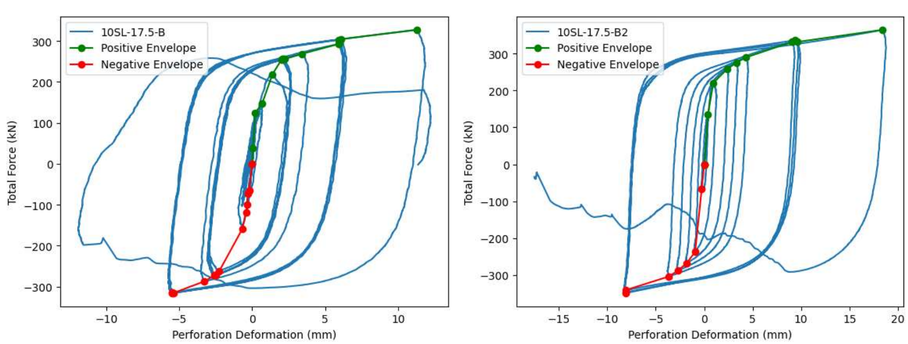
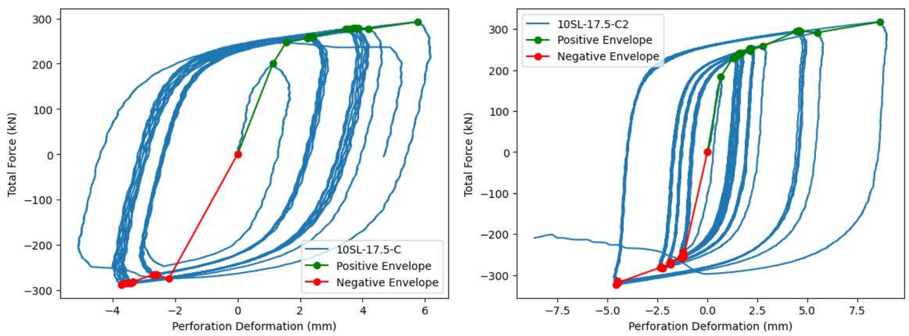


(c)

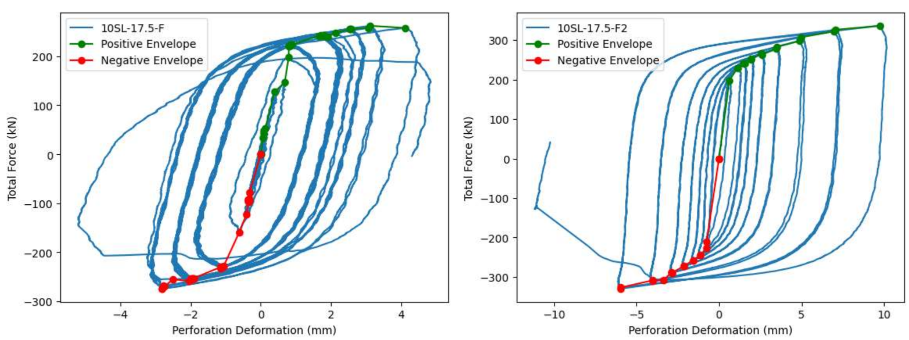
Figure 18. Deformed shapes and failure modes of specimens 10SL-17.5 for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C, (c) FEMA 461 (d) monotonic loading (magnified view)



(a)



(b)



(c)

Figure 19. Total force versus perforation deformation curves of specimens 10SL-17.5 for loading protocols (a) ASTM E2126 Method B, (b) ASTM E2126 Method C, (c) FEMA 461

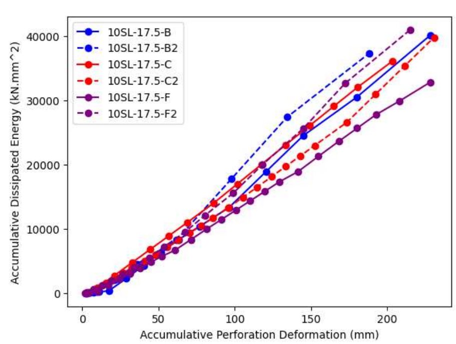
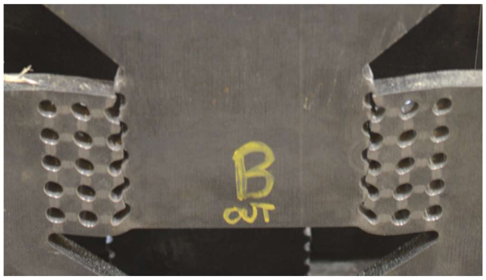


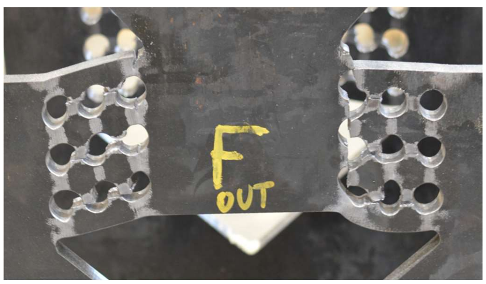
Figure 20. Accumulative dissipated energy versus accumulative perforation deformation of specimens 10SL-17.5 for loading protocols

Phase 1B:

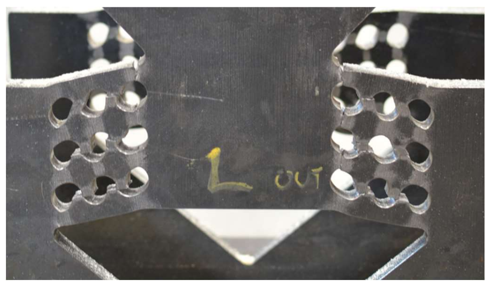


(a)

(b)

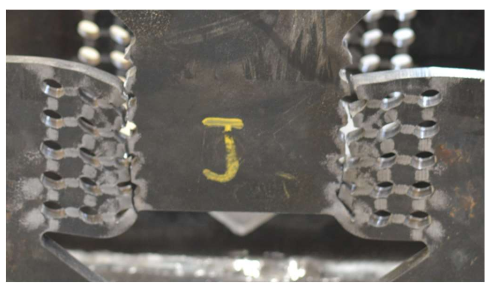


(c)



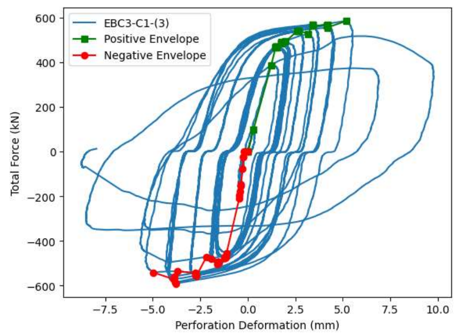
(d)

(e)

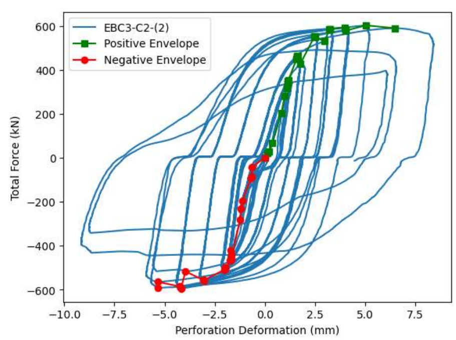


(f)

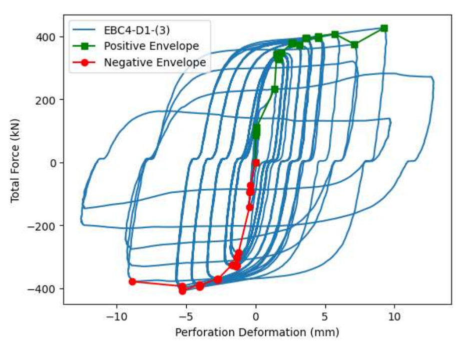
Figure 21. Deformed shapes and failure modes of specimens (a) EBC3-C-1-(3), (b) EBC3-C-2-(2), (c) EBC4-D-1-(3) (d) EBC4-D-2-(2), (e) EBC5-E-1-(3), (f) EBC5-E-2-(2)


EBC3-C1-(3)
Positive Envelope
Negative Envelope
Total Force (kN)
Perforation Deformation (mm)

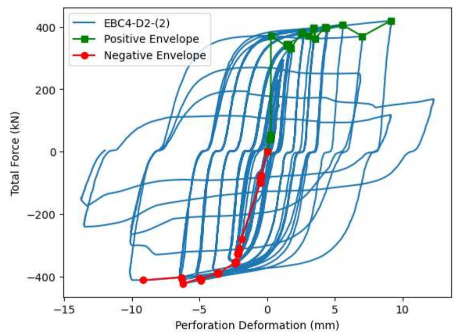
(a)


EBC3-C2-(2)
Positive Envelope
Negative Envelope
Total Force (kN)
Perforation Deformation (mm)

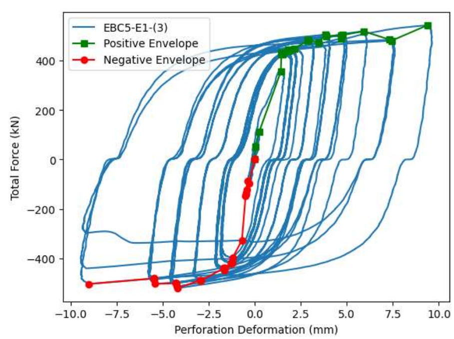
(b)


EBC4-D1-(3)
Positive Envelope
Negative Envelope
Total Force (kN)
Perforation Deformation (mm)

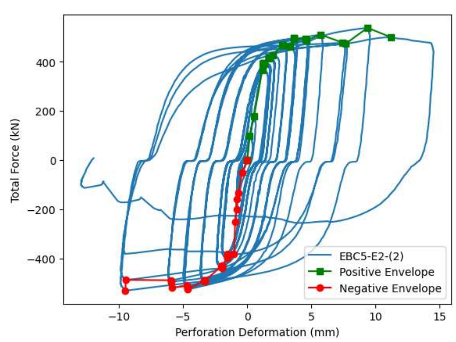
(c)



(d)



(e)



(f)

Figure 22. Total force versus perforation deformation curves specimens (a) EBC3-C-1-(3), (b) EBC3-C-2-(2), (c) EBC4-D-1-(3) (d) EBC4-D-2-(2), (e) EBC5-E-1-(3), (f) EBC5-E-2-(2)

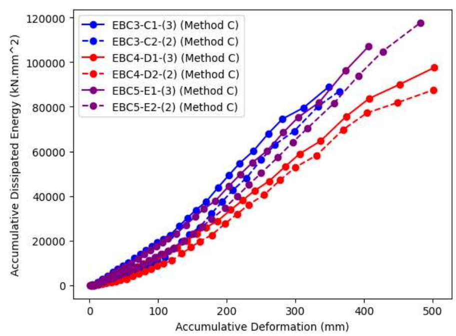
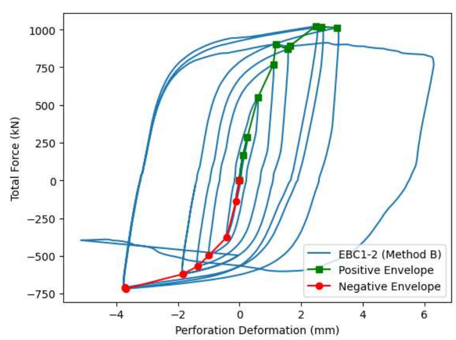
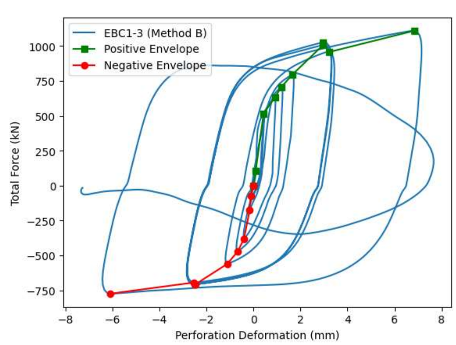


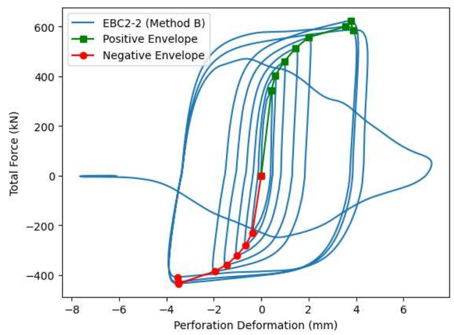
Figure 23. Accumulative dissipated energy versus accumulative perforation deformation of all six specimens



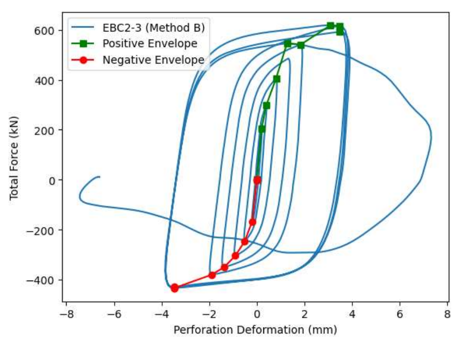
(a)



(b)



(c)



(d)

Figure 24. Total force versus perforation deformation curves specimens (a) EBC1-2, (b) EBC1-3, (c) EBC2-2 (d) EBC2-3)

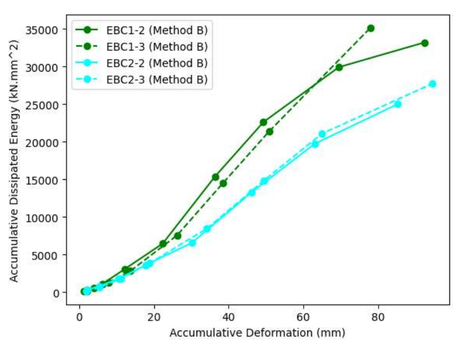


Figure 25. Accumulative dissipated energy versus accumulative perforation deformation of all four specimens

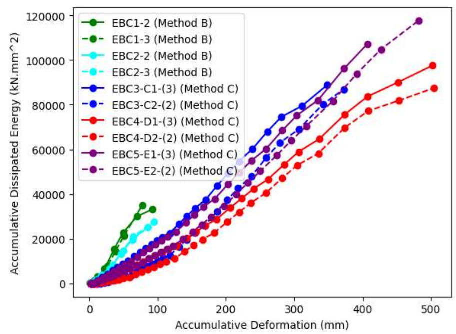


Figure 26. Accumulative dissipated energy versus accumulative perforation deformation of all ten specimens

Commented [HD2]: Not sure if it is correct. Need to check.

CONCLUSIONS

ACKNOWLEDGMENTS

Acknowledge the sources of support.

REFERENCES

References should be cited in the text in square brackets (e.g., [1], [2-4]), numbered according to the order in which they appear in the text. Only list references that are referred in the text. A complete reference should provide enough information to find the article.

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