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FE Analysis of Alternative Thermal Breaks for Steel Buildings

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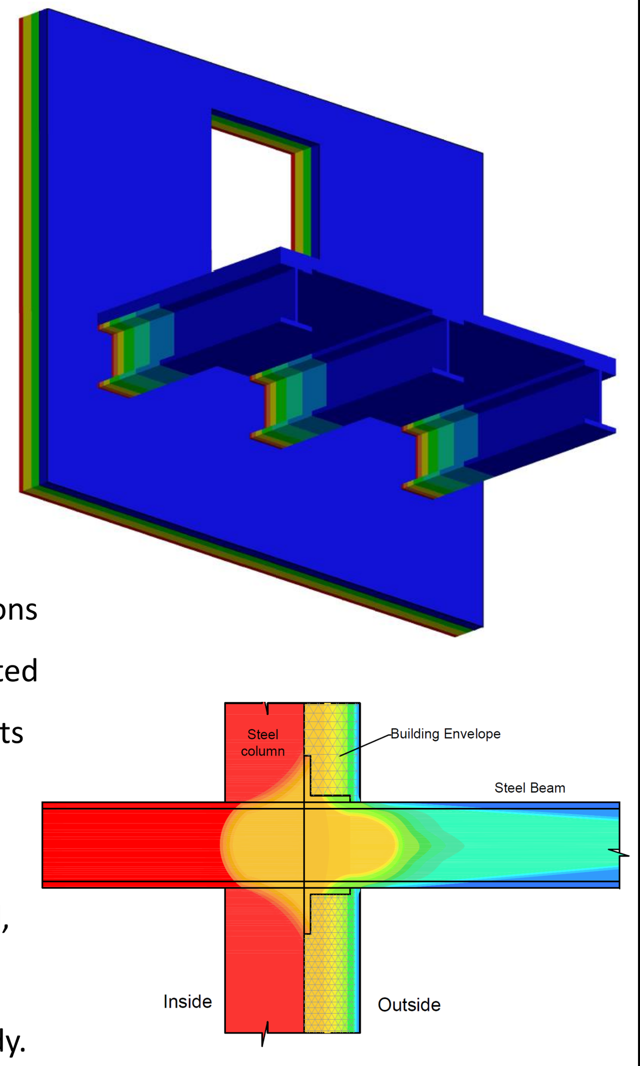
Abstract

"Thermal bridge" is a term used for structural or non-structural elements that have higher heat transfer than any other elements or spots in the building envelope, reducing the efficiency of the building thermal insulation (see Fig. 1). About 20% of the heat occurs via such thermal bridges [1]. Thermal insulations (thermal breaks) are used within a steel connection to mitigate the effect of thermal bridges (see Fig. 2). In this research, connections with steel fillers studied by Dusicka (2007)[2] were simulated using the finite element (FE) program ABAQUS. The results from the FE model were validated with those from the experimental work done by Dusicka (2007) and showed very close behavior. After validating the numerical model, the steel fillers were replaced by alternative fillers with improved thermal properties as part of a parametric study.



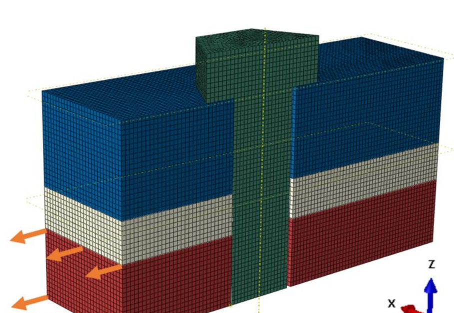
(Fig. 1) numerical model shows thermal bridges in a balcony

Research Objective and Motivation

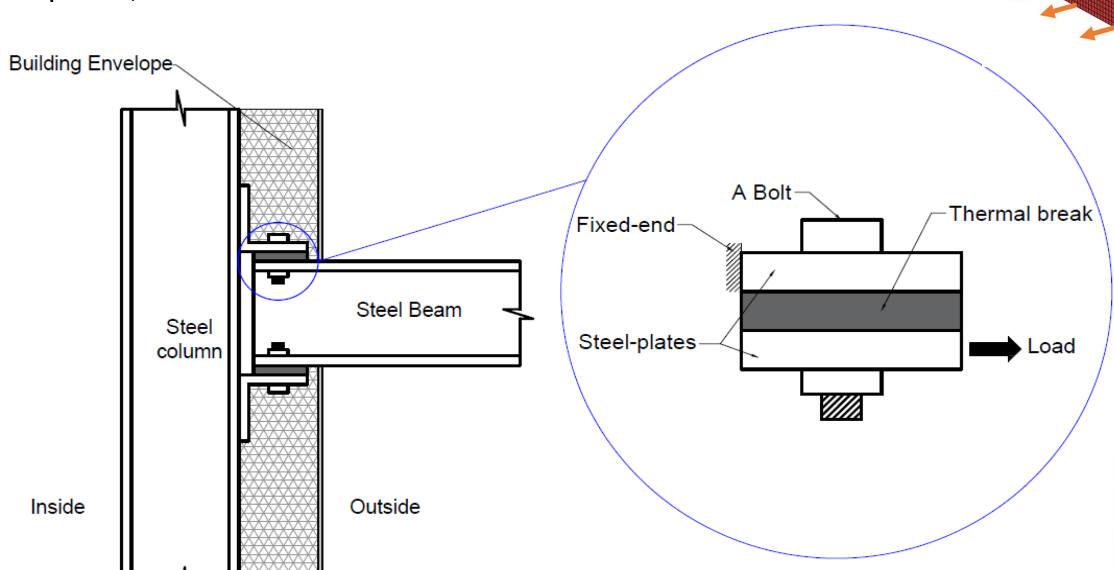
The main objective of this research is to prove the feasibility of using alternative fillers that have improved thermal properties for steel connections. This will provide structural engineers and architects with means to design buildings with improved thermal properties, hence advance their sustainability.

Methodology and Model Assumptions

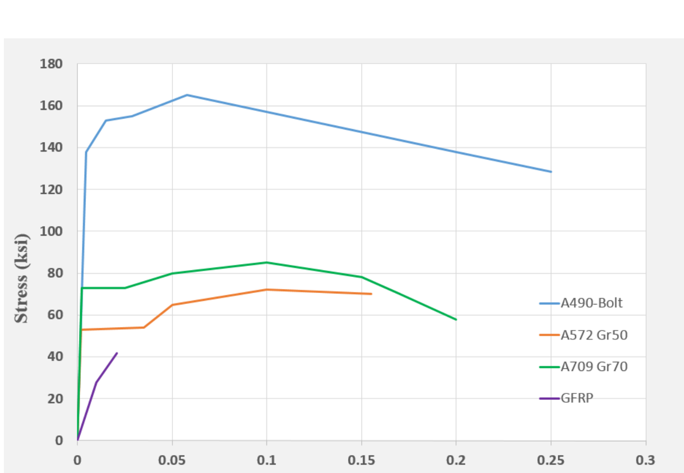
- Create a simplified model that can be analyzed with the FEA program ABAQUS (see Fig. 2).
- Boundary conditions for the upper plate (angle) assumed to be fixed while the filler plate is free to move along the x-axis.
- The load is applied through the bottom plate (I-beam flange).
- Due to symmetry, only a quarter of the assembly was considered (see Fig. 3) and the obtained results were multiplied by a factor of 4 and compared with the experimental work.
- 8-node 3-D elements (C3D8R) were used in conjunction with the implicit code to apply the bolt clamping force and then the explicit model was used to apply the horizontal load in displacement-controlled mode up to failure (see Fig. 3).
- Mechanical properties of steel and GFRP were tested in the lab to obtain stress-strain relations required for the FEA (Fig. 4).
- Materials used were A709 HPS Grade 70 for the upper and lower plates, while A572 Grade 50 and GFRP G10 were used as fillers.



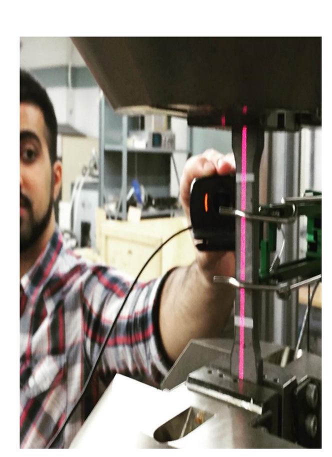
(Fig. 3) FEA model.



(Fig. 2) Simplifying the steel connection.



(Fig. 4) Stress-strain curves of used materials.



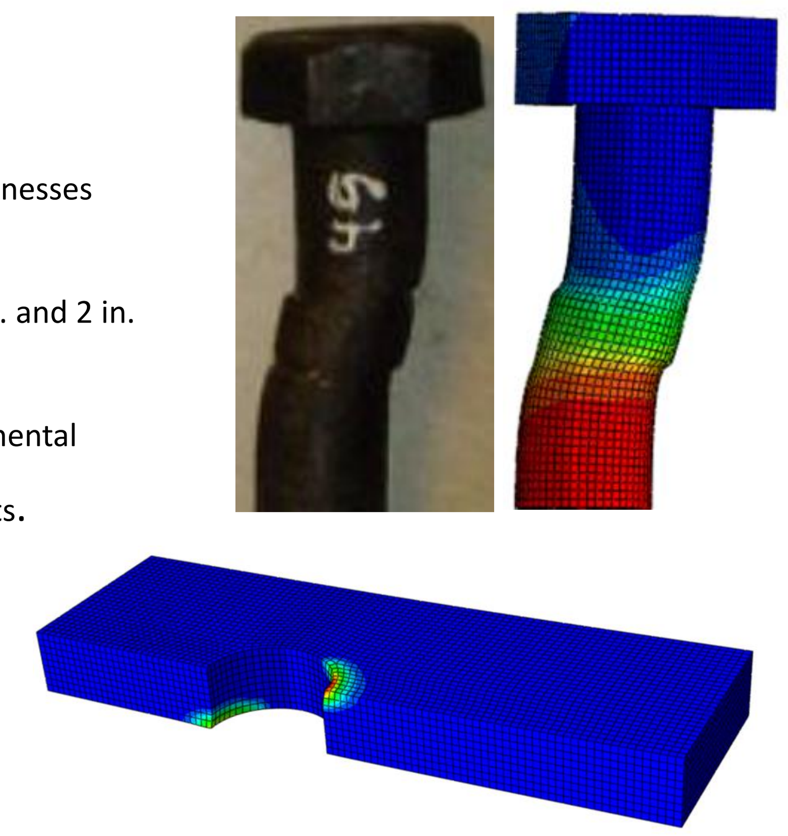
Material	Thermal conductivity (W/m.K)
Steel	50.2
GFRP	0.3
Air	0.024-0.03

(Fig. 5) Thermal properties of used materials.

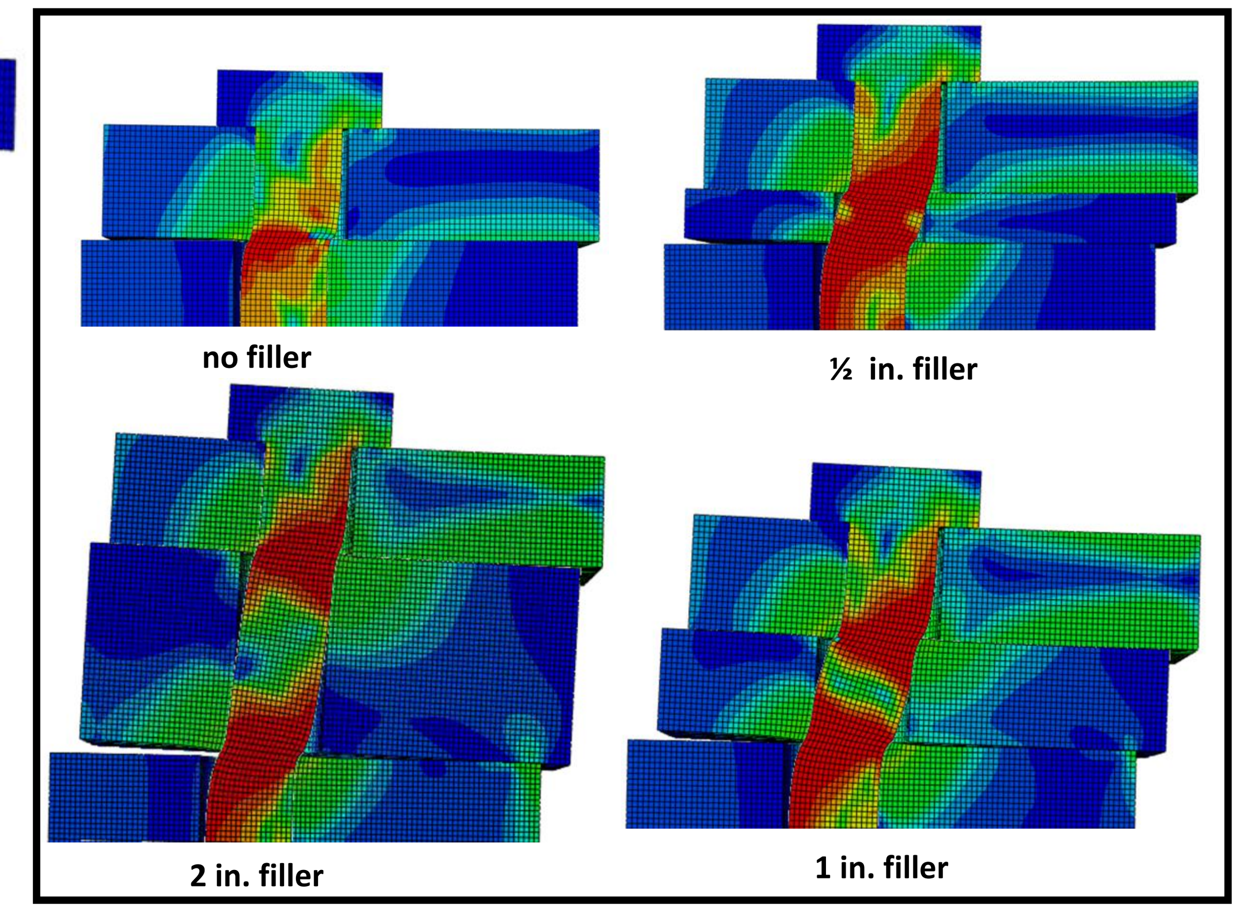
Findings

1- Model verification:

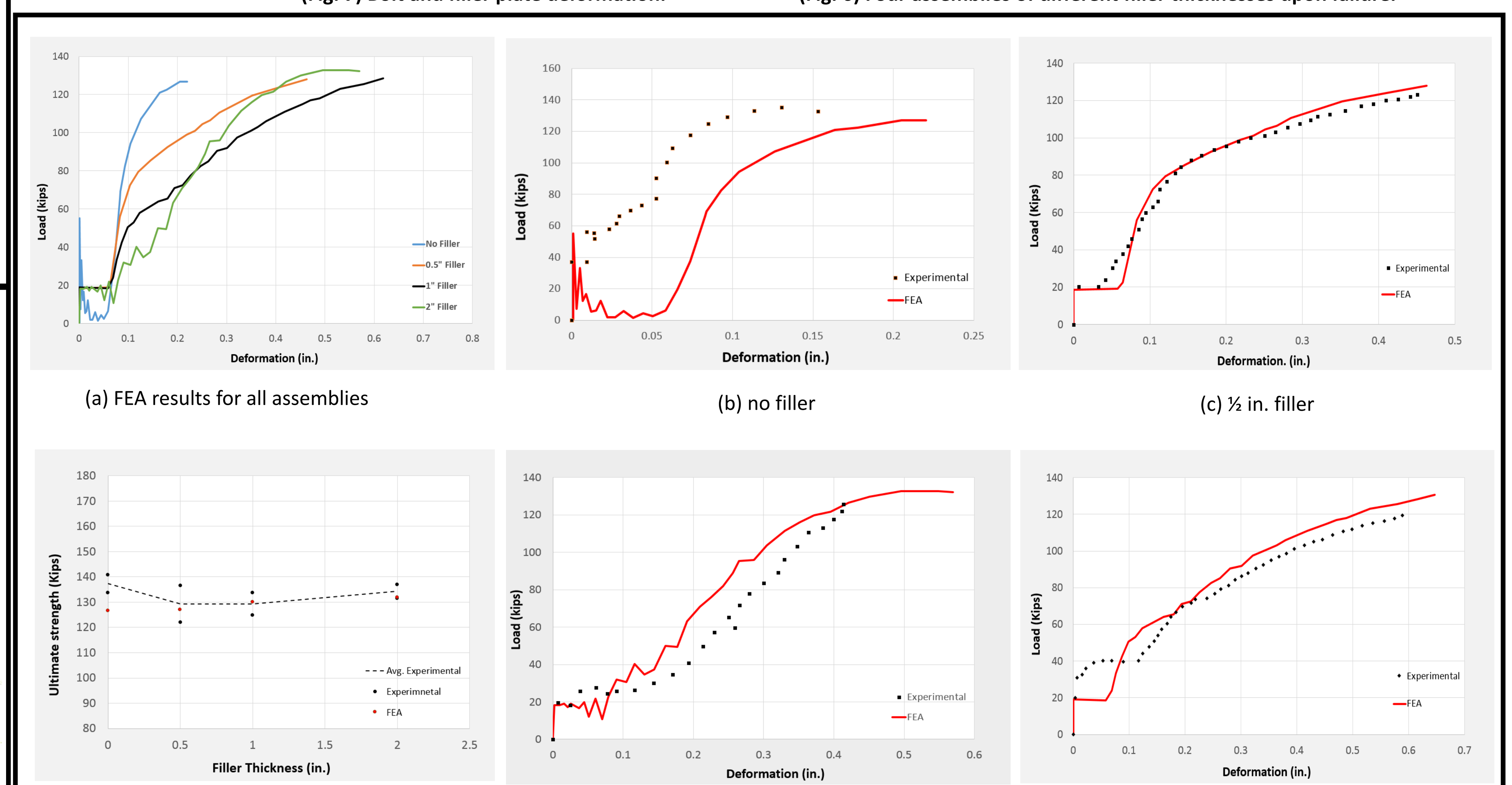
- Four steel filler thicknesses considered: no filler, 0.5 in. , 1 in. and 2 in. as shown in (fig. 6).
- Fig. 7 shows experimental results vs. FEA results.



(Fig. 7) Bolt and filler plate deformation.



(Fig. 6) Four assemblies of different filler thicknesses upon failure.



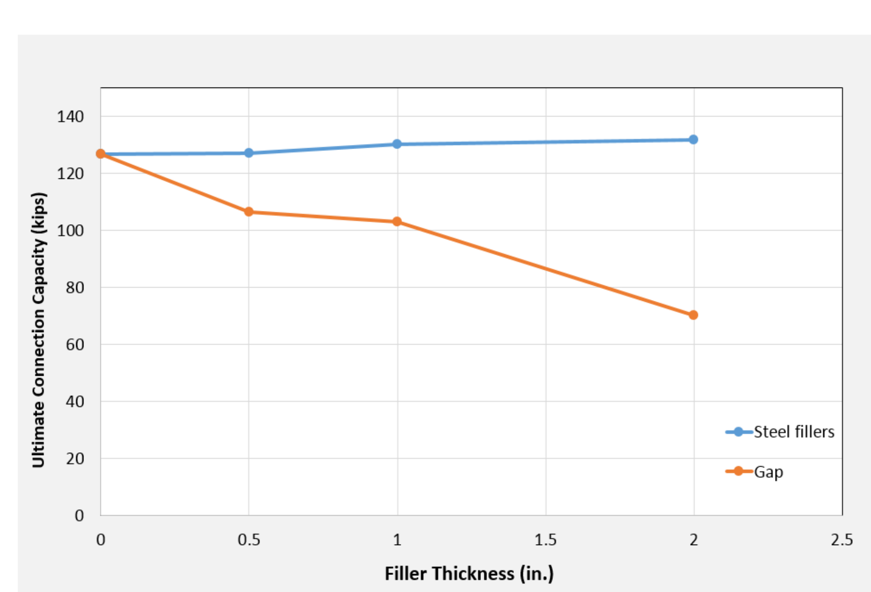
(a) FEA results for all assemblies (b) no filler (c) ½ in. filler

(f) ultimate connection capacity experimental work vs. and FEA. (d) 2 in. filler (e) 1 in. filler

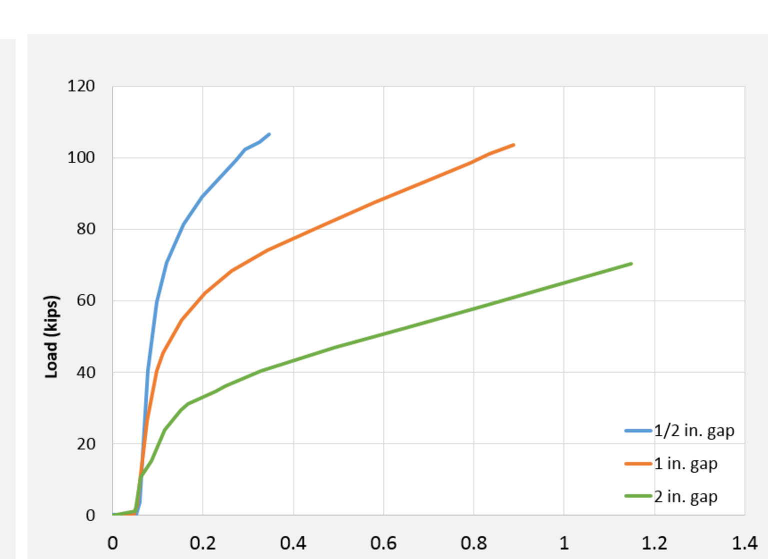
(Fig. 8) FEA results vs. experimental results:

2- Thermal breaks modeling (gap):

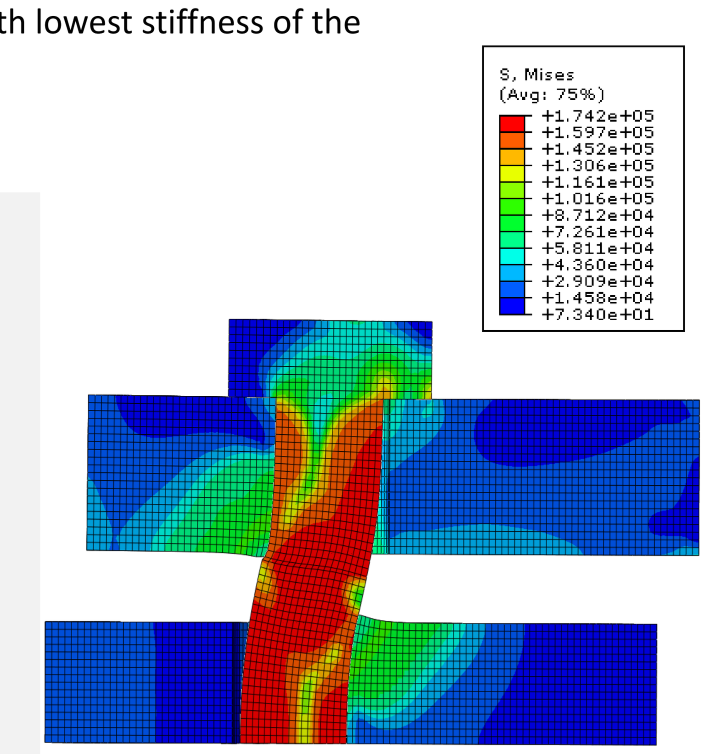
Steel plate fillers were replaced by air gaps between the connected plates to represent an extreme case with lowest stiffness of the bolted connection when fillers have zero load resistance and maximum thermal insulation characteristics.



(Fig. 9) Ultimate connection capacity for air gap vs. steel fillers from FEA.



(Fig. 10) Load vs. displacement response from FEA.



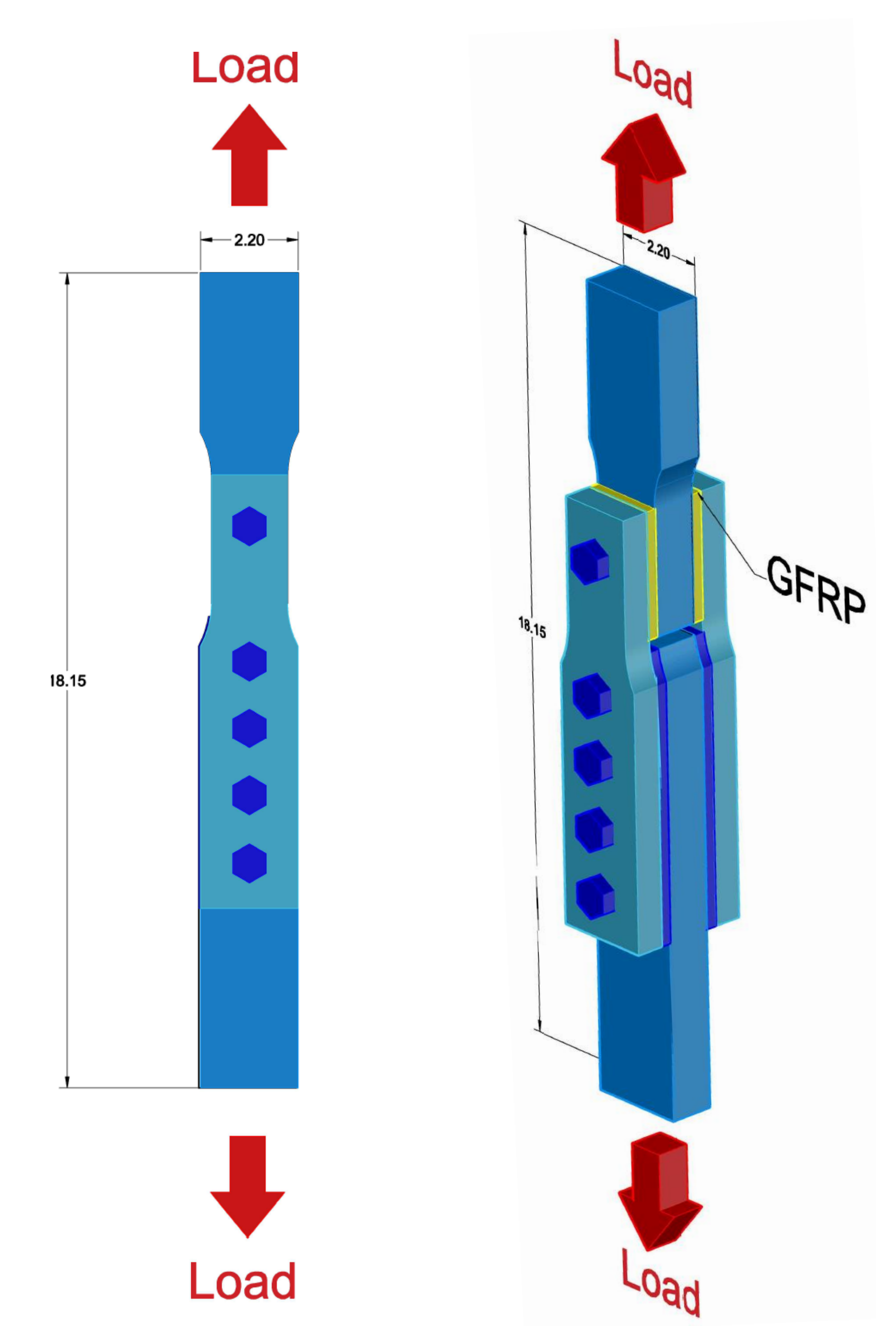
(Fig. 11) Stress contours of steel connection with air gap at ultimate load (FEA).

Conclusions

- FEA results closely match the experimental results for the case of steel fillers.
- For the case of no fillers, FEA results predict a 7.7% lower strength than the experimental values.
- For most of the steel fillers, the FEA showed larger deformation but very close ultimate strength comparing with those obtained by the experimental values.
- Replacing the steel fillers by air gaps reduces the connection capacity by 16%, 21% and 47% for 0.5 in., 1 in., and 2 in. air gap thicknesses, respectively.

Ongoing Work

- Test five steel assemblies with GFRP fillers as shown in (fig. 12).
- Verification of FE model with GFRP fillers



(Fig. 12) experimental test of the GFRP material with steel plates represent the flange of a flexural member in tension

References

[1] Jorge Gustavo Valerio (2007). "Impact Assessment of Thermal Bridges on Residential Buildings Performance", Instituto Superior Técnico, DECivil, Av. Rovisco Pais, 1049-001, Lisboa, Portugal

[2] Dusicka, P. and Lewis, G. (2007). "Effect of Fillers on Steel Girder Field Splice Performance Year 1 Progress Report," Research Council on Structural Connection, Department of Civil and Environmental Engineering, Portland State University, Portland, Oregon, October.