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# Parametric Investigation of PMC Infills Performance under Temperature Variation and Different Contact Restraints

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**Abstract:** This study investigates the structural performance of Polymer Matrix Composite infills (PMC infills) under diagonal compression load by means of numerical analysis with consideration of three important parameters. The three parameters considered in this study are variation of temperature, length of contact and type of support at the connection between infill and frames. These three parameters can greatly affect the performance of the infill panel. Results shown that the strength of PMC panels decreases as the temperature increases, this is due to the polymeric behaviour of fiber-reinforced polymer in the panel. Moreover, when the contact length increases, the strength of panel shows a converging trend. This result could assist in the decision of support type for the FE model.

**Key words:** Compressive, resistance, GFRP, temperature, dependent

## INTRODUCTION

The combined performance of a series of frame structures and infilling walls is a complex, statically indeterminate problem. Attempts at the analysis and design of infilled frames since the mid-1950s have led to several methods. One interesting method proposed by Saneinejad and Hobbs (1995) was to transform the infilled frames into equivalent diagonal strut bracing frames. Jung and Aref (2005) show that the diagonal stiffness and strength of the infill panels depend primarily on their dimensions, physical properties and length of contact with the surrounding structural frames.

During earthquake as the racking load increased on infill frame structures, failure occurs eventually at either the frames or the infill panels. By using Polymer Matrix Composite (PMC) materials new conceptual designs for seismic retrofitting were developed for application in existing buildings by Aref and Jung (2003). The research performed by Jung and Aref reveals that the failure of global buckling is dominant when designing the PMC infill panel.

In previous research, buckling response of infill panel systems under the influence of temperature and stacking sequences of Fiber-Reinforced Polymer (FRP) lamina was studied (Sim *et al*., 2016). In this study, the study focused on the type of support at the connection between infill and frames.

## MATERIALS AND MEHTODS

**Design and experiment of PMC infill:** A basic PMC infill wall system consists of two FRP laminates (skin) surrounding an infill of foam (core). Figure 1a shows configuration and dimensions of a PMC infill panel which consisted of 20 mm core and two 6 mm skin plates with a height and width of 2200 and 2400 mm, respectively. Figure 1b shows the pre-fabricated panel. Properties of core and FRP lamina present in Table 1 (Mivehchi and Varvani-Farahani, 2010; Mott *et al*., 2008; Reed and Golda, 1994; Roylance, 2000).

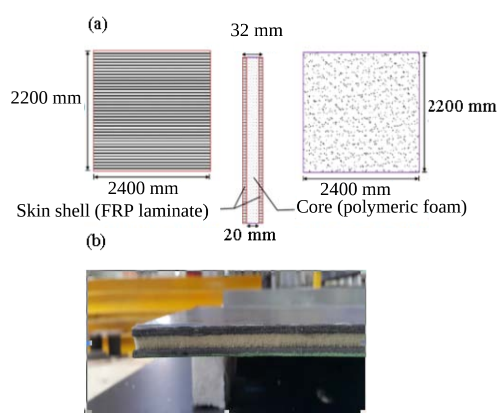


Fig. 1: a) Configuration diagram and b) pre-fabricated PMC infill panel

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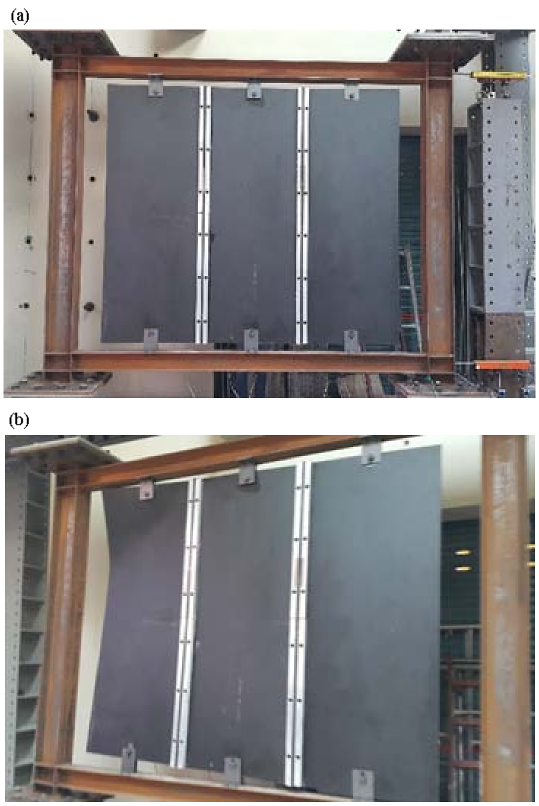


Fig. 2: a) Experiment set-up and b) Buckling failure of PMC infill

Table 1: Mechanical properties of core and PMC Skin at -20-60°C

| Temperature (°C) | -20 | 0 | 20 | 40 | 60 |
|---|---|---|---|---|---|
| **Polystyrene** | | | | | |
| E (MPa) | 130.70 | 125.40 | 120.00 | 113.90 | 110.90 |
| v | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| **Glass fiber reinforced polymer** | | | | | |
| E1(GPa) | 58.30 | 57.80 | 57.00 | 56.30 | 55.30 |
| E2 (GPa) | 16.40 | 16.20 | 16.00 | 15.80 | 15.50 |
| v12 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 |
| G12 (GPa) | 7.80 | 7.70 | 7.60 | 7.50 | 7.40 |
| v12 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 |
| G12 (GPa) | 2.20 | 2.20 | 2.10 | 2.00 | 1.90 |

Figure 2a shows the cyclic lateral loading experimental set-up of infilled frame structure. In this Fig. a PMC panel surrounded by steel frames and horizontal loading on the upper beam was applied. Loads transferred to PMC infill through connection on the upper and lower beam. Figure 2b shows the buckling failure of panel on the upper left side.

However in this study, we studied this buckling failure by means of numerical analysis. The numerical analysis referred to laminate skins with constant thickness and follow a general orthotropic fiber-orientation (Jones, 1975) as following: $(45_5/-45\ /45_{10}\ /-45_{10}/45_5/core/45_5/-45_{10}/45_{10}/-45_{10}/45_5)$.

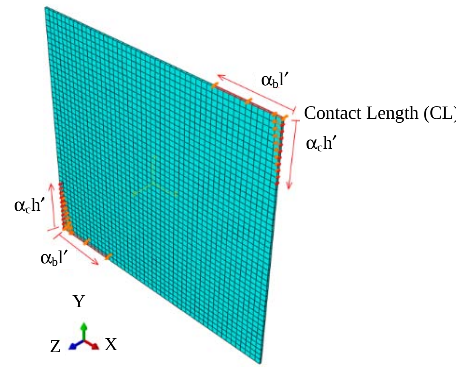


Fig. 3: FE Model of the infill panel in ABAQUS

**Numerical analysis of infill panel:** We study the buckling performances of PMC infill panel by developing a Finite Element (FE) model of infill panel without the surrounding frames in ABAQUS (10). The core sheet layer was modelled with 3-Dimensional solid elements (C3D8). The skin plates were modelled by composite layup of FRP lamina sheets and discretised with quadrilateral shell elements (S4R5). Material properties used for this analysis are given in Table 1. Triangular distributed compression loads were applied along the length of contact between columns and infills ($\alpha_c$h') as demonstrates in Fig. 3. The contacts between beams and infills ($\alpha_b$l') were modelled by three different types of boundary condition (support type) which constrain translational degree of freedoms (dof) as following:

- BC1: constrain translational dof Y-and Z-direction
- BC2: constrain translational dof X-and Z-direction
- BC3: constrain translational dof X-and Y-direction

## RESULTS AND DISCUSSION

**Numerical analysis of infill panel:** We study the buckling performances of PMC infill panel by developing a Finite Element (FE) Model of infill panel without the surrounding frames in.

**Failure mode of panel system:** Buckling mode shape of panel is shown in Fig. 4 for all three boundary conditions studied. Buckling resistance of the panel system is shown in Table 2.

**Effect of support type:** In this case of study, we assume three different types of boundary condition. The buckling strength from this three boundary conditions could be seen in Fig. 5. Resistance strength from the model with BC2 had the highest value. While the other two cases had similar result.

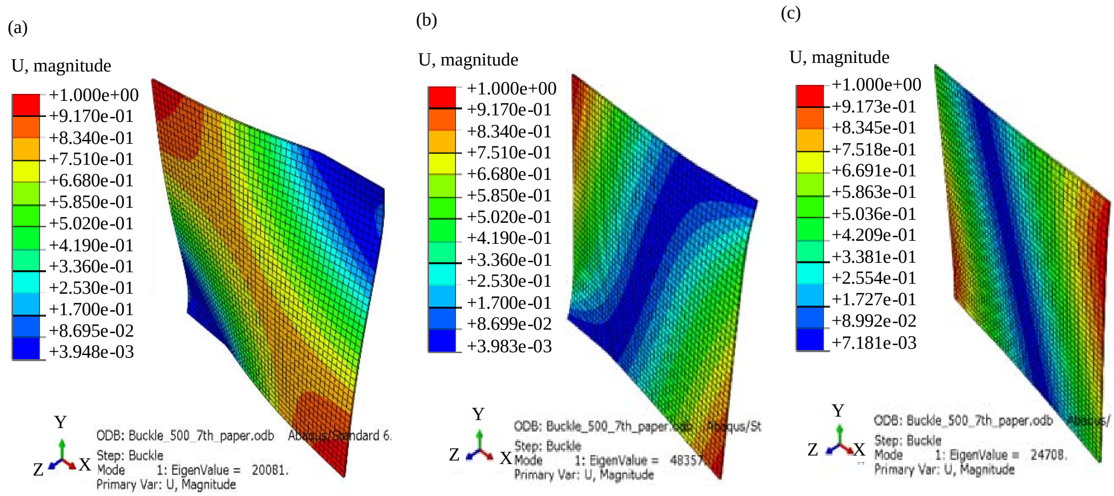


Fig. 4: Buckling failure of infill; a) BC1; b) BC2 and c) BC3

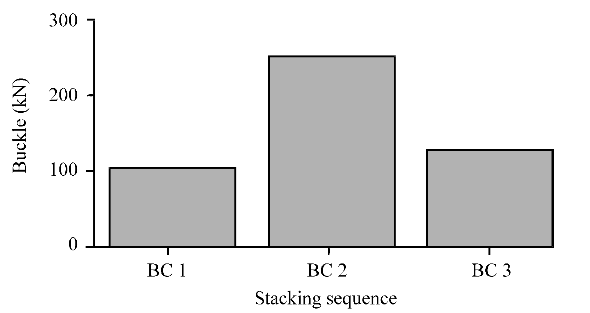


Fig. 5: Buckling resistance in each case of boundary condition

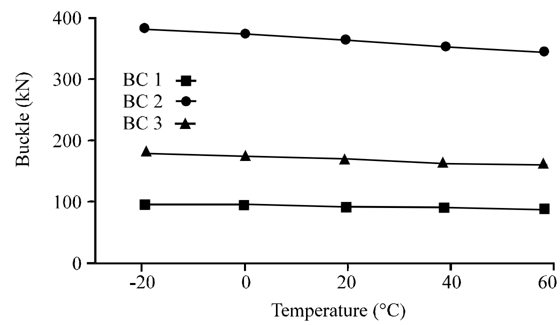


Fig. 6: Buckling resistance in function of temperature

Table 2: Buckling performance of infill panel in each case of BC, contact length and temperature

| C.L[mm]/T[°C] | -20 | 0 | 20 | 40 | 60 |
|---|---|---|---|---|---|
| **BC1** | | | | | |
| 100 | 78 | 76 | 74 | 72 | 71 |
| 200 | 92 | 90 | 88 | 86 | 84 |
| 300 | 100 | 98 | 96 | 93 | 91 |
| 400 | 106 | 104 | 101 | 99 | 96 |
| 500 | 110 | 108 | 106 | 103 | 101 |
| **BC2** | | | | | |
| 100 | 1076 | 1056 | 1033 | 1010 | 989 |
| 200 | 512 | 501 | 488 | 474 | 464 |
| 300 | 388 | 379 | 369 | 358 | 350 |
| 400 | 317 | 310 | 302 | 293 | 287 |
| 500 | 266 | 260 | 254 | 247 | 242 |
| **BC3** | | | | | |
| 100 | 354 | 345 | 334 | 323 | 316 |
| 200 | 224 | 218 | 211 | 203 | 198 |
| 300 | 184 | 179 | 173 | 167 | 164 |
| 400 | 157 | 153 | 148 | 143 | 140 |
| 500 | 136 | 133 | 129 | 125 | 123 |

**Effect of temperature variation:** In Fig. 6, the effect of temperature was introducing on buckling performances of infill panel system. As the temperature increased the buckling strength of panel decreased. BC2 shown the highest performance compare to the other two cases.

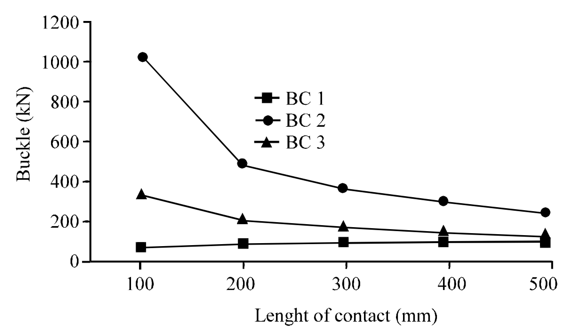


Fig. 7: Buckling resistance in function of contact length

**Effect of contact length:** Figure 7 shows a plot of buckling resistances versus contact length at temperature 20°C. In this Fig. 7, we could observe a converging trend of buckling strength for all three cases. BC1 had the least variation which mean it was the most appropriate boundary condition for this kind of modelling. A plot of normalize decrement rate of buckling strength in each case of boundary condition is shown in Fig. 8. It can be seen that only BC2 shown a unity decrement rate across all range of contact length conditions.

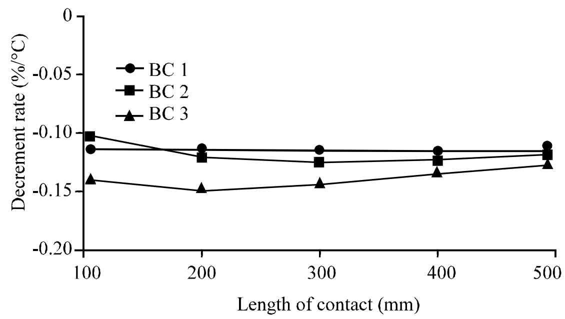


Fig. 8: Comparison of normalized decrement rate of buckling resistance

## CONCLUSION

The study of temperature effect on buckling strength of PMC infills for different cases of boundary condition and contact length was conducted. Result from Fig. 7 and 8 shown that the strength of infill panel for BC2 and BC3 converges to the same value of BC1. This mean that BC1 had the steadiest result which could be interpreted as it was the most appropriate amongst these three models. From this result we could conclude that to model the buckling performance for infill panel, the connection between infill and beam should use the boundary condition where degree of freedom on Y and Z direction is being constrained. Furthermore, increment of temperature decreased the performance of the panels, this is due to the polymeric behavior of fiber-reinforced polymer in the panel.

This study has developed a trend that serves as a framework for further study to determine buckling performance of infill panel by means of numerical analysis. Further study will compare this modeling method with more experimental results to increase their reliability.

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