Study on the influence of openings on the strength and stiffness of CLT walls panels
Part 4: Strain distribution of the experiment using DIC method and comparison with FEM analysis

Keyword:
CLT wall　Opening in CLT
FEM analysis　DIC analysis

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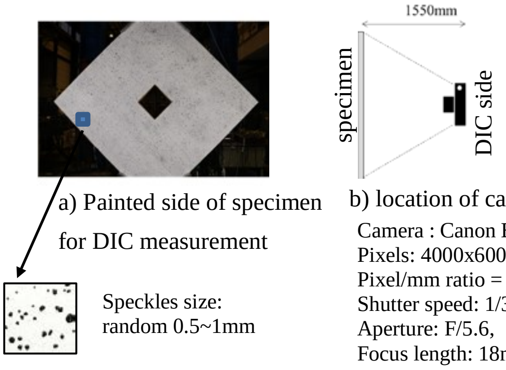
1. Introduction

Visualizing the strain distribution throughout tested structural components provides a better understanding of the internal load paths and the final failure mechanism that may not be immediately obvious from visual observation. The Digital Image Correlation (DIC) method allows a strain distribution field of an entire surface of tested components to be determined as is thus not limited to specific locations such as traditional displacement instrumentation. A comparison of strain distribution obtained using DIC with FEM analysis provides a means of verifying FEM and identify aspects of the model where accuracy can be further improved. The objective of Part 4 of this study is to determine the strain distribution of the tested CLT panels using the DIC method and compare this with the strain distributions obtained from the FEM analysis (discussed in Part 3). In this study, four CLT specimens with a square opening shape and different opening area are considered: A0-0, A2-2, A4-4 and A6-6.

2. Description of DIC set-up

Figure 1 shows the details of the DIC set-up used in the tests. Photos of one side of the panel were taken in RAW format and then converted and analyzed using the DIC Software OPTECAL [1]. The subset size and spacing used were 91 and 30 pixels, respectively.



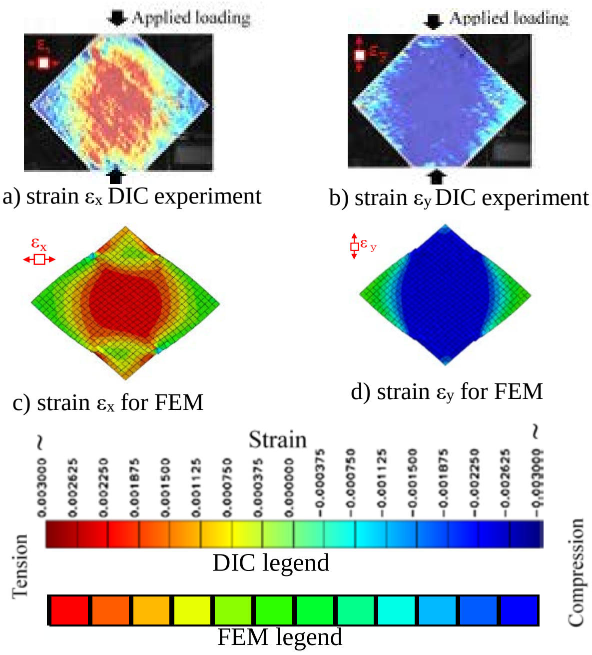
Camera : Canon EOS kiss x8i
Pixels: 4000x6000
Pixel/mm ratio = 3.13
Shutter speed: 1/30.
Aperture: F/5.6,　ISO: 100
Focus length: 18mm

Figure 1: DIC set-up and properties

3. Results and discussion

The results of DIC and FEM can be compared in several aspects; however, this study will only focus on horizontal (ε_x) and vertical (ε_y) axial strain distribution. Although the strain field comparison can be taken at several loading stages, the results shown in this study are pertinent to the point just before reaching maximum load P_{max} (specifically P_{max} minus 50 kN), since at P_{max} brittle failure occurred and an image could not be taken at that point.

Figure 2 shows the vertical and horizontal axial strain obtained using FEM and DIC for Specimen A0-0 (no opening). The legend of strain distribution of DIC and FEM were fixed in order to allow consistent comparison between specimens Overall, the strain distribution is similar in both FEM (Fig 1b) and DIC (Fig 1d) analyses, showing that the response is governed by one main compressive strut, which indicates that the FEM can correctly capture the general stress paths. A quantitative measurement of strain along two section-lines is shown in Figure 2-f) and g). Strains from FEM are generally in good agreement with DIC measurements, except around the opening area where FEM strains are lower. It is thought that some nonlinear deformation occurs at the center of the specimen that is underestimated by the elastic FEM model.



e) strain legend used in DIC and FEM for both ε_x and ε_y

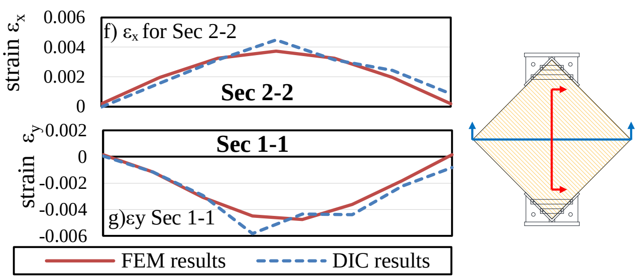


Figure 3: Comparison strain distribution between FEM strain distribution with experiment A0-0

Figure 3 and Figure 4, show the axial strain distribution obtained using DIC and compared with FEM analysis results for panels A2-2 and A4-4, respectively. As shown in Figure34-b) and 4-b), the FEM analysis could capture main strain distribution and the two main

CLT パネルのせん断耐力・剛性に開口が及ぼす影響に関する研究
その４　DIC デジタル画像相関よるひずみ分布と FEM 解析を比較

compression struts around openings, which also observed DIC. The strain values shown in Figure 3-e), 4-f), show similar strain magnitudes for specimens A2-2 and A0-0, respectively. As with A2-2, lower stress concentration around opening is observed in the FEM model compared to the DIC data. As before, it is presumed that there are nonlinear strains around the opening which the elastic FEM model cannot adequately capture.

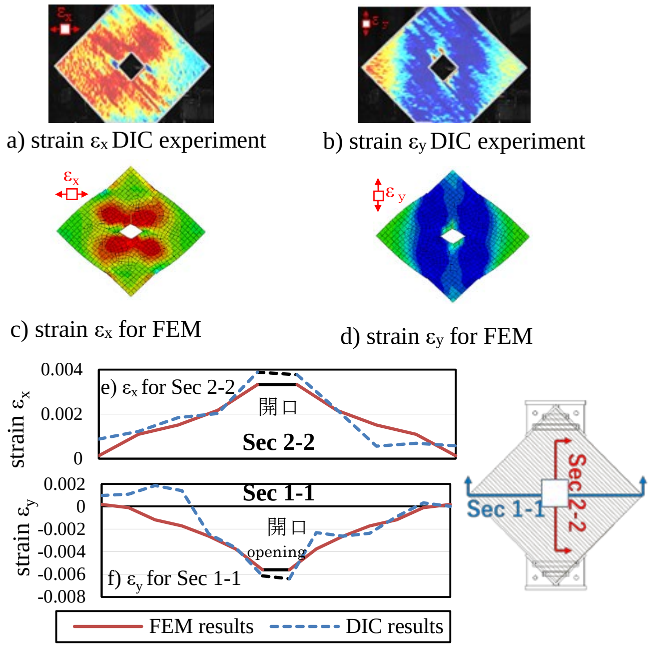


Figure 4 Comparison strain distribution between FEM strain distribution with experiment A2-2

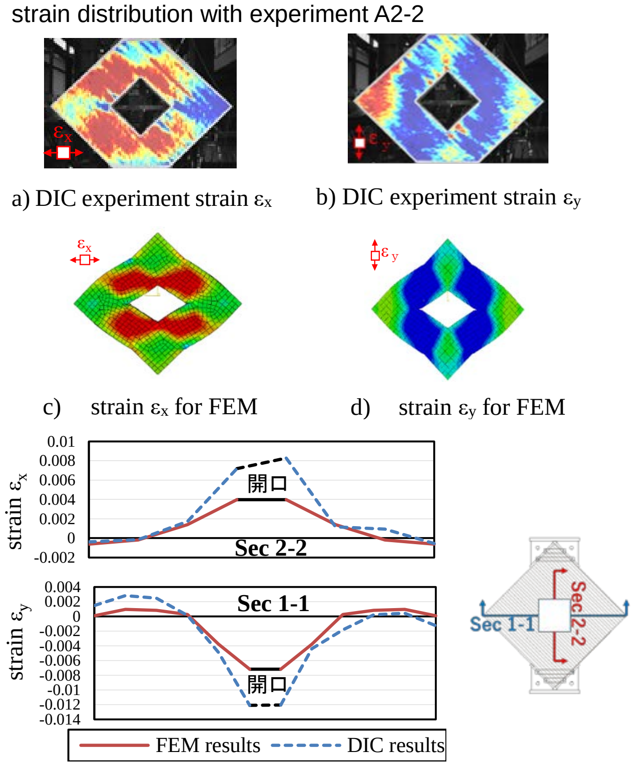


Figure 5 Comparison strain distribution between FEM strain distribution with experiment A4-4

For specimen A6-6 which had the largest opening, the strain distributions obtained by FEM and DIC are in less agreement than the previous panels. The FEM results could capture the main trend of strain distribution for horizontal strain (Figure 6-e), but the strain magnitudes are almost half of that observed in the experiment as determined with DIC. However, for the opposite is seen for vertical strain, where DIC strains were lower in value than those determined from FEM analysis. This discrepancy in values is clearly visible by the differences in color in Fig 6a-6d. This discrepancy can again be justified by the lack of consideration for nonlinearity in the FEM analysis. As the force-deformation response of A6-6 exhibits the most nonlinearity (early in the loading, as shown in the parabolic backbone curve of strength versus drift results in part 2&3), it also has the least agreement to the DIC results.

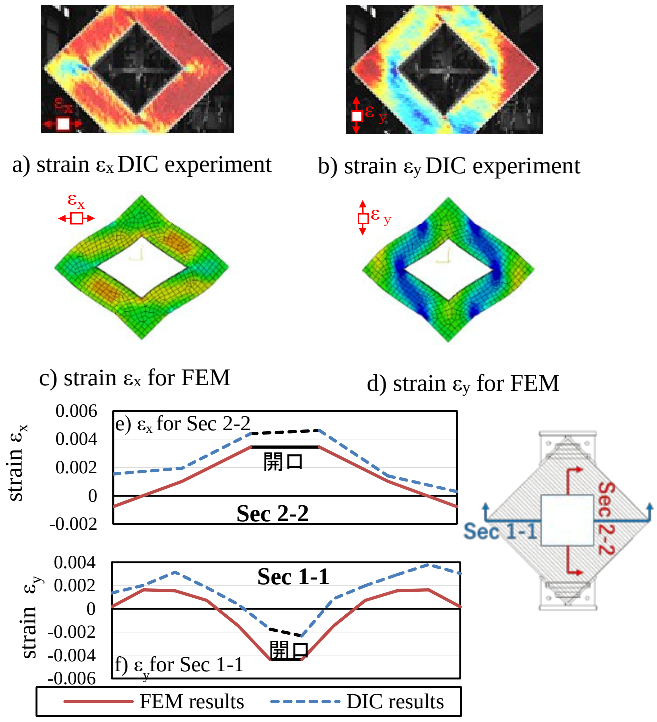


Figure 6 Comparison strain distribution between FEM with experiment Specimen A6-6

4. Conclusion:

In this study, CLT panel strains determined by DIC and FEM analyses were compared resulting in the following main findings:

1- The DIC method could capture the main strain distribution and the two main compression struts around openings.

2- For panels with no opening (A0-0) or a small opening (A2-2), FEM analysis had good agreement of strain distribution and magnitude with that determined using the DIC methodology.

3- As the area of the opening increases (A6-6) the FEM analysis could still capture the main trend of strain distribution but the compression strain magnitudes are significantly overestimated and tension strain magnitudes are underestimated. This difference in strain magnitudes is attributed to an increase in inelastic deformation at the early stages of loading for panels with large openings.

. References:

[1] OPTECAL Digital Image Correlation software 2020

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