NUMERICAL SEISMIC ASSESSMENT OF PRECAST PRE-STRESSED HOLLOW-CORE CONCRETE FLOORS

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1 Introduction

Reinforced concrete buildings have been historically designed and constructed in ways that jeopardize their seismic performance. Particularly, early use of precast pre-stressed hollow-core (PPHC) floors in ductile frames had support connections that were inadequate to accommodate earthquake deformations, making them prone to significant damage, and even collapse, at relatively low drift levels (Fenwick et al. 2010). While improved connection details were developed following past experimental research, concerns regarding the seismic performance of buildings containing PPHC floors have been raised following the 2016 Kaikōura Earthquake. To address these concerns, a campaign of detailed nonlinear finite element (FE) analyses is proposed, with the overall purpose of improving the understanding of the likely behavior of PPHC floors during earthquakes and enhancing the ability to define and/or validate broadly applicable procedures for design and assessment.

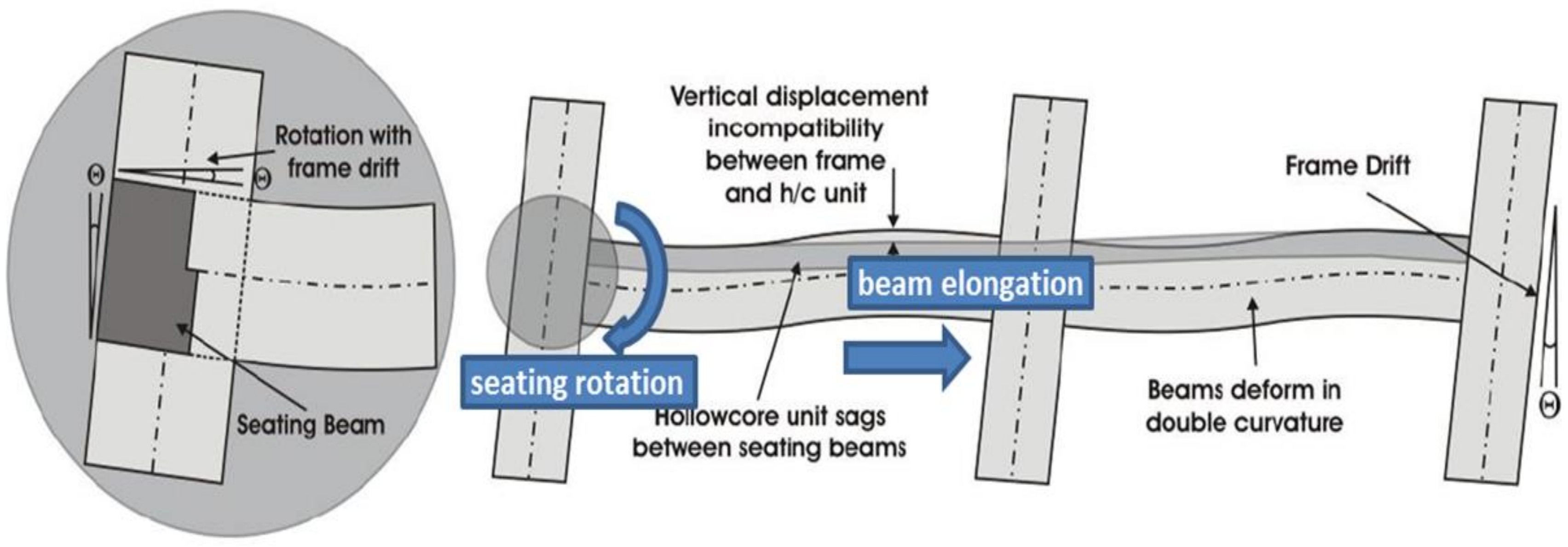

Figure 1. Beam elongation and relative rotation between floor units and support (Courtesy of: Elwood, 2018)

2 Modelling Program

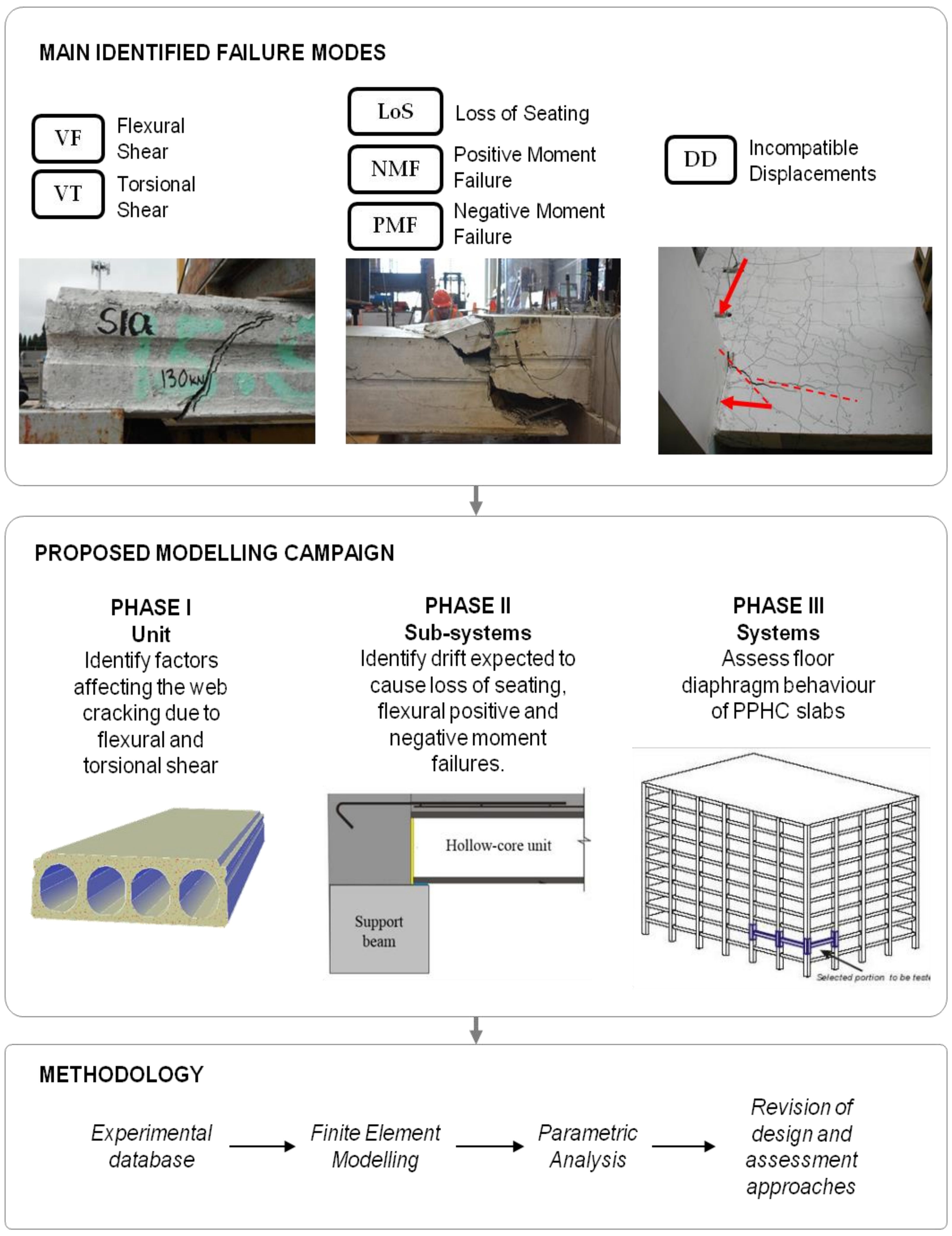

Figure 2. Proposed framework for the FE modelling campaign.

References

Fenwick R, Bull D, & Gardiner D. (2010). *Assessment of hollow-core floors for seismic performance.* Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch, New Zealand.

Nguyen TH, Tan KH, & Kanda T. (2019). Investigations on web-shear behavior of deep precast, pre-stressed concrete hollow core slabs. *Engineering Structures*, 183, 579-593.

Thorenfeldt E, Tomaszewicz A, & Jensen JJ (1987). Mechanical properties of high-strength concrete and applications in design. *Proceedings of the Symposium in Utilization of High Strength Concrete*, Trondheim, Norway, Tapir.

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3 Preliminary results

Numerical approach proposed:

- The total strain crack model was adopted to predict the brittle web-shear failure mechanism.
- The constitutive model was assumed to adopt a brittle function and Thorenfeldt et al. (1987) model for uniaxial tensile and compressive behavior, respectively.
- The Newton–Raphson iteration scheme was adopted with an energy-normalized convergence criterion and tolerance of 10^{-3}.
- The classical Von Mises yielding criterion with strain hardening was used for the pre-stressed steel strands, represented as embedded elements.
- To represent the strands-concrete interaction an equivalent parabolic pre-stress distribution was selected according to the work presented by Yang (1994).

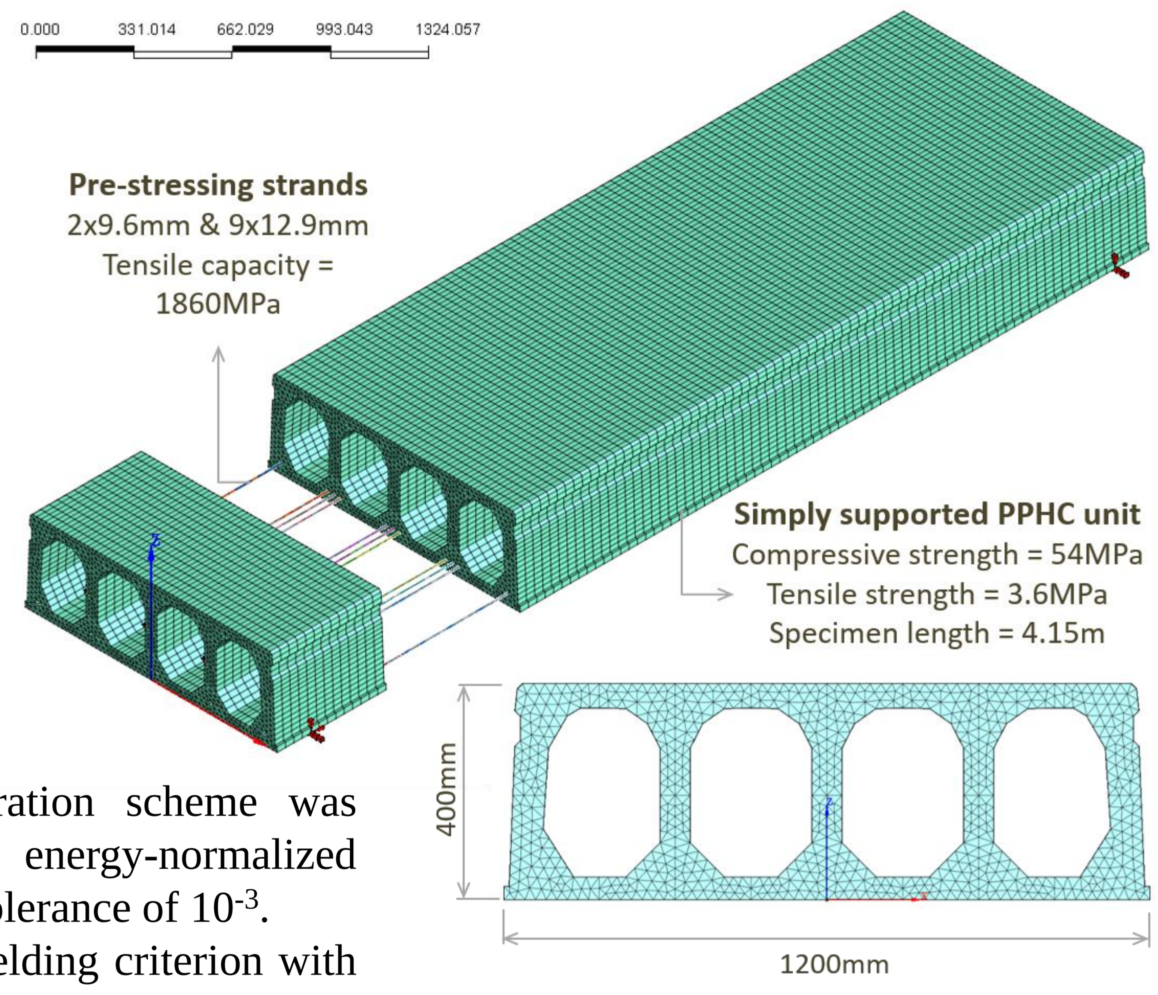

Figure 3. Detailed solid FE model developed for the 400mm depth specimen.

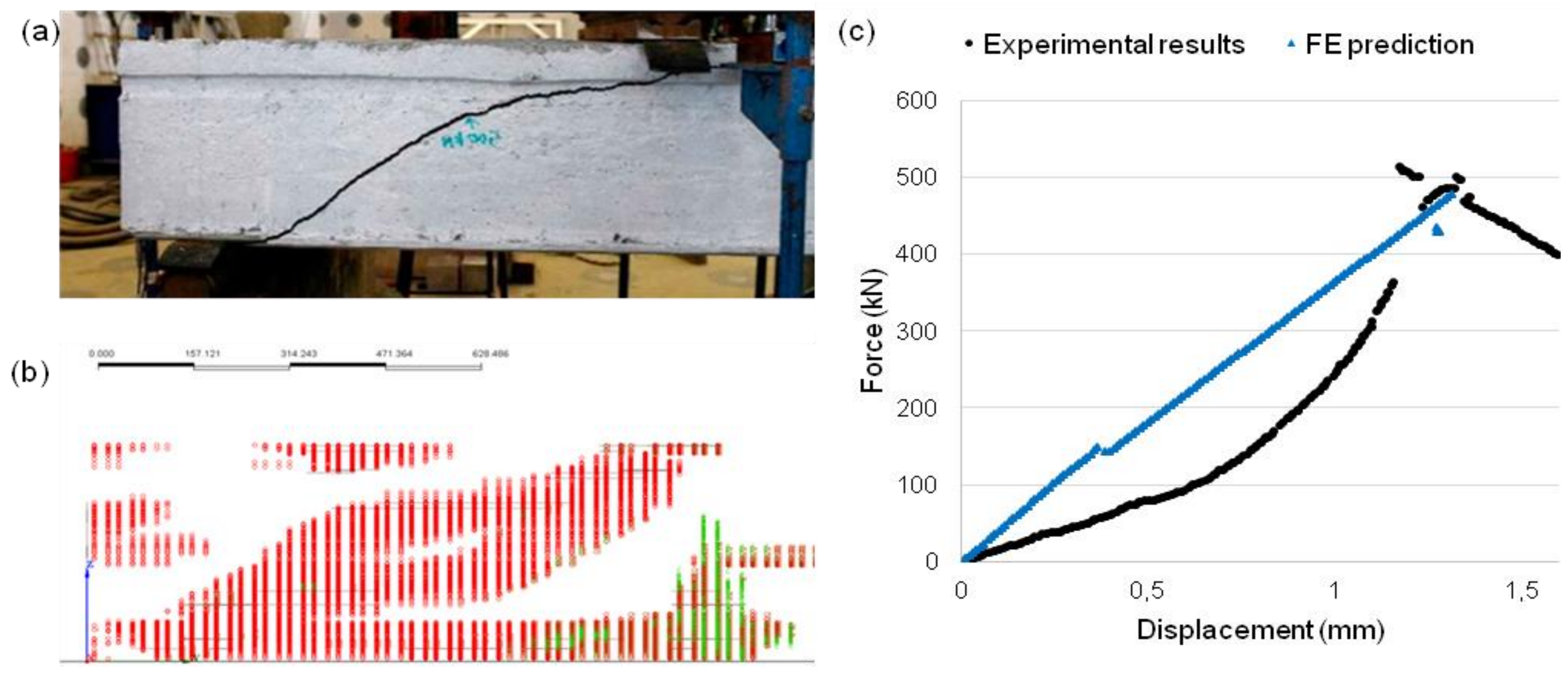

Figure 4. Comparison between experimental and numerical results: (a) failure observed during test (Nguyen et al. 2019); (b) crack pattern at ultimate conditions; and (c) load-displacement relationship.

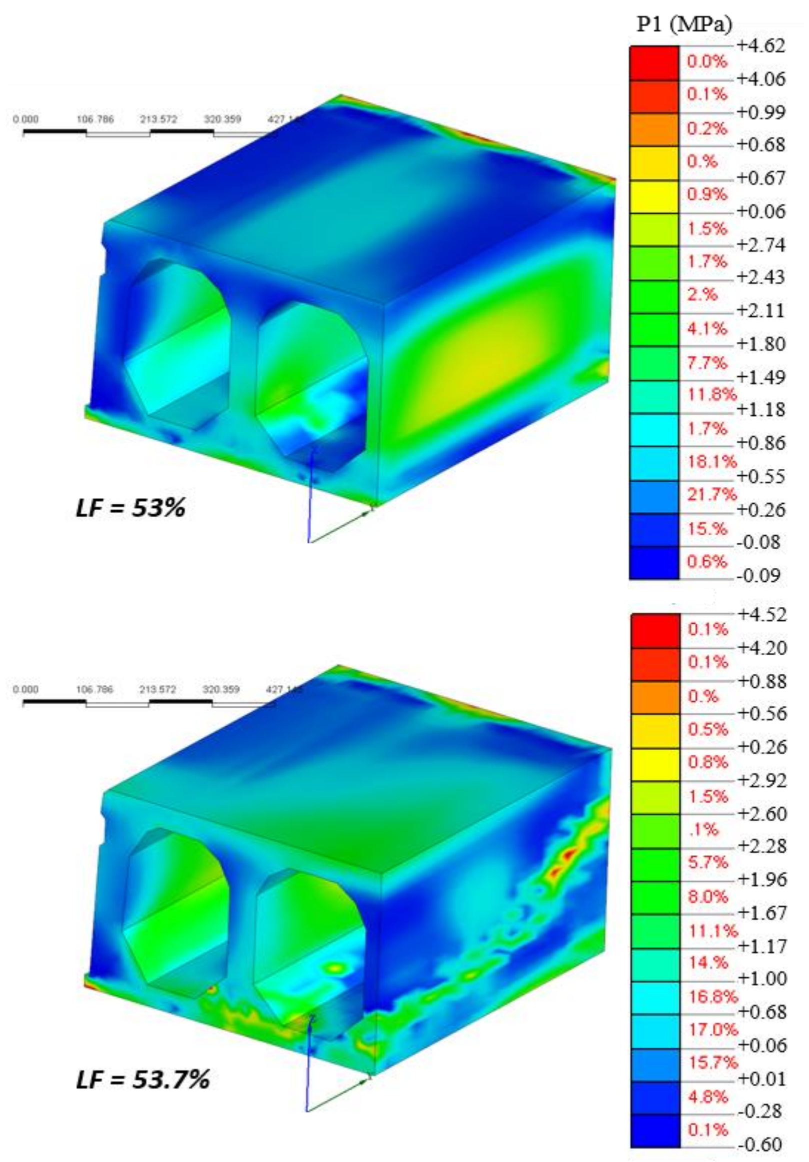

Figure 5. Evolution of principal tensile stresses P1

The principal tensile and compressive strains, crack pattern and shear stress distribution at failure are in close agreement with the collapse mechanism observed in the experimental test (Nguyen et al. 2019). An inclined crack emerges from both principal tensile strains and the numerical crack pattern. Simultaneously, an inclined compressive diagonal strut arises, resulting a predicted failure mode, also confirmed by a cut-off in the shear stress flow.

The differences in stiffness observed in arriving at the peak capacity values are attributed to the presence of rotation and sliding at the supports and/or initial deformations during the test. However, future research will look to better test this theory and quantify more rigorously the reliability of the FE modelling and analysis procedure.

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