Imperial College London

Nonlinear macro-modelling of masonry materials

S07

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1. Introduction

Macro-modelling has been widely used to improve the efficiency of modelling masonry structures. Numbers if authors have proposed different macroscopic models utilising different types of criterions. In this study evaluation of the performance of a model for plate and shells adopting a Rankine-Hill yield criterion [1] is conducted. The composite model was implemented in a MATLAB script and into ADAPTIC through a FORTRAN subroutine, and were used to investigate the robustness and the efficiency of the model at the local level. Numerical simulations using different specimens subjected to various loading and boundary conditions from literatures, along with different sets of material parameters to scrutinise the output of the model.

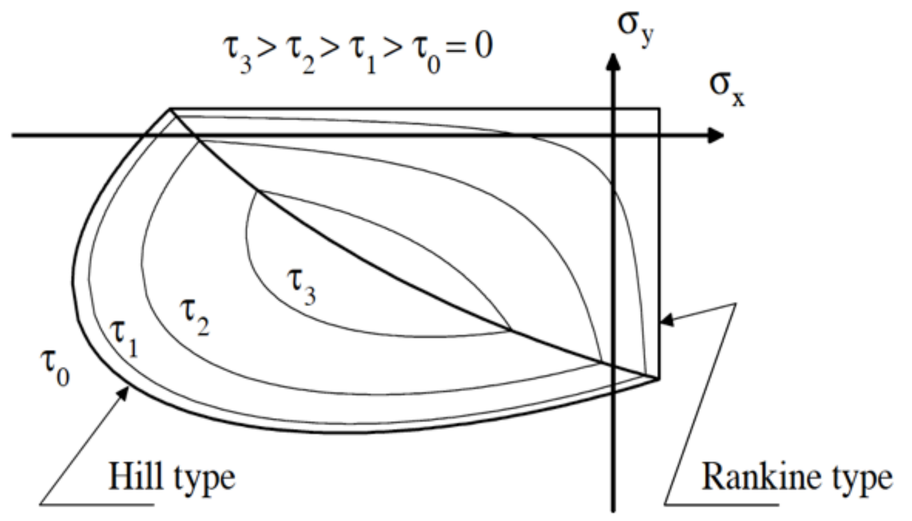

Figure 1: Rankine-Hill Yield surface.

2. Implementation

A Newton-Raphson iteration scheme is used to determine the solution of the local plastic problem along with Kuhn-Tucker conditions for the yield surface selection. Unique strategy is also applied in case for convergence issue at the apex.

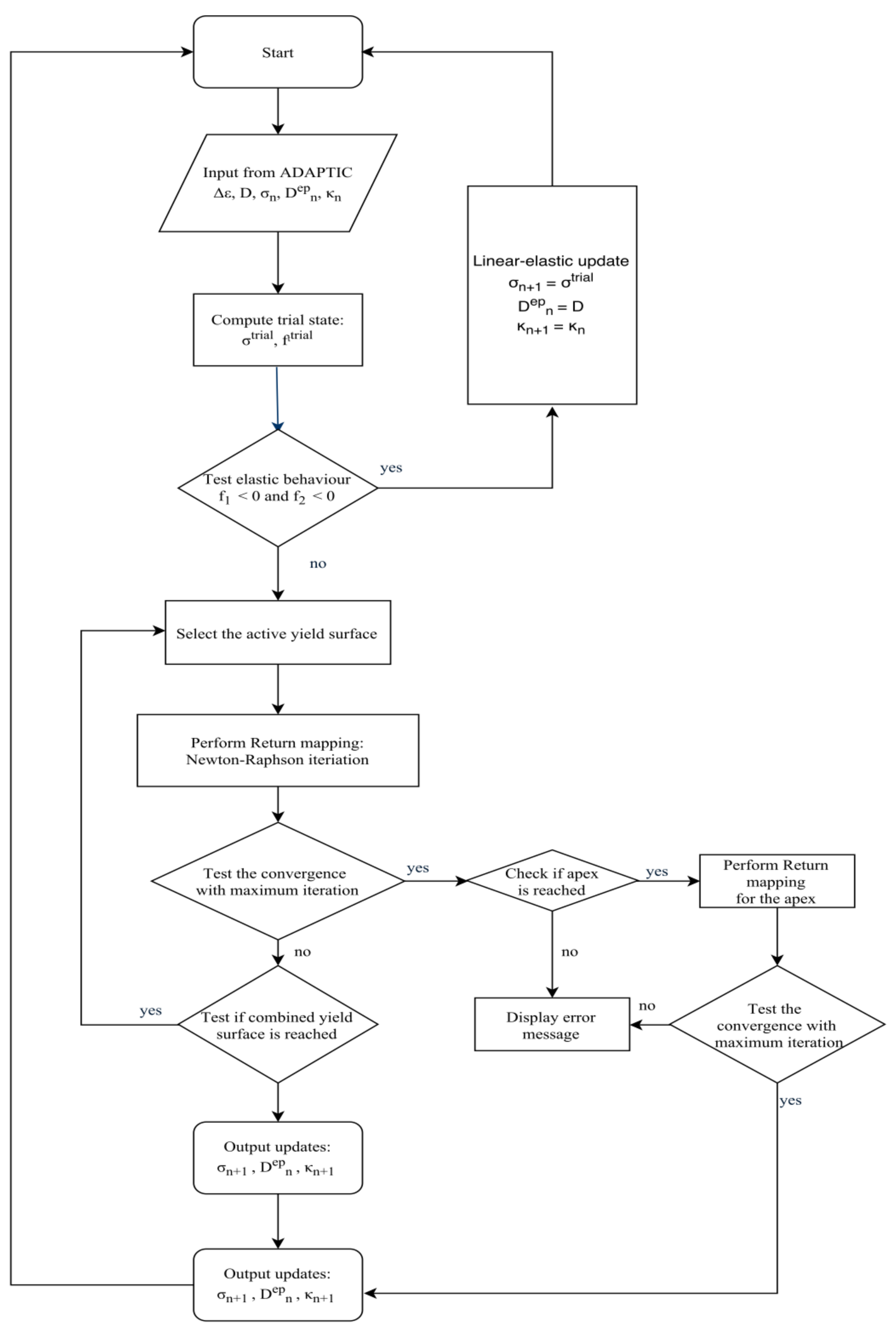

Figure 2: Flowchart of the implementation of the Rankine-Hill Model

3. Robustness of the algorithm

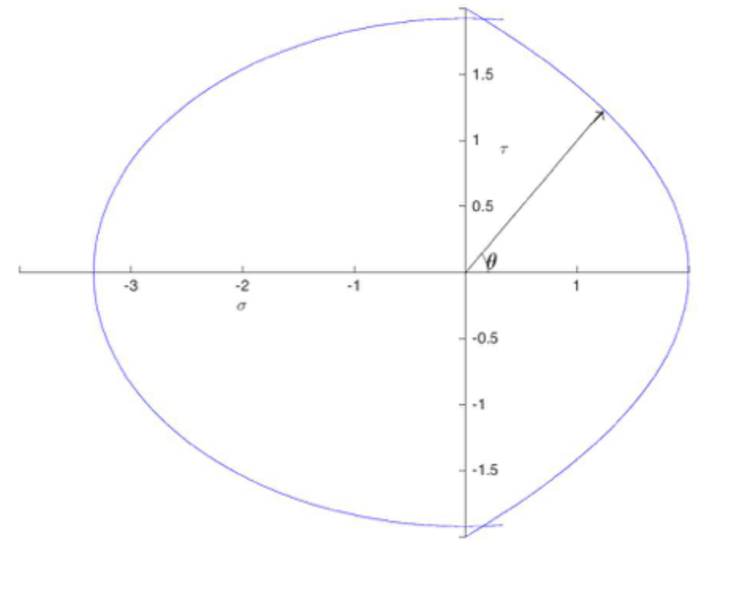

Figure 3: Initial yield surface in σ-τ stress space with polar angle θ

	$R=1\times10^{-6}$	$R=1\times10^{-5}$	$R=1\times10^{-4}$	$R=1\times10^{-3}$
$\theta=0^o$	3	4	4	Fail
$\theta=45^o$	4	4	5	Fail
$\theta=90^o$	7	9	9	9
$\theta=135^o$	7	9	9	9
$\theta=180^o$	7	9	9	10
Time taken (s)	237.9	26.8	2.7	0.3

Table 1: Convergence test results

To examine the robustness of the model in different loading and initial conditions, a test is conducted at the local level combining with different load path (θ), step of strain increment and initial stress state corresponding to the angle of the load path. The test is over when the target strain has reached and the test value is the maximum number of iteration required for a convergent solution.

The results suggest:

- The max iteration required is overall stable with increasing strain increment
- The compressive regime requires more iterations to achieve a convergent solution than the tensile regime.
- Convergence issues occurs in the tensile regime when the strain increment is 1×10^{-3} in this study. It suggests that problem in the algorithm has to be addressed.

4. Role and influence of material parameters to the response of the model

There are three unique inelastic material parameters (α, β and γ) in the Rankine-Hill criterion along with other conventional material parameters to describe the physical properties of the material and are being tested in this study. For illustration purposes only the responses with different value of the three unique parameters are demonstrated below:

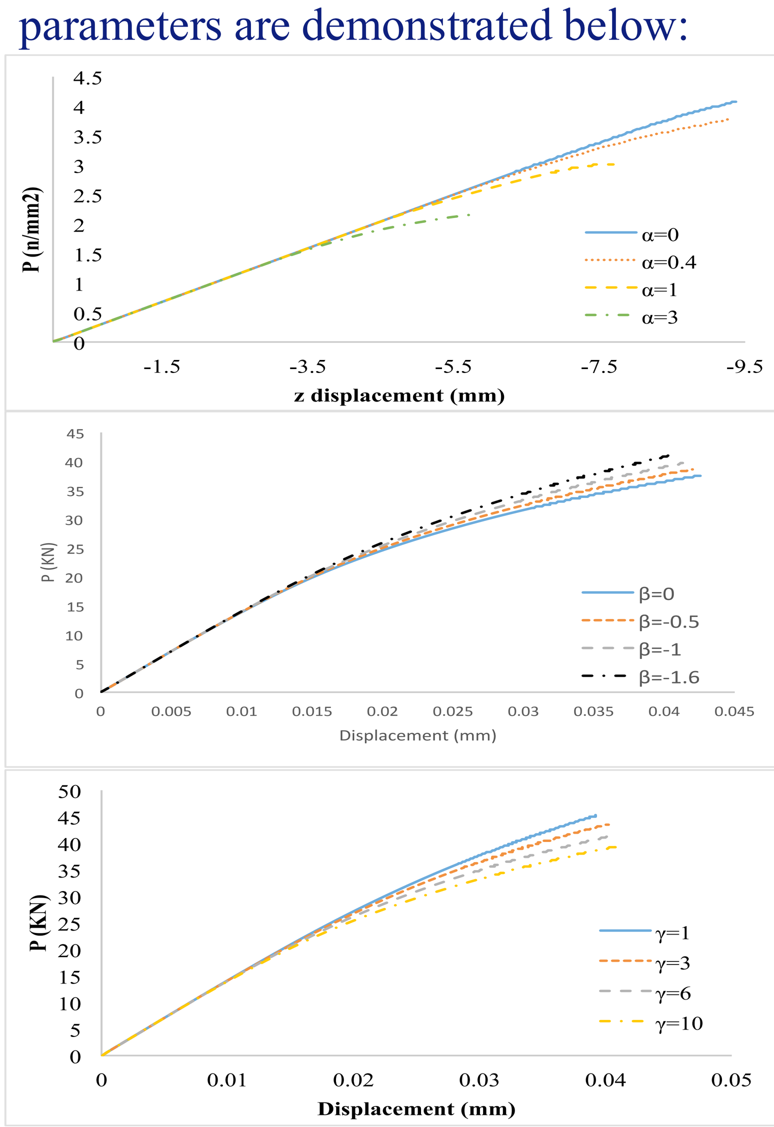

Figure 4: Responses of the model with different values of α, β and γ

- With larger value of α the response of the model becomes softer. Due to the fact that α is the measure of shear stress contributes in the failure surface of the tensile regime.
- With larger magnitude of β the response of the model becomes stiffer. Due to the fact that β is the measure of the coupling effect of the two principle stresses in the failure surface of the compressive regime.
- With larger value of γ the response of the model becomes softer. Due to the fact that γ is the measure of shear stresses contributes in the failure surface of the compressive regime.

5. Findings of the numerical simulations

Three distinct sets of numerical studies [2] [3] [4] with different types of loading and boundary conditions are conducted to investigate the limitation of the proposed constitutive model under various initial conditions.

Test 1:

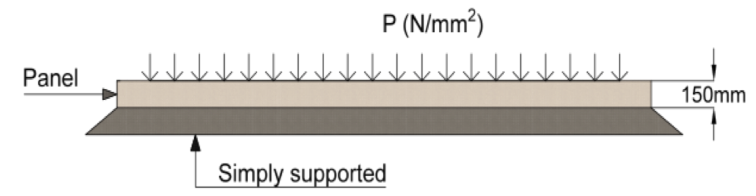

Figure 5: Layout and the loading case of test 1

Test 2:

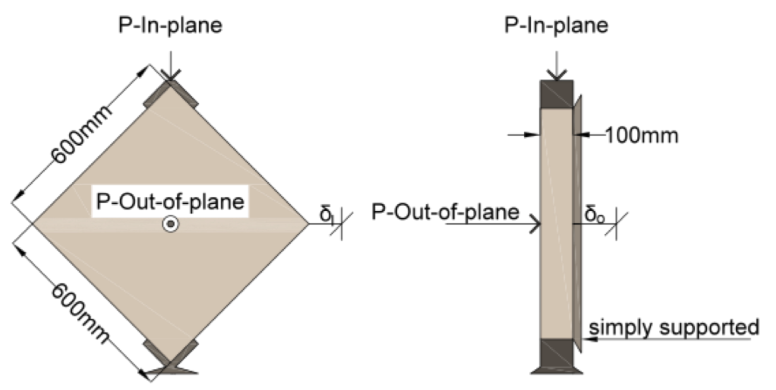

Figure 6: Layout and the loading case of test 2

Test 3:

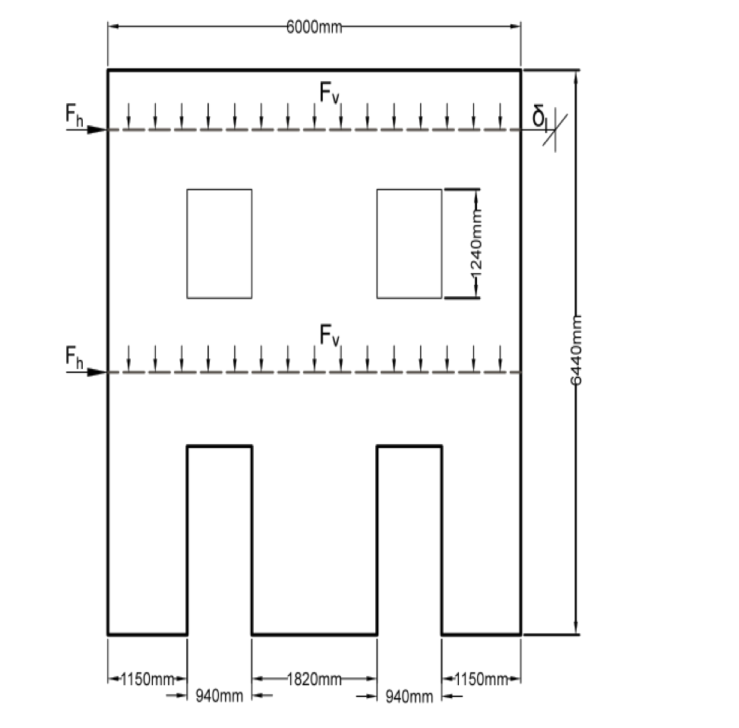

Figure 7: Layout and the loading case of test 3

Major findings from the numerical studies:

- The numerical results and response of the simulations generally agree relatively well with the experimental results, especially when the material parameters are determined directly from the experiment specifically for the Rankine-Hill type criterion.
- Convergence issues constant occur during modelling out of plane loading of specimens and reducing load increment does not solve the problem.
- Altering the value of the uniaxial tensile strength also shows reduction in robustness of the model.
- The value of the uniaxial tensile strength influence the response massively.

6. Conclusion

The model was found to be robust at the local level with expected convergence issue when being subjected to large strain increment. The influence of each inelastic material parameters are tested by varying their values, and the results fall in our expectation. From the findings of the numerical studies the convergence issues have been addressed. Further development on the algorithm should lead to a more robust model.

7. Acknowledgements:

I would like to take this chance to express my thanks of gratitude to my project supervisor and personal tutor Dr, Lorenco Macorini who gave me this valuable opportunity to participate on this research topic, numerous expect advise he gave on my project and those precious time that he spent with me on debugging my implementation.

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