Numerical Simulation of FRP Retrofitted Masonry Wall by 3D Finite Element Analysis

Md. Ataur Rahman
Civil Engineer, PhD
Research Student
Hokkaido University, Japan.
Ataur107@yahoo.com

Ataur Rahman, born 1975, received his civil engineering degree from BUET, Bangladesh

Tamon UEDA
Professor
Hokkaido University
Sapporo, Japan
ueda@eng.hokudai.ac.jp

Summary

This paper presents a simplified macro-mechanical models for both brick-mortar and brick-FRP interface in masonry wall. Model equations for Finite Element Analysis are chosen in such a way that only primary variable in those equations is the internal strain that comes from the incremental strain as input parameter during the loading steps of FEA. The interface is proposed as a zero thickness plane element where the brick unit itself is of 20-nodes solid element and FRP as 8-nodes shell element. The model equations were derived from phenomenological concept of load-reaction for masonry shear wall that can fully capture both the pre-peak and post-peak behavior of masonry wall. Model equations were carefully formulated for loading, unloading and reloading that can be experienced during the loading process. Modern concept of Elasto-Plastic and Fracture(EPF) model for non-linear plasticity is implemented in those equations for work-hardening behavior of the constituent materials and interface, where as the softening process itself was translated through non-linear equations that conform some of the experimental stress-strain curve. Finally the results from the analysis are compared with the experimental data that are available on some authentic literatures and they show good agreements. Some discrepancies were observed due to absence of sufficient experimental clarity. After successful completion of the analytical part of this study, a comprehensive experimental work of our own will be followed.

Keywords: *3D FEA, EPF model, FRP strengthening, Masonry shear wall, Pre-peak and Post-peak behavior.*

1. Modeling of Interface Behavior

In this study, brick-mortar interface was modeled as zero thickness plane elements of 16 nodes and 4 Gauss points. This element are then inserted either in horizontal plane between two adjacent units or in vertical plane (*Fig.1*). This element is modeled in such a way that it can capture all the three modes of failure [1] i.e. Mode I, II and III. At any instant, there are two stresses components acting on each Gauss point as shown in *Fig.2*. Among these two stresses, one is normal to the interface (σ_n) and the other is shear (τ) acts along the plane of interface. To model bond between FRP and brick, same interface element is used with different constitutive laws. The model equations are segmented into 4 components-linear elastic part, non-linear work hardening part [2] followed by a non-linear softening branch and at the end remaining strength as residual as shown in *Fig. 3*. All models have equations for both loading and unloading. Depending on the state of normal stress e.g. tension or compression, the interface model is divided into four cases namely tension model, tension-shear model, compression model and compression-shear model. As for instance the compression-shear model is given below. All other models can be found in the original paper.

https://doi.org/10.2749/222137809796078559

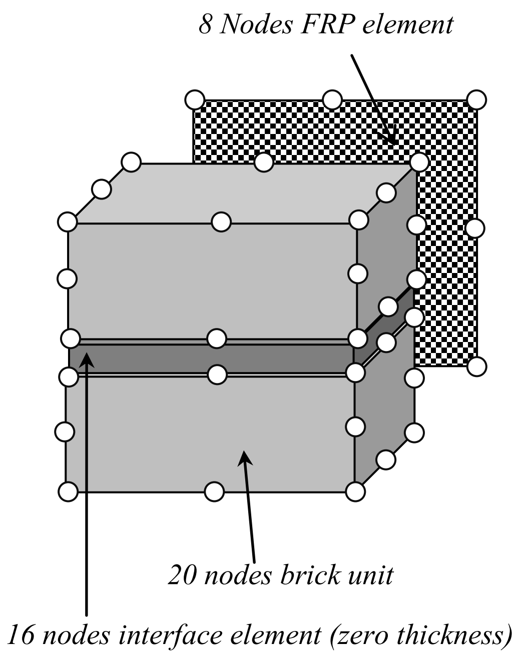

Fig. 1: Modeling for masonry units

1.1 Compression-Shear Model

The shear strength under compression is calculated by Coulomb Eq.1. The effective shear stiffness is not constant but vary with the change in compressive stress and is given by Eq. 2. The residual shear stress is the order of friction only as interface cohesion is assumed to vanish.

$$\tau_u = c + \sigma_n \tan\varphi \quad (1)$$

$$G_{eff}^{masn} = 731.8\sigma_n + G_e^{masn} \quad (2)$$

$$\gamma_u = \tau_u^0 / E_e^{masn} \text{; here } \tau_u^0 = c \quad (3)$$

$$\gamma_e = 0.33 \times \gamma_u \text{ and } \gamma_{\max} = 25 \times \gamma_u \quad (4)$$

And in the equation,

$\tan\varphi = 0.745$ *i.e* $\varphi = 36.68^\circ$; c = 0.811 *MPa*

Residual shear strength can be given by,

$$\tau_{res} = \sigma_n \tan\varphi_{res} \text{ ; } \tan\varphi_{res} = 0.7 \quad (5)$$

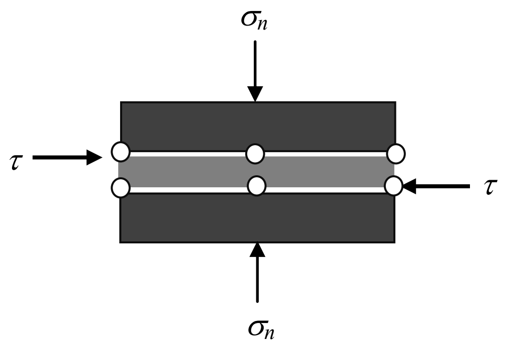

Fig. 2: Stress Component at Interface

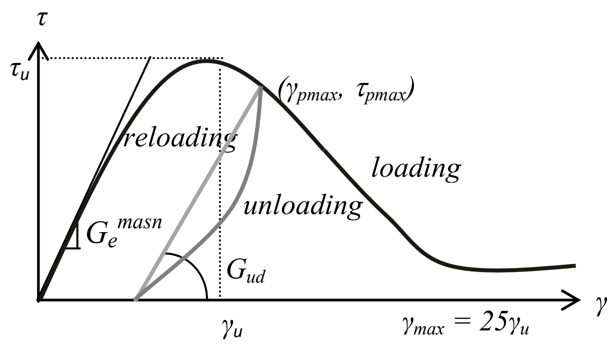

Fig. 3: Shear stress-strain relation under compression

2. Model Verification

All the model equations are verified for FE analysis and also for available experimental results. Most of the cases they show good agreements with both numerical and experimental results. Full scale analysis of walls were also carried out and compared with walls tested by Vermeltfoort et al.[1].

3. Discussion

The prime objective of this study is to come up with some decisive models that can fairly simulate both the pre-peak and post-peak behavior of masonry wall with some phenomenological explanation of load transfer and failure mechanism at ultimate load. It was not our aim to reproduce of some experimental results. To this aim this study is quite successful at this stage.

4. References

[1] LOURENCO P. B., J. G. ROTS, "*Multisurface Interface Model for Analysis of Masonry Structures*", ASCE Journal of Engineering Mechanics, Vol.123, No.7, July 1997, pp.660-668

[2] OKAMURA H, MAEKAWA K, PIMANMAS A, "*Nonlinear Mechanics of Reinforced Concrete*" ISBN 0-415-27126-6, First published 2003.