SIZE EFFECT IN BRICK MASONRY WALLETS

B. K. Raghu Prasad[1], Omer Bin Nasir[2], Amarnath K[3]

[1]*Professor, Dept of Civil Engineering, Indian Institute of Science, Bangalore, India*
[2]*Assistant Design Engineer, Prasad Consultants, Bangalore, India*
[3]*Professor and Head, Department of Civil Engineering, The Oxford College of Engineering, Bangalore, India*

Abstract

In the present paper, results of non linear finite element analysis of Brick Wallets have been presented. The non linear technique for analysis is described. The size of the brick wallets has been varied and overall compressive strength of the brick wallet is determined to study the size effect in brick masonry. As compared to size effect in concrete the behavior of size effect in quasi brittle material like Brick Masonry is not much understood due to its complexities and non homogeneity. The stress strain curves for different wallet sizes are compared. The peak stresses from stress strain curves for all sizes are compared and variations are discussed. The work is carried out for two combinations of bricks and cement mortar. Firstly, strong brick – weak joint (western conditions) is studied which has shown a reduction in strength as size increases. The latter case is for weak brick – strong joint (Indian conditions) where there is not much significant size effect.

Keywords: *Non linear finite element analysis, Size effect, Brick wallets*

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1. INTRODUCTION

A brick wallet is a composite continuum of bricks and cement mortar joints. A brick is a walling unit whose form may be generally defined as rectangular prism of a size that can be handled conveniently with one hand[1]. The strength of masonry depends on various factors such as strength and height of unit, composition and strength of mortar, relative deformation characteristics of unit and mortar, thickness of mortar joint, type of bond, workmanship, etc[2]. It is possible to reproduce the behavior of brick masonry by utilizing the material parameters obtained from experiments and using actual geometric details of both bricks and joints[3].

Although elastic and inelastic behavior of masonry made out of bricks, stones or even concrete blocks appear to be very familiar and obvious, it is really not so. As knowledge or information grows awareness about things not known, also make it look complicated. In the last few decades, theory of composites, law of mixtures, fracture mechanics of Quasi brittle materials have been developed enormously. At the same time they have revealed complexities not known, such as size effect. The effect of overall size of the masonry block is yet to be explored. Only a tool such as FEA has been so helpful to understand them.

Although size effect in a quasi brittle material like concrete is well known[7], a little may be known about a brick masonry wallet. In the absence of thorough experimental investigations which can really reveal the size effect in brick wallets, non linear finite element analysis can throw some light. In the present study, non linear finite element analysis has been carried out on Brick Wallets for different sizes.

The larger the difference between modulus of elasticity of units and mortar, the lesser is the overall compressive strength of masonry[4]. In western parts of the world, bricks are very strong and stiff compared to mortar joints. This is due to higher quality of bricks and improved brick manufacturing processes which are in practice there. In India, bricks are of poor quality. Therefore to obtain good strength of masonry, the mortar used for joints in masonry are made very strong and stiff comparatively. In the present work, both strong brick-weak mortar(western conditions) and weak brick-strong mortar(Indian conditions) have been studied.

2. FINITE ELEMENT ANALYSIS

To study the effect of size in brick masonry, brick masonry wallets of different sizes have been modeled in commercial finite element software ANSYS. The dimensions of bricks are 210mm×70mm×100mm. In the present study, 3 sizes of brick wallets with 10mm joint thickness are taken for analysis viz Wallet A(430mm×390mm), Wallet B(870mm×790mm), Wallet C(1310mm×1190mm). The model is meshed using 4 noded quadrilateral elements which have 2 degrees of freedom on each node. Plane stress analysis is carried out. The size of Brick wallet is varied with constant width to depth ratio that is equal to 1.1. Here three sizes of Brick wallets with 10 mm joint thickness are taken for analysis. The corresponding stress-strain curves are plotted with values obtained from ANSYS.

2.1 Assumptions

Bricks and mortar are assumed to be isotropic. The whole brick wallet is assumed to be non homogenous. Common nodes are taken at brick-mortar joints. Model is considered to be in a state of plane stress. Bottom edge of the wallet is assumed to be fixed i.e. displacements are constrained to be zero. Deflection increment is constant for all sizes.

2.2 Procedure for Non Linear Analysis

In the present work, analysis is done by deflection control method. A Brick Wallet comprising of bricks and mortar joints is modeled in ANSYS 10.0. Corresponding material properties are assigned to both bricks and joints separately. 4 noded plane stress(with thickness) elements with 2 degrees of freedom per node are used. Starting with zero, deflection is incremented on top edge of model and corresponding load is determined. Those elements in the model which have reached their limiting stress(compressive or tensile), are removed i.e. Young's Modulus of those elements will be made equal to 1×10^{-6}. After removing the elements, the same deflection as on which the elements failed is applied to the model. This is only for first step. Corresponding load is calculated. Now some more elements will reach their ultimate stress. Again these elements are removed and deflection is incremented to next value and corresponding load is calculated. This process is carried out till all the elements have failed or till the solution does not converge. This procedure gives non linear response curve.

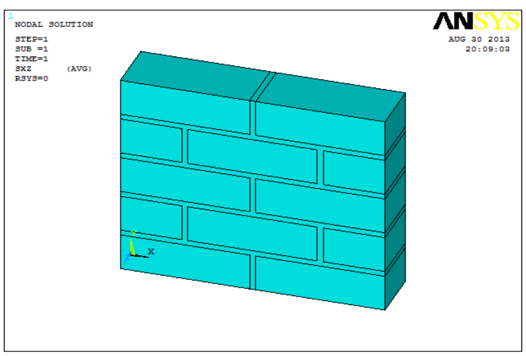

Fig 1: Wallet A (430mm×390mm)

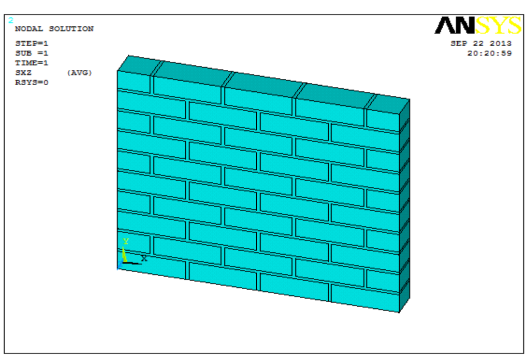

Fig 2: Wallet B (870mm×790mm)

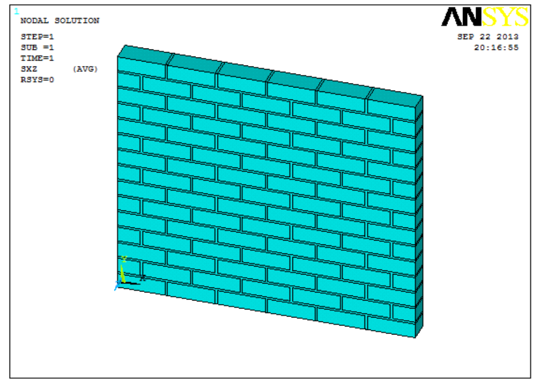

Fig 3: Wallet C (1310mm×1190mm)

The properties of bricks and cement mortar for both the combinations are presented in Table 1 [5].

Table 1: Properties of brick and cement mortar

	Strong Brick – Weak Joint		*Weak Brick – Strong Joint*	
Properties	Brick	Cement mortar	Brick	Cement mortar
Young's Modulus	5000 N/mm^2	2000 N/mm^2	2000 N/mm^2	5000 N/mm^2
Poisson's ratio	0.2	0.15	0.2	0.15
Density	2×10^{-6} kg/mm^3	2.2×10^{-6} kg/mm^3	2×10^{-6} kg/mm^3	2.2×10^{-6} kg/mm^3
Compressive strength	8.5 N/mm^2	5 N/mm^2	5 N/mm^2	8.5 N/mm^2
Tensile strength	0.85 N/mm^2	0.5 N/mm^2	0.5 N/mm^2	0.85 N/mm^2

3. RESULTS AND DISCUSSIONS

From non linear finite element analysis, the values of peak stress of brick wallets are obtained from Figure 4 and Figure 5. The obtained values are the compressive strength of the brick wallets which are presented in Table 2.

Table 2: Compressive strength of Brick Wallets

	Strong Brick – Weak Joint		*Weak Joint – Strong Joint*	
	Compressive strength(N/mm^2)	Maximum Strain	Compressive strength(N/mm^2)	Maximum Strain
Wallet A	4.56	0.001282	2.57	0.001282
Wallet B	4.21	0.001139	2.55	0.001392
Wallet C	3.98	0.001134	2.52	0.00126

From Figure 4, for strong brick – weak joint wallet, it is observed that, as size of the wallet increases, the overall strength of wallet decreases. This is due to weak joint phenomenon. As size increases, the number of weak links i.e. joints become more. The smaller the size of the masonry the stronger and stiffer is its behavior. Most failure of elements is due to failure in joints. Strength of masonry depends on joints, but they play a minor role in contribution to the overall strength of the masonry.

From Figure 5, for weak brick – strong joint, as the size increases the linear portion of the stress strain curves for different sizes overlap each other. As size increases there is a small decrease in overall strength of wallet. Sudden failure for large size is observed.

As each failed joint is removed, two edge surfaces, each of the two adjacent bricks become free to deform thus degrading the stiffness. More number of such joints as the size increases, causes the non linearity in the stress strain response and further to decreased overall strength.

Softening of material becomes less as the size of wallet is more. Wallets become brittle as the size of the wallet is more.

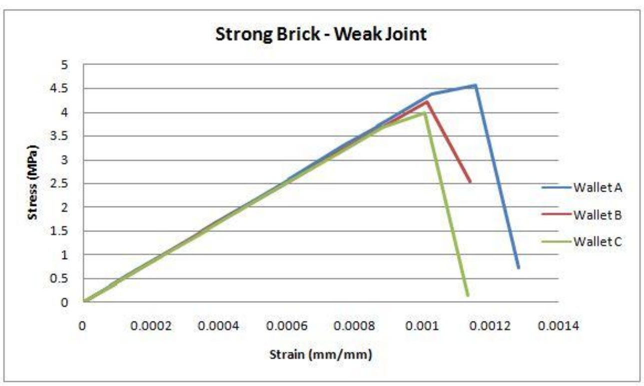

Fig 4: Comparison of Stress Strain curves SB-WJ

Fig 5: Comparison of Stress Strain curves WB-SJ

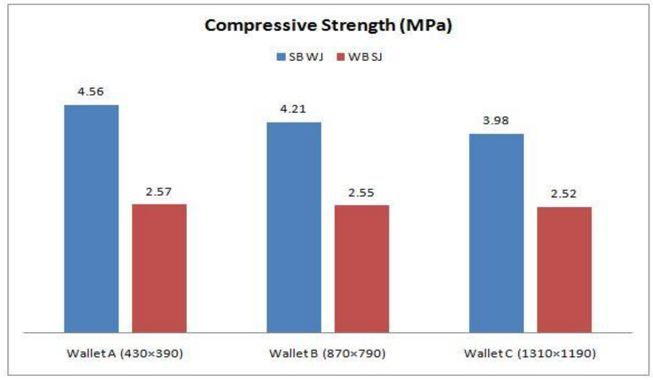

Fig 6: Strength Comparison for different sizes

For strong brick - weak joint, it is observed that there is a reduction of 6 – 8 percent of overall strength as the size is increased. For weak brick – strong joint, there is a reduction of 2-3 percent of the overall strength as the size is larger (Figure 6). The latter case is gives less reduction comparatively, as the joints are strong and stiff compared to bricks.

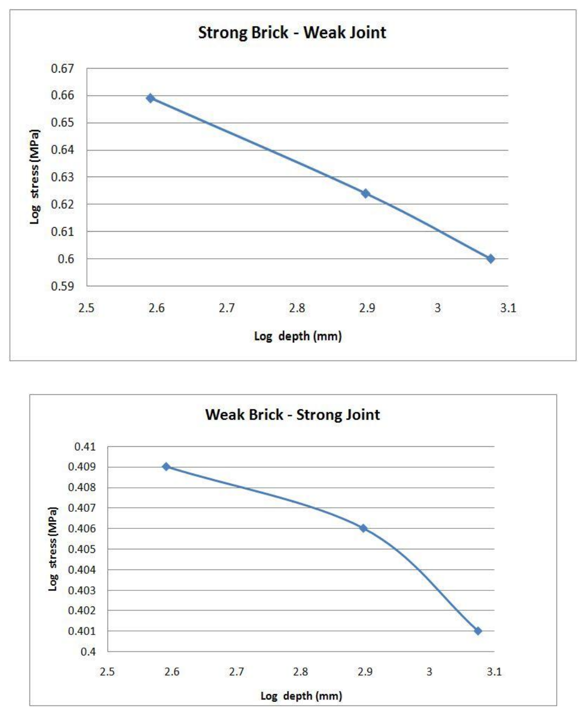

Figure 7: Universal size effect law

Figure 7 shows the graph of logarithm of maximum stress in a wallet vs logarithm of depth of the same wallet. The universal size effect law was given by Bazant[7] according to which the there should be a decrease in stress as depth increases. For strong brick – weak joint, the curve is almost linear. For weak brick strong joint, the cuvature is more, comparatively. Hence the latter case is much closer to Bazant size effect.

4. CONCLUSIONS

As the overall size of the brick masonry with strong brick – weak joint increases, the compressive strength of the masonry reduces. It may be attributed to the Weibull's effect which is the weakest link hypothesis. As the number of joints increases, the number of joints which fail also increases and then the overall strength decreases. Whereas in brick masonry with weak brick – strong joint, although there is reduction in compressive strength, the reduction in compressive strength due to failure of more number of joints may not be the cause. However, the universal size effect law proposed by Bazant[7] is valid for brick masonry wallets also.

The reduction in the overall strength for weak brick – strong joints joint is much less compared to strength reduction for strong brick – weak joint. It is also observed that the overall strength of the brick masonry for any combination (strong brick weak joint or weak brick strong joint) is closer to 50% of the compressive strength of the units(Bricks).

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