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Simulation of the Walls Dynamic Behaviour by the Modelling of the Block-Mortar Set

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ABSTRACT

This work looks to contribute to the study of the walls stability. It's based on the comparisons of simulations of the dynamic behaviour of some walls built from different combinations of the block-mortar set. These comparisons concern essentially the answer of the walls to the external forces through the determination of their dynamic amplification factor. At the end of the analysis of the simulation results, walls built from the compressed earth blocks and the earth mortar seem to resist better to external forces than walls built from all others block-mortar associations which we used in this work.

Keywords: *Wall, Block, Mortar, Compressed earth blocks, Concrete, Breeze blocks, Cement, Finite Element Method, Amplification dynamic factor.*

1. INTRODUCTION

The earth is always used by men as a building material since years ago in its constructions [1]. In order to perform the mastering of theirs security conditions, many researchers are working on the behaviour of walls built from this material [2]. The work done here aims to improve the dynamic study of houses and tries to show out again the qualities of the houses built from Compressed Earth Blocks (CEB), on the dynamic point of view with regard to external forces like earth-quark for example.

The paper has the following organization: firstly, we make the modeling of the block-mortar set by an association mass-spring-damper. Afterwards, we present the method used to resolve the system of the dynamic equations. The solving of those equations allows computing the dynamic amplification factor (DAF) of much kind of walls. According to the reference [3], the DAF is among parameters which can inform deeply about the stability of a construction.

2. MODELLING OF A WALL

2.1 Wall Morphology

The block and the mortar are among the most important elements of the wall masonry. A wall can be represented by the following figure 1 [3, 4]:

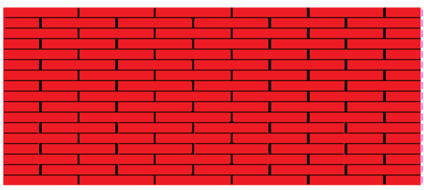

Figure 1: Wall outline

On this figure 1, one can see the way some blocks are joined to others through the mortar. In order to study a wall, we will model the block-mortar set by an association an association mass-spring-damper. The unit of this set is shown in the figure 2.

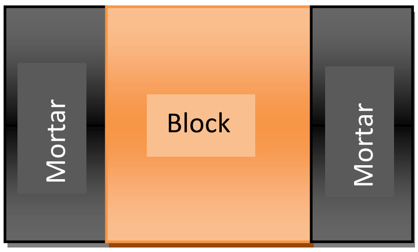

Figure 2: Unit of the block-mortar set in a wall

2.2 Modelling of a Wall

The block-mortar set can be modeled by an association of mass-spring-damper [4;5]

2.3 Motion Equations of a Wall

A motion equation of a wall modeled by an association of mass-spring-damper has the following general form [6]

$$M\ddot{x} + C\dot{x} + Kx = F(t) \qquad (1)$$

Where:

x is the degree of freedom in physical space,
M is the mass matrix,
C is the damper matrix,
K is the stiffness matrix,
and F(t) the vector of external forces.

The simulation of the dynamic behaviour goes to the use of numerical methods to resolve the system (1) of motion equations. For that, the Finite Element Method (FEM) is the most effective method which is ran [7] With this method, triangular elements are used for blocks and also for mortar [8] Often, the modal analysis is used when the FEM is employed in the resolution of those equations. This method is exposed in the reference [9]. It consists to go from the physical space to the mode space in which the system of motion equations is resolved. After that, the inverse transformations are realized to come back in the physical space. If we suppose that the external force is harmonic, in order to go from the physical space to the mode space, we can write in the space of the physical coordinate we have:

$$x(t) = qe^{j\omega t}.$$

For each mode, we have:

$$x_i(t) = \phi_i \; q_i, \qquad (2)$$

Where ϕ_i is the modal matrix, q_i is the mode i. To resolve the equations (1), we search first for the solution of the homogeneous equation and after thus, the solution of the particular solution of the inhomogeneous equation. The solution of the homogeneous equation in mode space has the form:

$$q_i(t) = e^{-\xi\omega_i t}\left(A_i \cos\omega_{ai} t + B_i \sin\omega_{ai} t\right) \qquad (3)$$

Where:

$$\omega_i^2 = \frac{\phi_i^t K \phi_i}{\phi_i^t M \phi_i} \qquad (4)$$

is the self throb.

The resonant throb of the damped system is:

$$\omega_{ai} = \omega_i \sqrt{1-\xi_i^2} \qquad (5)$$

The damped matrix is written as:

$$C=[2\xi_i m_i \omega_i] \qquad (6)$$

Where

ξ_i is the damped factor.

The solution of the homogeneous equation in the space of the real coordinate is given by the following relationship:

$$x_1(t) = \sum_{i=1}^{m} x_i(t) \qquad (7)$$

Where

m is the total number of degrees of freedom.

The search of a solution of the inhomogeneous equation, by the modal analysis, goes to the following system:

$$\phi_i^t M \phi_i \ddot{q}_i + \phi_i^t C \phi_i \dot{q} + \phi_i^t K \phi_i q_i = \phi_i^t F(t) \qquad (8)$$

We can write:

$$f_i(t) = \phi_i^t F_i(t),\; m_i = \phi_i^t M \phi_i,\; c_i = \phi_i^t C \phi_i \qquad (9)$$

Like this, equation (9) becomes:

$$\ddot{q}_i + 2\xi_i \omega_i \dot{q}_i + \omega_i^2 q_i = \frac{1}{m_i} f_i(t) \qquad (10)$$

We can also write:

$$q_i(t) = Y_i e^{j\omega_f t}, \text{ and } f_i(t) = \phi_i^t F_0 e^{j\omega_f t} \qquad (11)$$

Where

Y_i, and $f_i(t)$ the components of F_0 are complex numbers. The motion equation of mode i in the harmonic regime is finally written:

$$-\omega_f^2 Y_i e^{j\omega_f t} + 2j\xi_i \omega_i \omega_f Y_i e^{j\omega_f t} + \omega_i^2 Y_i e^{j\omega_f t} = \frac{1}{m_i} f_i(t) \qquad (12)$$

We have:

$$Y_i = H_i(\omega) Y_{io} \qquad (13)$$

With:

$$H_i(\omega_i) = \frac{1}{\left[1-\left(\frac{\omega_f}{\omega_i}\right)^2\right] + j\left(2\xi_i \frac{\omega_f}{\omega_i}\right)} \qquad (14)$$

The static participation factor of the i mode is:

$$Y_{io} = \frac{1}{m\omega_i^2} \phi_i^t F_0 \qquad (15)$$

and the DAF is:

$$\left|H_i(\omega)\right| = \frac{1}{\sqrt{\left[1-\left(\frac{\omega_f}{\omega_i}\right)^2\right]^2 + \left(2\xi_i\frac{\omega_f}{\omega_i}\right)^2}} \qquad (16)$$

The phase displacement θ of the answer according to the external force is evaluated from the module in the relationship:

$$\left|Y_i\right| = \left|H_i(\omega)\right| \left|Y_{io}\right| \qquad (17)$$

And we have:

$$\text{tg}\,\theta = \arg\left|H_i(\omega)\right| = \frac{2\xi_i\frac{\omega_f}{\omega_i}}{1-\left(\frac{\omega_f}{\omega_i}\right)^2} \qquad (18)$$

The particular solution which we are seeking is:

$$x_i(t) = X_i\sin(\omega_f t - \theta) \qquad (19)$$

Where:

$$X_i = G_i(\omega)\ F_0 \qquad (20)$$

The amplitude of the masse i is:

$$X_i = \frac{1}{\sqrt{\left[1-\left(\frac{\omega_f}{\omega_i}\right)^2\right]^2 + \left(2\xi_i\frac{\omega_f}{\omega_i}\right)^2}}\frac{1}{m_i\omega_i^2}\phi_i\phi_i^t F_0 \qquad (21)$$

The dynamic flexibility is:

$$G_i(\omega) = \frac{1}{\sqrt{\left[1-\left(\frac{\omega_f}{\omega_i}\right)^2\right]^2 + \left(2\xi_i\frac{\omega_f}{\omega_i}\right)^2}}\frac{1}{m_i\omega_i^2}\phi_i\phi_i^t \qquad (22)$$

The particular answer of the mode i of the structure is thus written as:

$$x_i(t) = \frac{1}{\sqrt{\left[1-\left(\frac{\omega_f}{\omega_i}\right)^2\right]^2 + \left(2\xi_i\frac{\omega_f}{\omega_i}\right)^2}}\frac{1}{m_i\omega_i^2}\phi_i\phi_i^t F_0 \qquad (23)$$

The particular solution is the superposition of the modal solutions:

$$x_2(t) = \sum_{i=1}^{m} x_i(t) \qquad (23)$$

The general solution of the motion equations is the superposition of the free and forced answers (6) and (23).

3. SIMULATIONS

We made many simulations by combining the elements of the block-mortar set. Taking into account the geometry of the wall, we suppose that the wall is fixed on is basis and we use only a half part of the wall, thanks to its geometrical shape. The dimensions of wall are:

Length: 3365mm; Height: 1773mm; Thickness: 140mm either 11 down put Or 18 in height.

We consider four kinds of walls: a wall built entirely in concrete, a wall with breeze blocks and the cement mortar, a wall in CEB and a cement mortar, and at last a wall in CEB and the earth mortar. The mechanical characteristics of the materials used in the simulations and shown in tables 1 and 2 are coming from the reference [10;11;12]].

Table1: Earth Material Characteristics

Characteristics	Earth material	
	CEB	Mortar
Young's modulus **E (Mpa)**	326	22,7
Poisson's coefficient **ν**	0,3	0,3
Density **ρ (kg/m³)**	2000	1700
Resistance to compression **Rc (Mpa)**	2,24	0,5

Table 2: Cement Material Characteristics

Characteristics	Cement material		
	Concrete	Breeze Blocks	Mortar
Young's modulus **E (Mpa)**	20000	15000	28590
Poisson's coefficient **ν**	0,2	0,27	0,2
Density **ρ (kg/m³)**	2400	2100	2250
Resistance to compression **Rc (Mpa)**	35	4.5	60

Simulations concern vertical, horizontal and torsion oscillations. In the analysis study of the comparison of the dynamic behaviour, we choose the DAF because according to the reference [6; 13] it's the best parameter in characterization of the wall stability. When simulating the wall motions, for each block-mortar set, in the relation (16), we fixe the parameter ω_f , we suppose that walls slowly damped that is

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$\xi_i \langle 1$. As the parameter ω_i is varying, the parameter β (beta) $= \dfrac{\omega_f}{\omega_i}$ is also changing. This evolution will allow representing $|H_i(\omega)|$ as a function of the parameter beta. The results we have obtained are shown in the following figures 3, 4, 5 and 6.

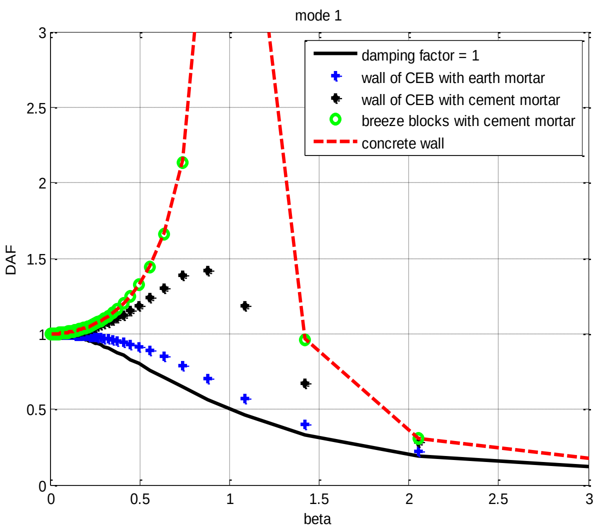

Figure 3: DAF as a function of beta in mode 1 vibration

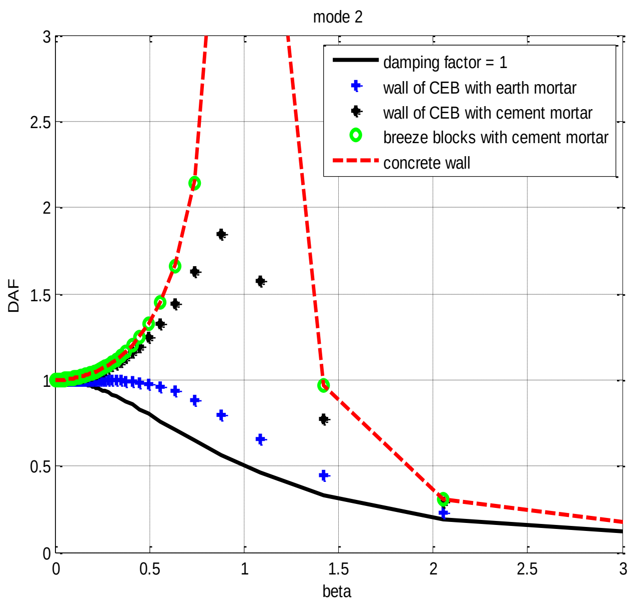

Figure 4: DAF as a function of beta in mode 2 vibration

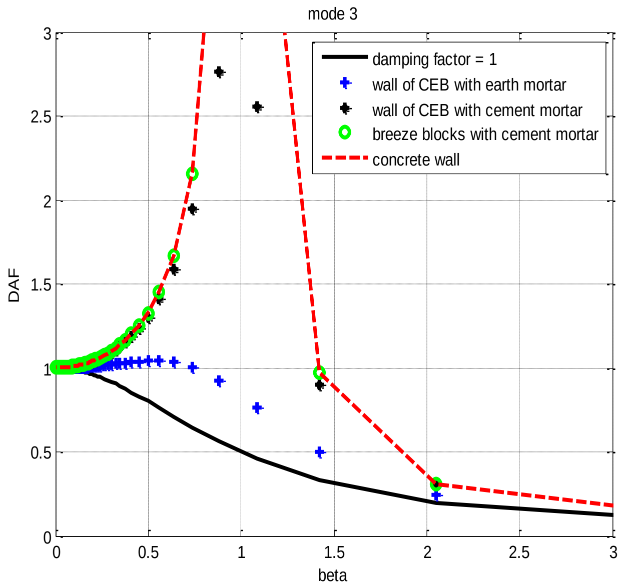

Figure 5: DAF as a function of beta in mode 3 vibration

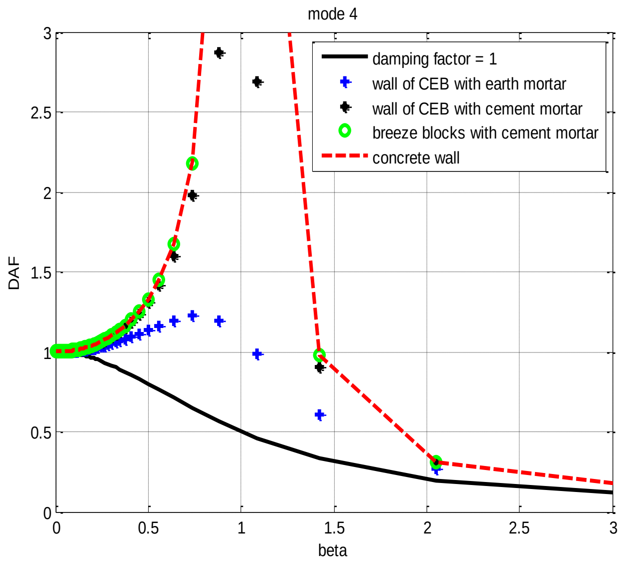

Figure 6: DAF as a function of beta in mode 4 vibration

4. DISCUSSION

In the figures 3; 4; 5 and 6, we have shown the evolution of the DAF as a function of the parameter beta in some vibrational mode. In those we have represented four kinds of combinations of the element of the block-mortar set in a wall. Firstly, we have a wall built in concrete, secondly we have a wall in breeze blocks and the cement mortar, thirdly we have a CEB and the cement mortar, and at last we have a wall in CEB and earth mortar.
According to the figure 1 where the wall is vibrating in mode 1, the DAF of the wall made in concrete is greater than 3. The

DAF of a wall made in Breeze Blocks and the cement mortar is around 1.8. The DAF of a wall made with CEB and the cement mortar is growing like a concrete wall one and the smallest value of the DAF is for the wall made with CEB block and earth mortar with the least value.

Ones can see that we have the same behaviour in the figure 2, where the wall is vibrating in mode 2. The results are similar in the figure 3 and 4. In all those simulations the smallest value of the DAF which is related to the most stability is for the wall made in CEB and the earth mortar. We have done many simulations, by taking different values of the damping parameter, the results were the same: the walls built from CEB and earth mortar have always the smallest values of the DAF.

5. CONCLUSION

The simulations done in the work allow us to evaluate the DAF of some walls by combining their important elements which are the block and the mortar. The walls we are simulating are not the wall of the building, but the house ones. The DAF which is the comparison parameter we use in this study is one of the parameter which can precisely show the stability of the wall, and a wall is more stable when his DAF is small. After many simulations, we fought that, the best stable wall is one with a small value of the DAF. So, according to our simulations the smallest value of the wall is observed in the wall made with CEB and earth mortar. Like this, those walls seem to cause little damage after external forces like earth quakes.

REFERENCES

[1]. CRAterre-ENSAG-Culture (2006): la terre, constructive et développement durable.

[2]. CRATerre-ENSAG (Avril 2008.): Approche pluridisciplinaire du matériau terre pour la construction. Séminaire scientifique, Grenoble.

[3]. M. Lanne, P. Berthier, J. Der Hagopian (1986): mécanique des vibrations linéaires 2e édition MASSON.

[4]. A. Bennani, V. Blanchot, G. Lhermet, M. Massenzio, S. Ronel. (2007): Dimensionnement des structures.

[5]. F. Olivier.(2005) Vibration des systèmes mécaniques.

[6]. Laurent Baillet – Thomas Gallot. (2009) : Cours dynamique des structures, laboratoire de Géophysique Interne et Tectonophysique UFR Mécanique / université Joseph Fourier Grenode.

[7]. Yves. Debard.(Octobre, 2009):Méthodes des Eléments finis : Elasticité Plane. Université de Mans, master modélisation numérique et réalité virtuelle.

[8]. Zienkiewicz, O, C, Taylor, R, L, (1991): La méthode des éléments finis: formulation de base et problèmes linéaires. Afnor technique.

[9]. Imbert, J, F, (1991): Analyses des structures par elements finis. Edidtion CEPADUES-EDITION.

[10]. Milan Zacek (novembre 2009): Béton et construction parasismique: cahier des modules de conférence pour les écoles d'architecture.

[11]. Y.Ke, L. Beaucour, S. Ortola, H. Dumontet, R. Cabrillac : Comportement Mécanique des Béton de Granulats Légers : Etude Expérimentale et Modélisation. Revue Volume X-n x/année

[12]. APN UEMOA (Union Economique et Monétaire Ouest Africaine), (2010) : Blocs de terre comprimée ;code de bonne pratique pour la production des BTC.

[13]. T. Beda. (2010) : Calcul des structures. Notes de cours master 2, Université de Ngaoundéré.