ANALYSIS OF EMI SHIELDING EFFECTIVENESS OF BUILDING MATERIALS

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ABSTRACT

Modern radio electronic devices with intensive usage of electromagnetic resource cause electromagnetic interference problems, which also affects neighboring systems functionalities. It is necessary to secure high sensitive electronic equipment in a shielded room from an electromagnetic interference. Generally, these equipments are shielded through metallic enclosures. In this paper, building materials are proposed to enhance shielding effectiveness of shielding enclosures. The shielding effectiveness (SE) of building materials are studied using CST-MWS and simulated results are presented over the frequency up to 2 GHz.

KEYWORDS

Electromagnetic Interference, Shielding effectiveness, Building Materials.

1. INTRODUCTION

The development of IT technology, highly integrated micro-electronic elements is used in kinds of military and civil electrical equipments more and more. Different natural, man-made, intended or unintended high power electromagnetic radiation further deteriorates the electromagnetic environment which increases the damage possibility of electrical or electric equipment. Electromagnetic shielding is the preferred means of electromagnetic protection. In order to reduce the EMI environment the conductive cement is a good choice. However, the progress in improving the conductivity of cement is very slow which limits its application to engineering. At present, the research on conductive cement-based material is mainly focus on how to obtain the good conductive performance through mixing conductive components, such as carbon fiber, steel fiber, lead and so on. EMI may be a conducted and/or radiated electromagnetic signal from any electrical or electronic devices. Actually, it’s the key of the problem to decide the conductivity level in order to reach a satisfying shielding effectiveness.

In this study the SE of the materials were evaluated. The results obtained for the SE can be used to provide an estimation of the potential attenuation inside a building constructed with cement and concrete. Our proposed method is using building material as a shield to give susceptibility to the electronic equipments inside the building. The shielding effectiveness of shielded rooms or building is of importance for the security of confidential information.

2. SHIELDING EFFECTIVENESS

The SE describes the ability to prevent the transmission of electromagnetic waves from the outside to the inside or vice versa. According to the national military standard G186190-2008, the definition of SE [2] & [5] is:

$$SE = 20 \log E_0 / E_1 = 20 \log H_0/H_1 \qquad (1)$$

where E_0 and H_0 are the intensity of electric field and magnetic field at any point in the space where there are no shielding materials respectively. E_1 and H_1 are the intensity of electric field and magnetic field where there are shielding materials in the same place. First, E_0, H_0, E_1 and H_1 are measured by experiment. Then SE of the material was calculated at some frequency by using formula 1.

According to the shielding theory of Schelkunoff, when the shielding plate infinite and the direction of incident wave is vertical, also be defined as:

$$SE = A + B + R \qquad (2)$$

Where SE is the total material's shielding effectiveness, A is the absorption loss, R is the reflection loss, and B is the repetitious absorption loss. The unit is dB.

The main factors which determine the shielding effect are the capability of shielding materials (the conductivity and the permeability) [1], the thickness and the frequency of the incident wave. If we know all these factors, the material's shielding effects can be calculated by Formula 2. If these factors are unknown, we can measure the intensity of electric field and magnetic field when there are shielding materials and not, and then SE is calculated by equation 1.

3. SIMULATION MODEL

Concrete is a well-known building material consisting of cement, water, sand and aggregates. All of those are mixed together uniformly and through a chemical reaction called hydration, the mixture hardens and gains strength to form the rock-like mass known as concrete.

Concrete is a porous, heterogeneous material with pores partially filled with ionic solutions. It is possible to decompose concrete into three phases: a solid phase consisting of all solid components, a liquid phase and a gaseous phase. The electrical properties of concrete thus relate to the phases; for instance the complex permittivity of the solid phase is real and thus this phase presents negligible losses, whereas the inevitable mixture of the solid and gaseous phases results in a non-dispersive medium whose permittivity is not frequency dependent. Dispersion in concrete is feasible due to the presence of free water in pores. Since the complex permittivity of water varies with frequency it follows that the degree of dispersion of concrete is dependent on its water content.

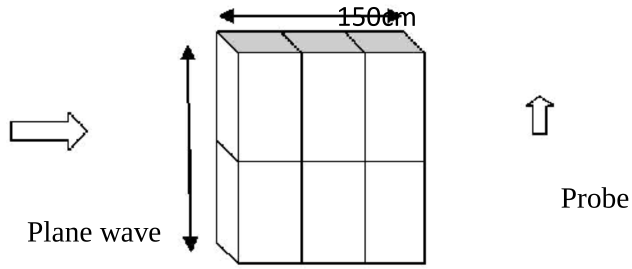

Figure 1. Simulated Structure

The efficiency of concrete structures as a shielding material depends on its electromagnetic properties: electrical conductivity, permittivity and magnetic permeability. As concrete is a nonmagnetic material, its magnetic permeability is deemed equal to that of free space.

4. SIMULATION RESULTS

In this paper, the SE of two types of concrete is investigated, which are one year old concrete and more than one year old concrete using CST-MWS [4] and [6]. The model concrete with size of 150cm x 150cm x 150cm. A plane wave in the range of 0 to 2 GHz is applied as a source, on the concrete. The excitation signal and the E-field waveform of one year old concrete can be seen in figure 2 and 3 respectively. The electric field of the one year old concrete was measured by fixing probe inside the block or concrete. The E-field waveform of more than one year old concrete which is also calculated by the same course of action as in one year old concrete is shown in figure 5. The E-field waveform is calculated by fixing the probe inside and outside of the building material [2].

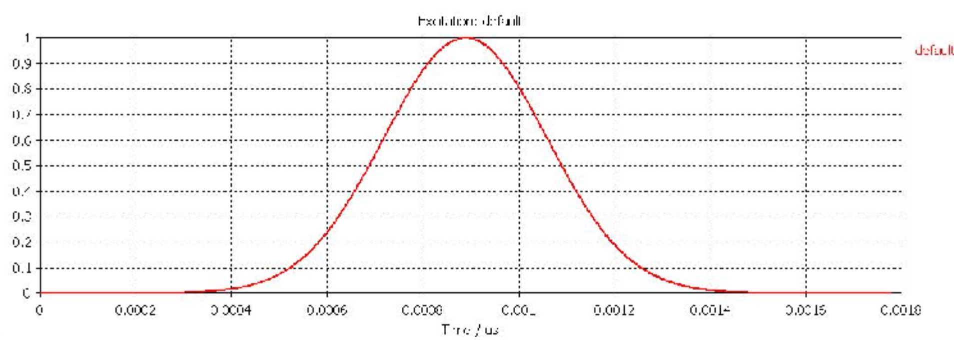

Figure 2. Excitation signal

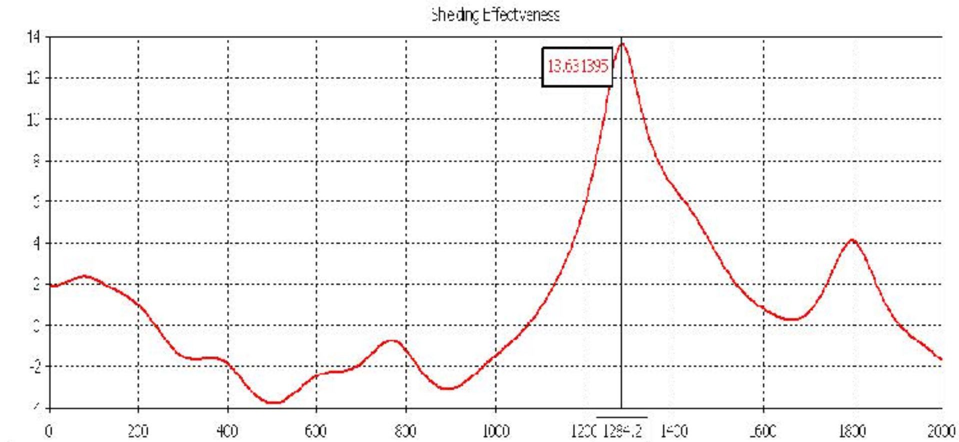

Figure 3. SE of one year old concrete

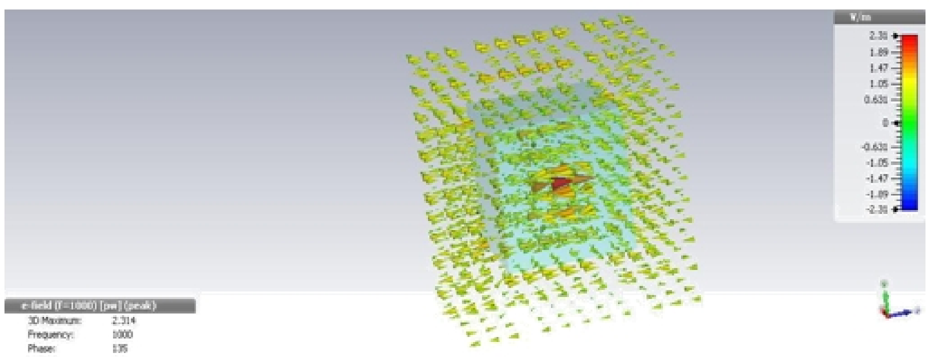

Figure 4. E-field distribution of one year old concrete.

The shielding effectiveness is analyzed using the permittivity of one year old concrete. The E-field distribution of one year old concrete is seen in figure 4 and its peak value is 2.314 v/m.

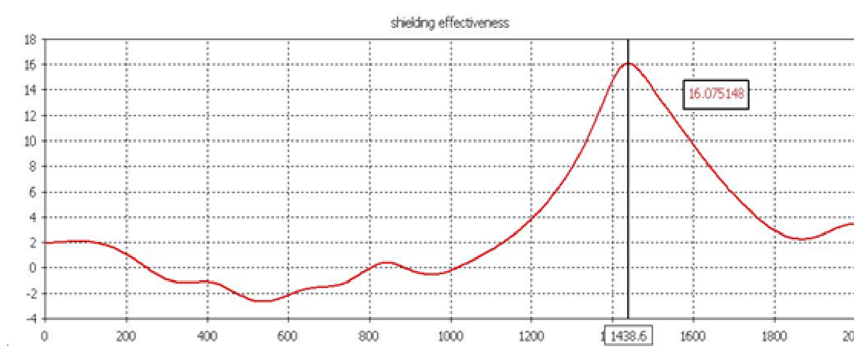

Figure 5. SE of more than one year old concrete

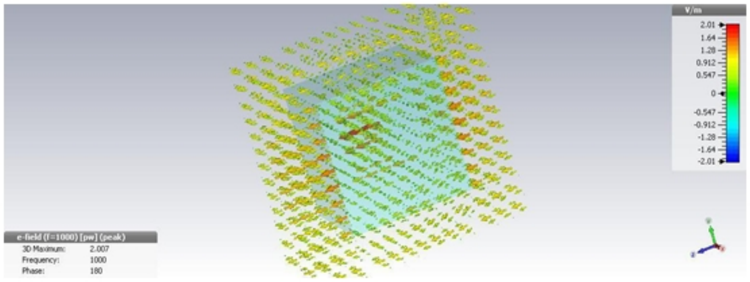

Figure 6. E-field distribution of more than one year old concrete.

The shielding effectiveness is analyzed using the permittivity of more than one year old concrete identical as before. The E-field distribution of more than one year old concrete is seen in figure 6 and its peak value is 2.007 v/m.

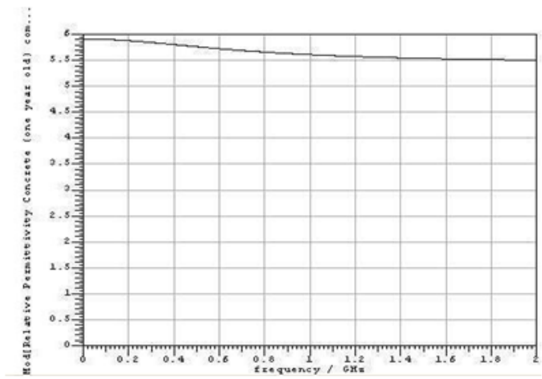

Figure 7. Relative permittivity of one year old concrete

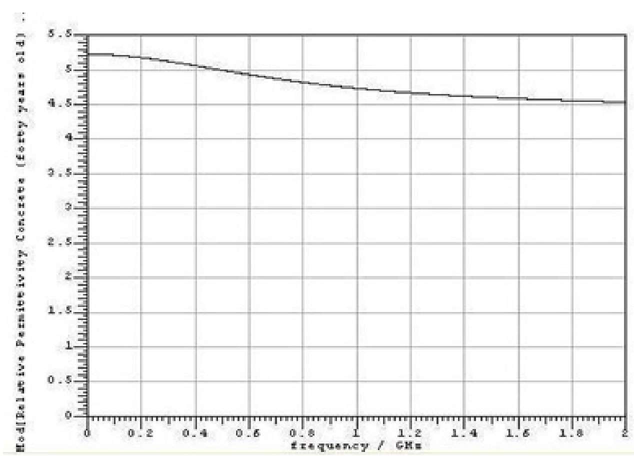

Figure 8. Relative permittivity of more than one year old concrete

The Relative permittivity of one year old concrete and more than one year old concrete can be seen respectively in figure 7 and figure 8. The Relative permittivity of one year old concrete is 5.5 and those of more than one year old concrete is 4.5 only. This evaluation shows that the one year old concrete has higher relative permittivity than more than one year old concrete. When the relative permittivity is increased the shielding performance is also increased.

To justify the SE value of the one year old and more than one year old concrete, here we experimented two more materials to calculate SE value using CST-MWS as before. The materials are Portland cements with different dielectric values i.e. Cement-1 has 4.4 and cement-2 has 3.9 in epsilon value. The cement-1 model is shown in Fig. 9 and the Relative permittivity of the cement-1 is shown in Fig 10. The relative permittivity of cement-1 is 4.323.

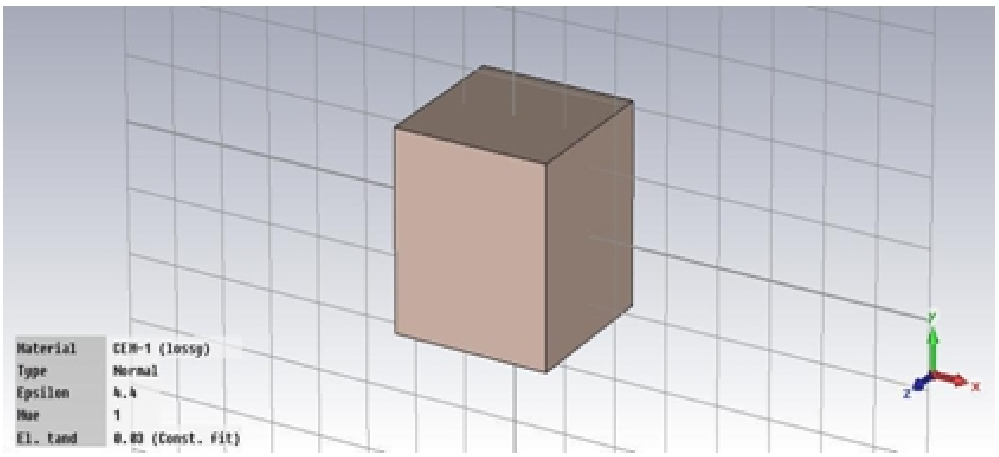

Figure 9. Portland cement-1model in CST-MWS

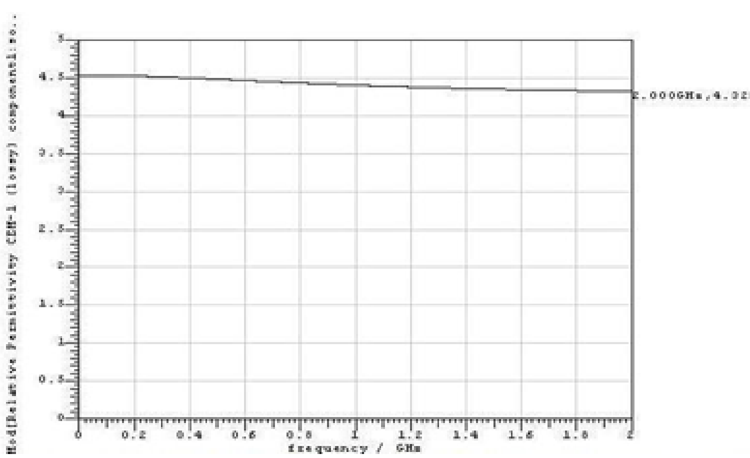

Figure 10. Relative permittivity of Portland cement-1

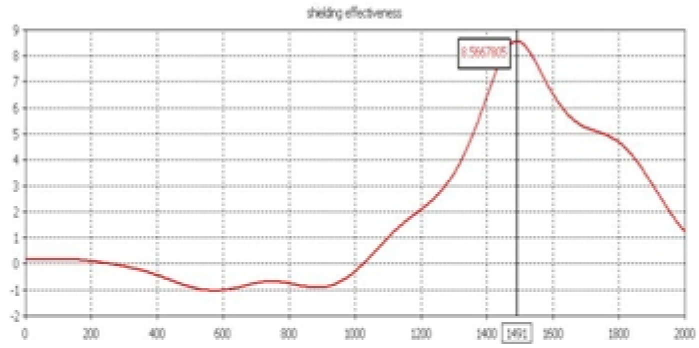

Figure 11. SE of Portland cement-1 material

The shielding effectiveness of this Portland cement-1 is 8.566dB which is shown in Fig 11. The SE of the portland cement-1 is less than the SE of one year old concrete and more than one year old concrete. Then the model of Portland cement-2 which has less epsilon value than the Portland cement-1 is shown in Fig 12.

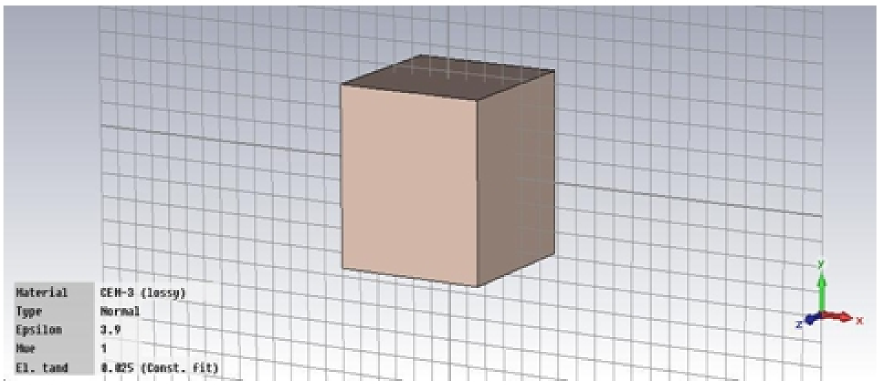

Figure 12. Portland cement-2 model in CST-MWS

The relative permittivity of the Portland cement-2 is 3.805 which is less than the Relavite permittivity of the Portland cement-1. The Relative permittivity of Portland cement-2 is shown in Figure 13, and the shielding effectivenes of the Portland cement-2 is shown in Fig. 14. The shielding effectiveness value of the Portland cement-2 is 4.7429dB and is less than the shielding effectiveness of the Portland cement-1 material.

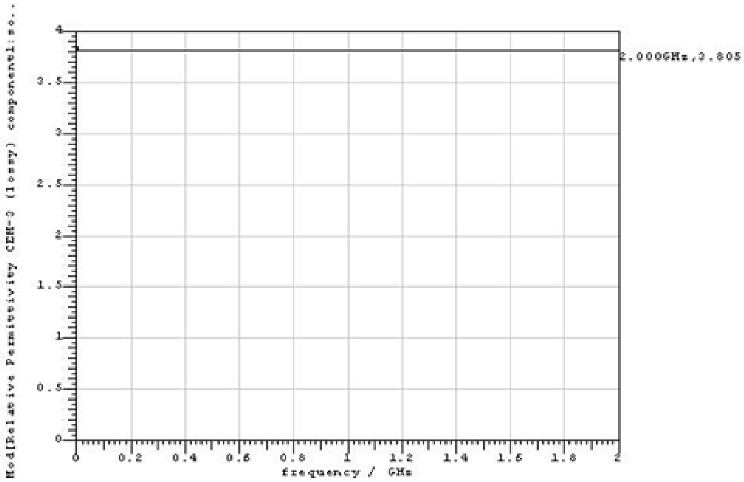

Figure 13. Relative permittivity of Portland cement-2

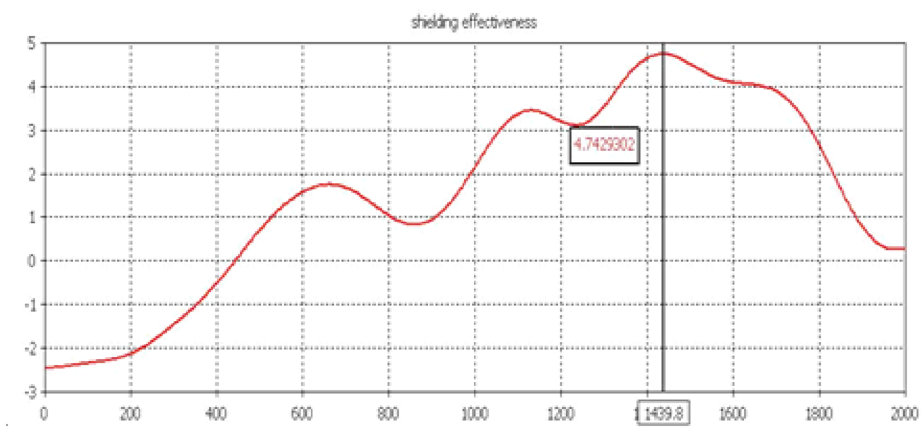

Figure 14. SE of Portland cement-2 material

5. CONCLUSIONS

The EMI shielding performance of the building materials are investigated. From these results it is evident that the one year concrete has given a good shielding performance when compared to more than one year old concrete and other building materials. From the analysis of shielding effectiveness of Portland cements, SE of Portland cement-1 is greater than that for Portland cement-2.

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