

# Experimental Study on Modified Shielding Functional Mortar

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**Abstract.** The mortar board was prepared with the content of reduced iron powder, thickness and shielding fabric as variables. The results showed that appropriate content of reduced iron powder could improve the shielding efficiency of mortar, and the peak shielding efficiency of 10mm thick specimens with a dosage of 300kg/m<sup>3</sup> reached 16.9db and the 20mm-thick specimens reached 17.1db. The 10mm-thick specimens with shielding fabric reached 73.5db, and the 20mm-thick specimens reached 59.3db

## 1. Introduction

Cement-based materials have a wide range of uses. The shielding effectiveness of cement-based materials prepared by adding copper-nickel powder and fiber has been studied [1]. The absorption effect of prepared cement-based materials in high frequency band was studied with graphite powder [2]. The shielding performance of copper-nickel wire mesh reinforced cement-based material is studied [3]. Mortar, as a kind of cement-based material, is often used in masonry and plastering, etc. The functional plastering mortar can reconstruct the old engineering and meet the special needs. There are few studies on cement-based materials mixed with reduced iron powder. Some scholars studied its electromagnetic wave reflectivity and transmittance in a certain frequency band [4]. As an ultrafine powder, reduced iron powder has good electromagnetic properties [5]. Adding the plastering mortar prepared by the powder can provide a choice for the reconstruction with needs of electromagnetic shielding.

## 2. Experiment

### 2.1. Raw Materials

Reduced iron powder: 200 mesh secondary; Cement: grade 42.5 ordinary Portland cement; Sand: medium river sand; Fly ash: 1250 mesh first class; Shielding fabric: copper-nickel composite fabric with shielding efficiency up to 70dB in the 1MHz-10GHz band.

### 2.2. Mix Proportion

According to the proper regulation, select the proportion. The specific ratio is shown in table 1.



**Table 1.** Mix Proportion

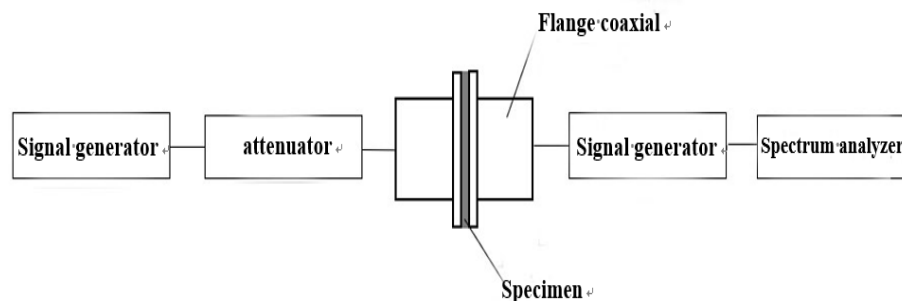
number	Fabric form	Thickness (mm)	Content (kg/m <sup>3</sup> )				
			iron powder	Cement	Sand	Fly ash	Water
A1	-	10	0	450	1498	50	300
A2	-	10	100	450	1473	50	300
A3	-	10	200	450	1448	50	300
A4	-	10	300	450	1423	50	300
A5	-	10	400	450	1398	50	300
B1	surface	10	0	450	1498	50	300
B2	surface	20	0	450	1498	50	300
B3	surface	10	300	450	1423	50	300
B4	surface	20	300	450	1423	50	300
C1	-	20	0	450	1498	50	300
C2	-	20	300	450	1423	50	300

### 2.3. Methods of Preparation

According to the selected mix proportion. The cement and reduced iron powder were put into the mixer for 60s dry mixing at a slow speed, followed by 60s dry mixing at a fast speed. Sand and fly ash were added at a uniform velocity, and water was added at the same time. Put the mortar into the mold used in the test, remove the mold after 1d, and experiment after curing to the specified age.

### 2.4. Method of Experiment

According to the proper method, the shielding effectiveness at specific frequency points was tested by using the coaxial flange. The method is shown in figure 1.

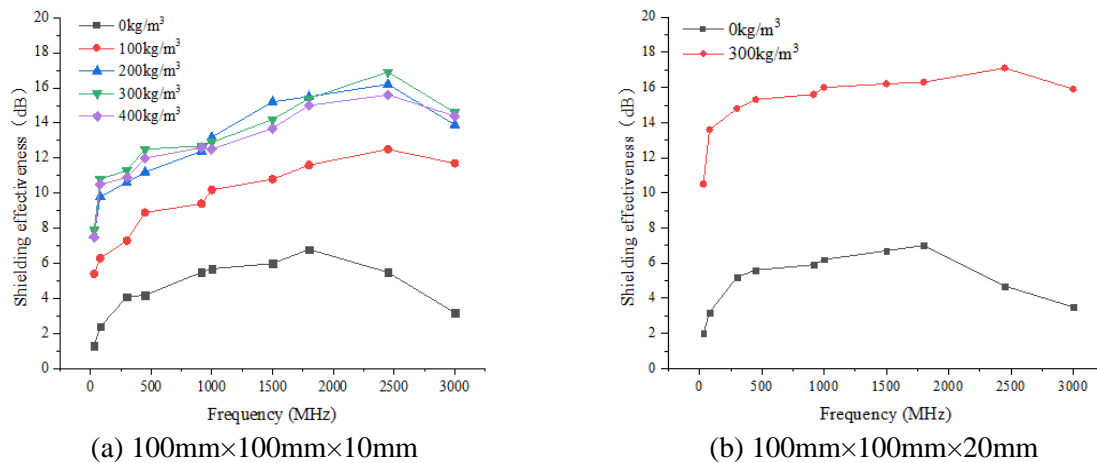
**Figure 1.** Measurement Method of Signal Generator/Spectrum Analyzer

## 3. Results of Experiment

### 3.1. Effect of Reduced Iron Powder on Shielding Efficiency

#### 3.1.1. No Shielding Fabric

When no shielding fabric was added, the shielding efficiency of 10mm thick specimen first increased and then decreased. The shielding efficiency of 20mm one was the same, the effect is shown in figure 2.

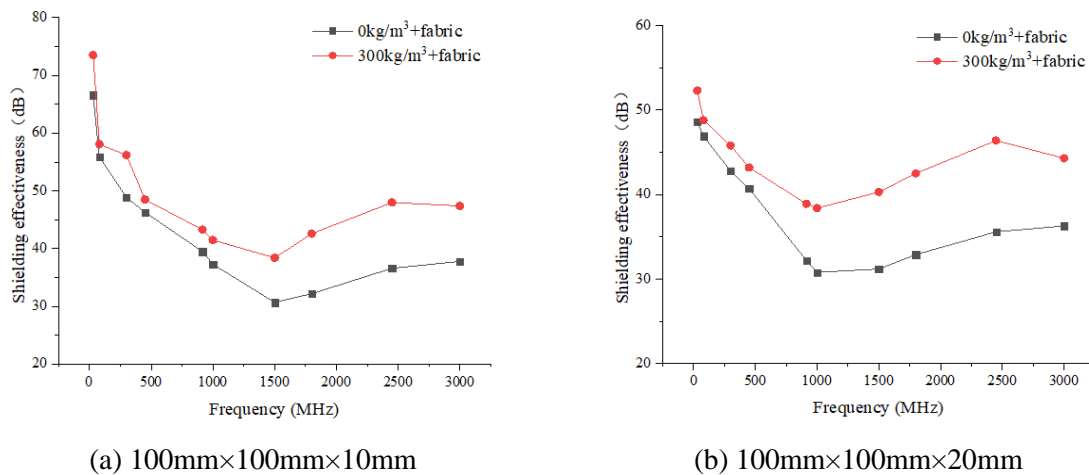


**Figure 2.** Effect of Reduced Iron Powder on Shielding Efficiency of Functional Mortar Specimen

When the thickness is 10mm, the peak shielding efficiency of the specimens mixed with reduced iron powder moves towards high frequency. the reference mortar specimen reached the peak of 6.8db at the point of 1800MHz, and the specimen with a mixture of 300kg/m<sup>3</sup> reached the peak of 16.9db at 2450MHz. In the frequency band of 30MHz-915MHz, when the content is less than 300kg/m<sup>3</sup>, the shielding efficiency gradually increases. The sample with the content of 300kg/m<sup>3</sup> increases most obviously, with an average of 7dB. When the content increases to 400kg/m<sup>3</sup>, the shielding efficiency decreases. At the low-frequency point, the shielding mainly depends on the absorption. The powder belongs to the electric loss absorbing medium and has a good permeability. When the powder is added, the internal conductivity and permeability rise, so that the wave can get better absorption loss. However, as the electrical conductivity increases, the difficulty of the internal magnetic permeability material increases, which reduces the loss ability. In the frequency band of 1000MHz-3000MHz, when the content is more than 100kg/m<sup>3</sup>, the shielding efficiency crossed. The sample with the content of 300kg/m<sup>3</sup> has a better shielding efficiency, and the average increase is about 10dB compared with the reference. At the high frequency point, electromagnetic shielding mainly depends on the surface reflection. The addition of powder forms an amount of conductive aggregates, so that the surface conductivity increases. When the content is 300kg/m<sup>3</sup>, the powder has a good dispersion effect, can form a good surface conductive network. When the content increased to 400kg/m<sup>3</sup>, the distribution of powder changed because of the density, and the conductivity decreased, leading to the decrease of shielding efficiency. When the thickness is 20mm, the reference reaches the peak of 7dB at the 1800MHz frequency point, and the specimen with a content of 300kg/m<sup>3</sup> reaches 17.1db at the 2450MHz frequency point. Similar to the 10mm thick ones, the powder made the peak value move towards the high frequency.

### 3.1.2. With Shielding Fabric

When shielding fabric is added, the shielding efficiency of specimens with different thickness decreases first and then increases. The effect is shown in figure 3.



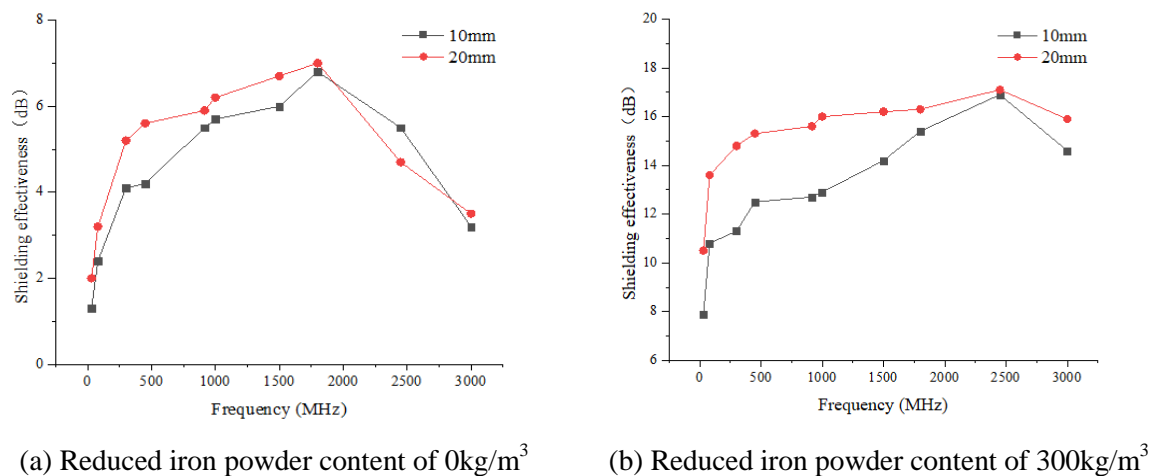
**Figure 3.** Effect of Reduced Iron Powder on Shielding Efficiency of Functional Mortar Specimen

When the thickness is 10mm, with the increase of frequency, the difference between the two groups' increases gradually, which is only 2.2db at the 80MHz frequency point and 11.4db at the 2450MHz. When fabric is added, the effect of powder on high frequency is better. The powder has a good conductivity. When the content is 300kg/m<sup>3</sup>, it forms a good conductive network. When the frequency is low, the fabric can reflect most electromagnetic waves. With increasing frequency, the penetrate ability of wave is stronger, due to the impedance mismatch of wave, making electromagnetic wave gets reflection loss at the border and internal absorption. When the thickness is 20mm, the difference tends to increase gradually, which is only 2.5db at 450MHz frequency point and 10.8db at 2450MHz. Similar to the 10mm ones, when fabric is added, the powder can improve high-frequency shielding efficiency.

### 3.2. Effect of Thickness on Shielding Efficiency

#### 3.2.1. No Shielding Fabric

When no shielding fabric was added, the shielding efficiency of the two groups increased first and then decreased with the increase of frequency. The effect is shown in figure 4.



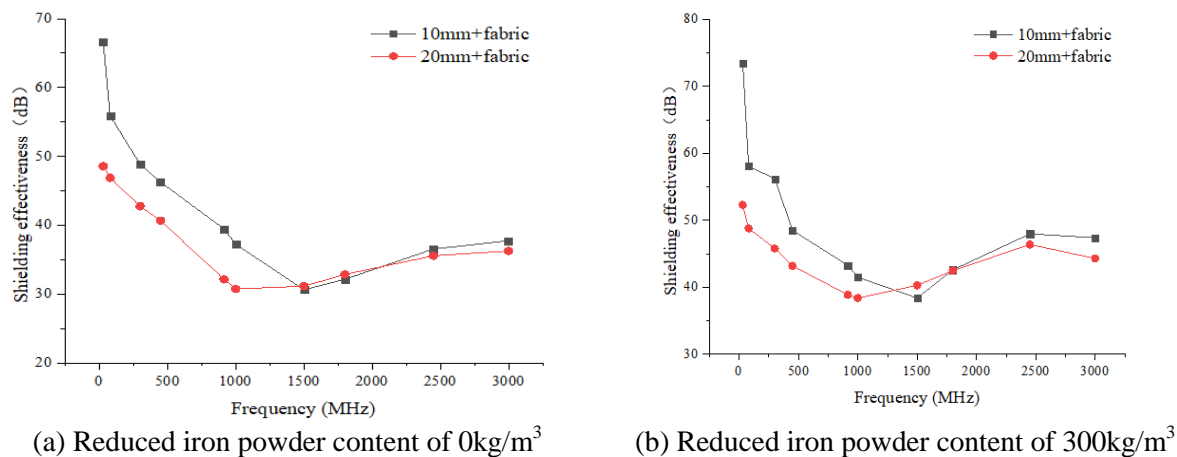
**Figure 4.** Effect of Thickness on Shielding Efficiency of Functional Mortar Specimen

Aimed at reference mortar, the shielding efficiency of 20mm thick specimen is about 1dB higher than that of 10mm one in the frequency band of 30MHz-1500MHz, with the increase of frequency, the

shielding efficiency of the two specimens appears to intersect. Increasing the thickness can increase the internal reflection and absorption loss. However, there is little material with high permeability in the reference. For high frequency, thickness has little effect, and the lack of high conductivity material leads to the intersection. In addition, the larger the thickness is, the larger of the fixture is. The coaxial waveguide method requires the thickness to be below 5mm. When the thickness is larger than 5mm, the external electromagnetic wave is easy to enter the receiving cavity, causing the error. When the content is  $300\text{kg/m}^3$ , in the frequency band of 30MHz-1000MHz, the shielding efficiency of 20mm thick one is about 3dB higher than that of 10mm. With the increase of frequency, the difference tends to decrease gradually. In the low frequency, the increase of thickness can improve the chance of wave being reflected and absorbed, thus improving the shielding efficiency. When the thickness reaches a certain critical state, increasing the thickness has a limited effect. In addition, with the error caused by the increase of the thickness, the improvement is limited. In the high frequency band, the shielding mainly depends on the surface reflection loss. The increase of thickness has little effect.

### 3.2.2. With Shielding Fabric

When the shielding fabric is added, the shielding efficiency of the two groups has the same trend. The efficiency first decreases and then increases. The effect is shown in figure 5.



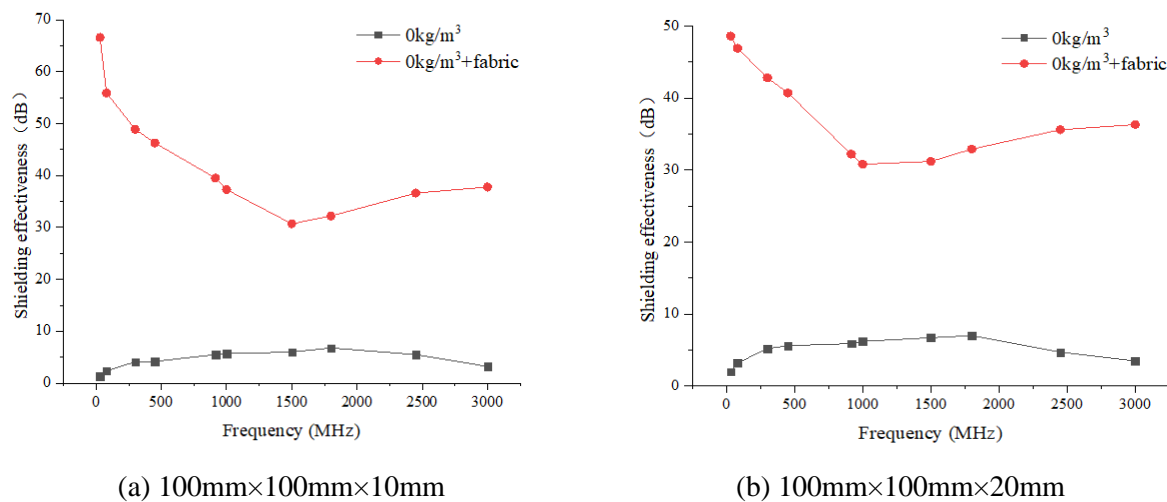
**Figure 5.** Effect of Thickness on Shielding Efficiency of Functional Mortar Specimen

The difference of shielding efficiency is more obvious in the low frequency band. When there is no powder, shielding effectiveness is mainly by fabric, thickness has little effect, when the thickness is 20 mm, the gap of fixture is too large. Also, the specimen with fabric is affected by binder, which leads to the bad roughness. Flange clamp can't completely clamped specimen, making external electromagnetic wave receiving waveguide cavity, thus to reduce the result. With increasing frequency, more electromagnetic wave through the fabric, because of the impedance mismatch differs; the wave will get lots of reflection losses, compensating for the error of the thickness. When powder is added, among the 30MHz-1GHz band, the shielding efficiency of 10mm thick specimen is higher. When the frequency is beyond 1GHz, the shielding effectiveness appears to be crossed. At the low-frequency point, increasing the thickness can increase the absorption loss, less wave penetrates the fabric, leading to a small loss in this part. At the same time, due to the effect of the excessive gap, which has a greater effect on the results of the 20mm ones. At this time, the test error brought by the thickness is larger than the absorption gain. In high point, the wave through the fabric, because the surface wave impedance mismatch, wave gets multiple reflection losses and absorption loss, compensating for the error caused by the thickness.

### 3.3. Effect of Shielding Fabric on Shielding Efficiency

#### 3.3.1 Reference Mortar

Aimed at reference mortar, the shielding effectiveness of the specimens without fabric increases first and then decreases, while that of the specimens with fabric opposites. the effect is shown in figure 6.

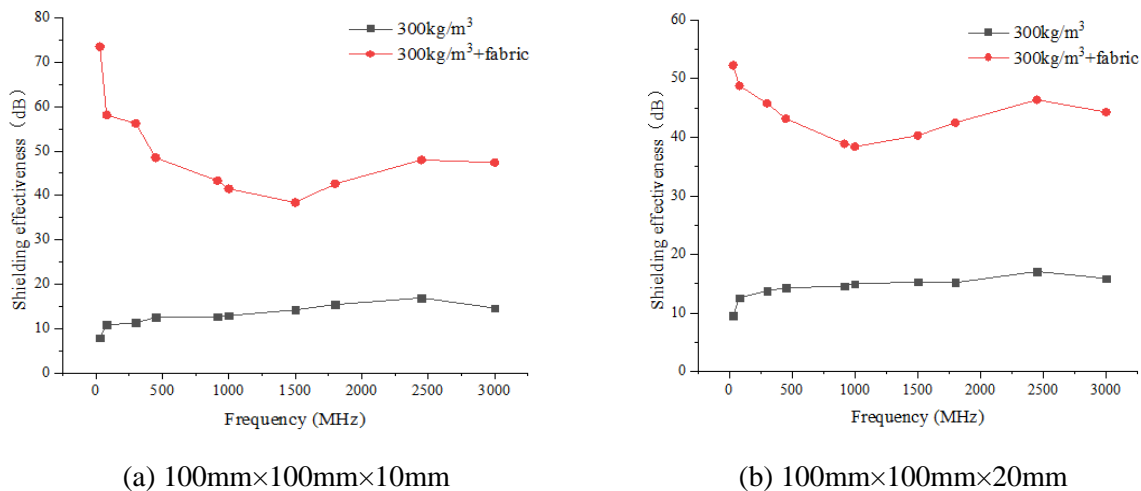


**Figure 6.** Effect of Shielding Fabric on Shielding Efficiency of Functional Mortar Specimen

The difference between the two groups of 10mm thick specimens decreased first and then increased. At the frequency point of 30MHz, the difference was 65.3db, at 1500MHz, the increase was 24.7db, and the average increase was 38.7db. The shielding fabric's shielding efficiency in the test frequency band can reach 70dB. It can significantly improve the shielding efficiency at the low-frequency point, but the performance at some frequency points is not ideal. With the increase of frequency, the shielding efficiency at the high-frequency point rises. The thickness of the specimen with shielding fabric is more than 10mm, which has a large test error compared with the single fabric. In addition, epoxy resin adhesive is used to bond the fabric and it will affect flatness and internal structure, so as to reduce the loss of electromagnetic wave. At the high frequency point, due to the mismatch, the electromagnetic wave gets multiple reflection losses between the specimen surface and the inner surface of the fabric. The difference between the 20mm thick specimens decreased first and then increased. At the 30MHz frequency point, the difference was up to 46.6db, at the 1000MHz frequency point, the smallest increase was only 24.6db, the average increase was 30.6db. Compared with 10mm thick ones, the increase in the shielding effect of fabric on the reference mortar specimens reduced. This is mainly because the increase in thickness causes the larger gap, which makes it easier to cause the decrease of results.

#### 3.3.2. Mortar Mixed with Reduced Iron Powder

With the increase of frequency, the shielding efficiency first increases and then decreases, while that of the sample with fabric opposites. The effect is shown in figure 7.



**Figure 7.** Effect of Shielding Fabric on Shielding Efficiency of Functional Mortar Specimen

The shielding efficiency difference between the two groups of 10mm thick specimens decreased first and then increased. At the frequency point of 30MHz, the maximum increase was up to 65.6db; at 1500MHz, the minimum increase was only 24.2db; and the average increase was up to 36.3db. When shielding fabric and reduced iron powder work together, they shield electromagnetic wave in the low frequency band better. On the one hand, at the low-frequency point, the shielding fabric can reflect most wave, which can effectively improve shielding efficiency. On the other hand, the electromagnetic wave passed through the fabric got multiple reflection losses and absorbed between the fabric and the specimen surface. The combination is conducive to improve the overall shielding efficiency. The difference between the two groups of 20mm thick were the same. At the frequency point of 30MHz, the maximum increase was up to 42.8db. At the 1000MHz, the increase was only 23.4db, and the average increase was 29.3db. Compared with 10mm ones, the shielding efficiency of 20mm thick specimens is improved less by adding fabric. Because the increase of thickness will lead to greater test errors, resulting in the further reduction of shielding effectiveness at some frequency points.

#### 4. Conclusion

(1) When no fabric is added, an appropriate content of reduced iron powder can improve the shielding efficiency, which has a more obvious effect on high frequency electromagnetic wave. The shielding efficiency of specimens with a mixture of 300kg/m<sup>3</sup> is better. When fabric is added, the shielding efficiency of the specimen against high frequency electromagnetic wave can be effectively improved.

(2) When no fabric is added, the increase in thickness can improve the shielding efficiency at the low-frequency point. When fabric is added, the increasing thickness will reduce the shielding efficiency.

(3) The addition of shielding fabric can significantly increase the shielding efficiency, especially in the low-frequency band. The increase is more obvious for specimens of 10mm thickness.

#### 5. References

- [1] Chen Yangru, Xiong Guoxuan, Zhang Zhibin. The application study of shielding media in cement-based materials, *J. New Building Materials*, 2010, 37 (10) 80-82.
- [2] Han bin, Ji Zhi jiang, Zhang Zhong lun. Research on Absorbing Properties of Cement-based Coating Material *J. Materials Review*, 2009,23 (z1) 370-373.
- [3] Dai Yinsuo, Gong Lei, Yan Fengguo, et al. Research on electromagnetic protection performance of metal wire mesh reinforced cement-based materials *J. China Concrete and Cement Products* ,2015(12):6-9.

- [4] Zheng Guozhi, Chen Bin, Zhang Zehai, et al. Reflection and transmission performances of concrete slabs mixed with reduced iron powder J. High Power Laser and Particle Beams, 2015,27 (4) 151-156.
- [5] Xu Fangxing, Zeng Guoxun, Zhang Haiyan, et al. Preparation and electromagnetic properties of flaky reduced iron powders J. Electronic components and materials, 2014, (12) 41-48.