Preparation and Performance Study of Light Weight Gypsum Mortar

Xiangquan Yang, Mengdan Zhang, Mifeng Gou*

School of Materials Science and Engineering, Henan Polytechnic University, Jiaozuo 454000, Henan, China

Abstract

In order to prepare a lightweight gypsum mortar with stable performance, low density and high strength, further expand the use of FGD building gypsum and improve the utilization rate of FGD building gypsum. In this paper, based on the cementitious material (GM-PO-S95 system) prepared from desulfurized building gypsum (FGD gypsum) as the main raw material, the experimental design was carried out with two kinds of lightweight aggregates (Eubert Perlite (EP), Vitrified Microbeads (VM)). The low-density and high-performance gypsum-based lightweight mortar was prepared by analyzing the mechanical properties, density, water resistance, and microscopic morphology and pore size distribution of the lightweight gypsum mortar. The study showed that: the density of the specimen decreased significantly after adding lightweight aggregate, and the 3d density decreased to 715kg/ m^3 at 20% VM admixture, which was decreased by more than 60%; while the density decreased, the mechanical properties were still good, with the compressive strength maintained at 12MPa, flexural strength maintained at 2.8MPa, and the water absorption rate decreased to about 26%; the addition of VM, together with the hydrated gypsum crystals of GM-PO-S95 system, not only reduces the ratio of pore size distribution, but also gypsum crystals enter into the interior of glass beads, interact with glass beads, and together hold up the internal structure of lightweight gypsum mortar.

Keywords

Gypsum; Lightweight Mortar; Low-field NMR; Microstructure.

1. Introduction

China's annual desulfurization gypsum emissions of nearly 100 million tons in 2021[1], In order to enhance the extensive utilization of desulfurization gypsum, different research scholars have respectively adopted different ways and methods to carry out a series of studies on the composite cementitious materials with desulfurization building gypsum as the main component. Liang Hongchao et al. prepared gypsum-based thermal insulation materials with compressive strength of 0.7MPa and dry density of 350kg/m3 using VM as lightweight aggregate [2]. Zhang Dajiang et al. used expanded perlite as lightweight aggregate to prepare gypsum-based thermal insulation material with compressive strength of 2.5MPa and dry density of 1300kg/m3 [3].S. Liao [4] et al. investigated the effect of lightweight clay terra cotta on the thermal insulation properties of gypsum, with the composite having a density of 1102 kg/m3, an adiabatic flexural strength of 1.89 MPa and an adiabatic compressive strength of 8.12 MPa. Sanantonio-gonzalez et al. used discarded EPS particles as aggregate to prepare lightweight gypsum, and prepared lightweight materials with low density and good thermal insulation performance[5].Although many of the above scholars have done a lot of research on light gypsum mortar, the problems such as poor mechanical properties of light gypsum mortar still limit the promotion of the application range and the large-scale utilization of solid waste gypsum.

2. Materials and Methods

2.1 Raw Materials

The Gypsum-based cementitious materials are mainly prepared by adding mineral powder and Polenta cement to flue gas desulphurization building gypsum. The lightweight aggregates used in this paper include expanded perlite (EP) and vitrified microbeads (VM), which were obtained from Xinyang Building Material Co. expanded perlite and vitrified microbeads micro-morphology is shown in Figure 1. Both of them have the characteristics of light weight, heat insulation and stable physical and chemical properties, and are widely used in heat insulation projects. Through the determination of EP and VM, the average particle size D(50) of EP and VM were found to be 465 μm and 478 μm, respectively.

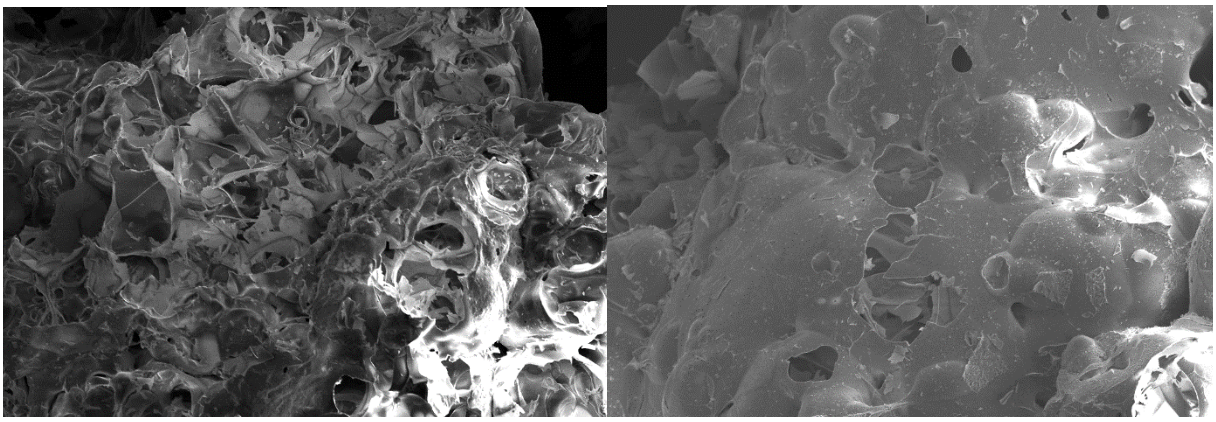


Figure 1. SEM of EP and VM

2.2 Mix Proportions and Research Framework

2.2.1 Experimental Design

Table 1. Test proportioning of lightweight gypsum mortar (wt/g)

Samples	GM-PO-S95	Lightweight aggregate	Water
0	700	0	490
1V	500	25	350
2V	400	40	280
3V	400	60	280
4V	350	70	245
1E	500	25	350
2E	400	40	280
3E	400	60	280
4E	350	70	245

Two kinds of lightweight aggregate EP, VM were 0%, 5%, 10%, 15%, 20% of the mass of gypsum-based cementitious materials(GM-PO-S95 system), the experimental mixing ratio shown in Table 1, the preparation process due to the lightweight aggregate EP, VM in the mixing process will be a large amount of water absorption, so after exploratory tests through the use of the water-to-cementitious ratio of 0.7, the mixing ratio of lightweight mortar is shown in Table 1.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202406_10(6).0013

2.2.2 Preparation of Test Samples

After weighing each of the above mentioned materials and using a net slurry mixer, water was added and mixed for 2 min to obtain a homogeneous mixture. The homogeneous slurry was quickly poured into the mold. 24 h later the mold was demolded and cured at room temperature of 24±2°C until age for different performance tests.

3. Results and Discussion

3.1 Density

Figure 2 shows the effect of different lightweight aggregates (EP, VM) on the density of gypsum-based lightweight mortar. In terms of different age periods of 3d and 14d, the mass and density of the test samples undergo a continuous decreasing trend when different mass proportions of lightweight aggregates (VM, EP) are added into the GM-PO-S95 system.

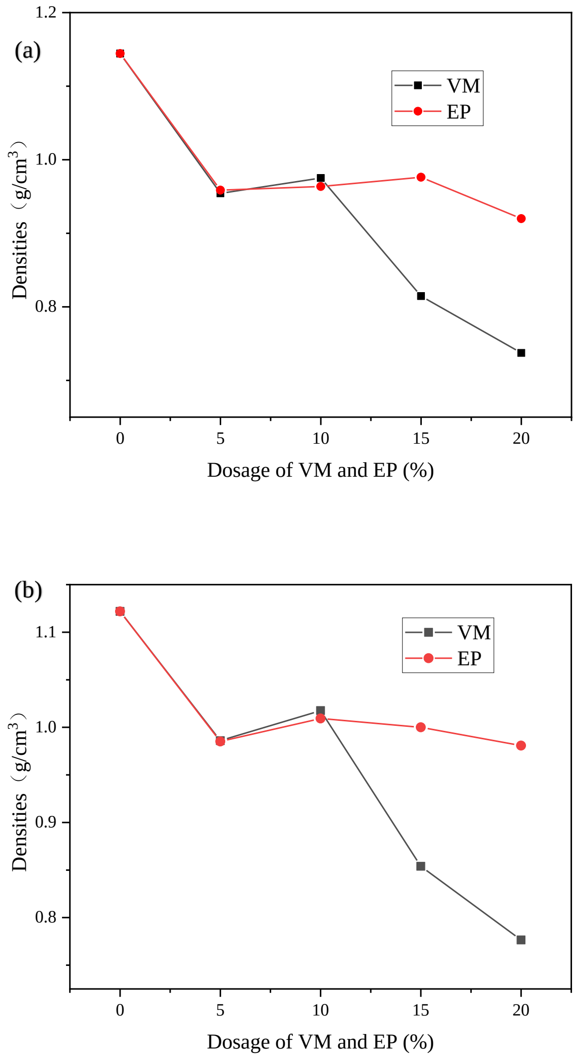


Figure 2. Density of Lightweight gypsum mortar (a)3d, (b)14d

From the 3d situation, the addition of EP decreased the mass of the sample from 1150 kg/m³ to about 910 kg/m³, the decrease was not obvious enough at 5%-15% EP doping, and the fastest decrease was at 5%; the addition of VM decreased the mass of the sample from 1150 kg/m³ to about 715 kg/m³, which was 37.8% compared with that of the blank group, but the overall trend of change was not

Volume 10 Issue 6, 2024
DOI: 10.6919/ICJE.202406_10(6).0013

obvious enough at 5%-10% EP doping, and the decrease was faster at both 0%-5% and 10%-20%. 10% EP doping, the overall trend is not obvious enough, and the decrease is faster at both 0%-5% and 10%-20%. From the 14d situation, the addition of EP made the mass of the samples decrease in a similar trend as it showed in 3d, and finally reached about 960 kg/m³; the addition of VM made the mass of the samples decrease from 1120 kg/m³ to about 755 kg/m³, which was about 32.6% lower than that of the blank group, and the overall decreasing trend was the same as that in 3d. The density is lower than 800kg/m³, which is in line with the standard of lightweight wall materials, and at the same time, it can be seen that the light aggregate has a greater effect on the density of gypsum-based lightweight mortar [6].

3.2 Compressive Strength

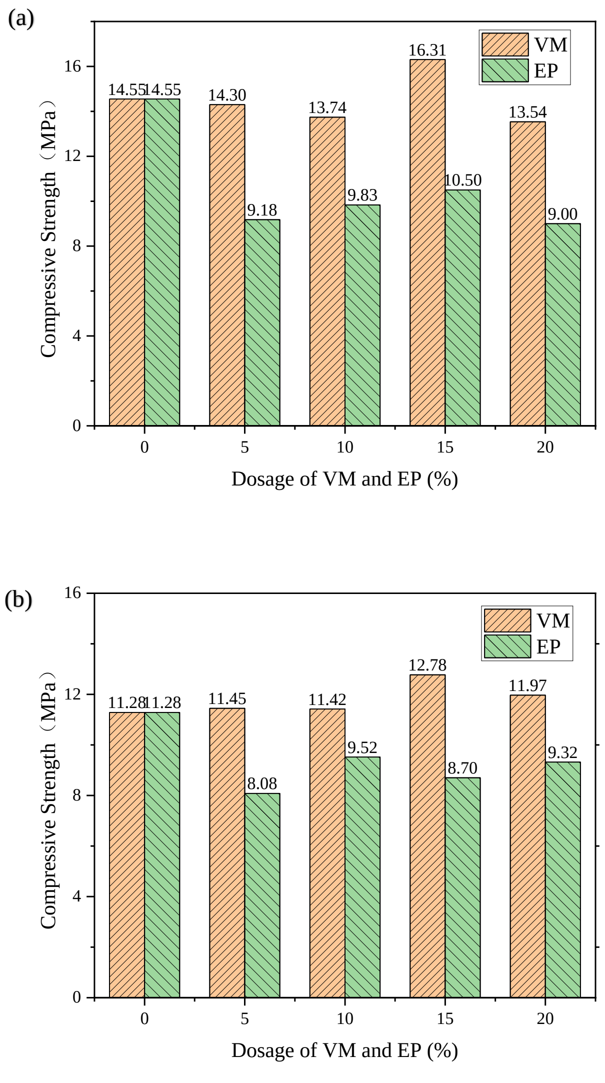


Figure 3. Compressive strength of Lightweight gypsum mortar (a)3d, (b)14d

The effect of different lightweight aggregate (EP, VM) addition on the compressive strength of gypsum-based lightweight mortar is shown in Figure 3. From the condition of different ages of 3d and 14d, the compressive strength of the test samples changed differently when different mass ratios of lightweight aggregates (VM, EP) were added into the GM-PO-S95 system. From the 3d case, the addition of EP produced a significant decrease in the compressive strength of the gypsum-based lightweight mortar samples, from 14.55MPa to 9.0MPa at 0% dosing, but the compressive strength was more stable at 5%-15% EP dosing, which was in line with the performance of the density decrease;

ISSN: 2414-1895 DOI: 10.6919/ICJE.202406_10(6).0013

the addition of VM made the samples undergo different changes in the compressive strength, which showed a decreasing-rising-decreasing The compressive strength of the samples changed differently with the addition of VM, showing a decreasing-rising-decreasing trend, from the initial 14.55 MPa to 13.74 MPa, then increasing to the highest point of 16.31 MPa and decreasing to the lowest of 13.54 MPa at 20% VM dosage. From the 14d situation, the addition of EP produced a decrease in the compressive strength of the gypsum-based lightweight mortar samples [7], which was similar to the development trend at 3d, from 11.28MPa to 8.08MPa at 0% dosing, but the compressive strength at 5%-20% dosing of EP only showed a weak trend; the addition of different amounts of VM resulted in the compressive strength of the samples to undergo a different magnitude of growth which increased from 11.28 MPa initially to 12.78 MPa at the highest 15% VM doping, and then decreased slightly to 11.97 MPa at 20% doping. It can be seen that the addition of VM has a positive effect on gypsum-based lightweight mortar, and the compressive strength can still reach 11.9MPa and above when the density drops to 750kg/m³ at 20% dosage. The addition of light aggregate EP and VM does not have a great influence on the compressive strength of gypsum-based lightweight mortar, mainly because of the large water-cement ratio, after adding EP and VM, the water absorption of the two solves the excess water after the reaction and provides water for the hydration at a later stage, especially for VM, the compressive strength is improved to some extent under the joint action with GM-PO-S95.

3.3 Flexural Strength

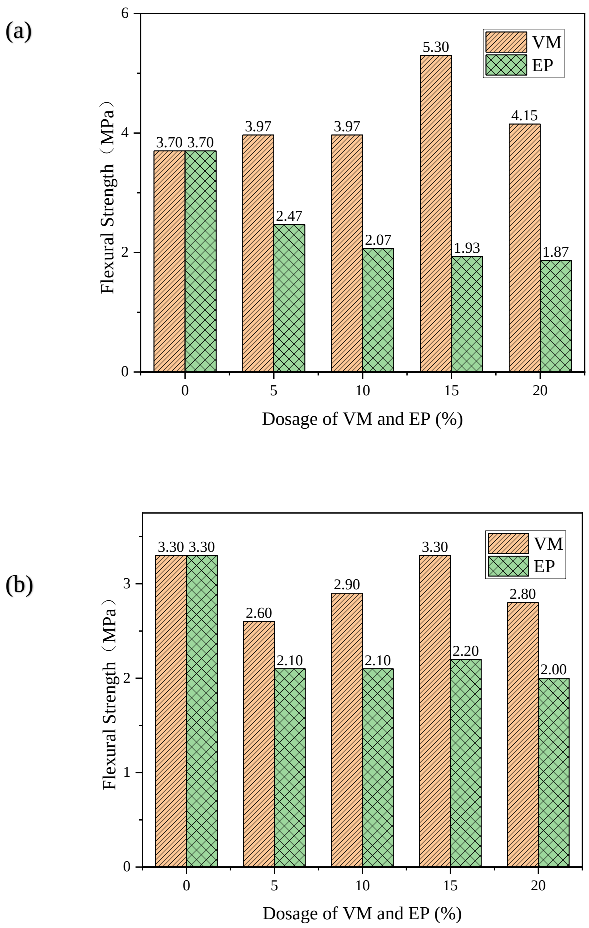


Figure 4. Flexural strength of Lightweight gypsum mortar (a)3d, (b)14d

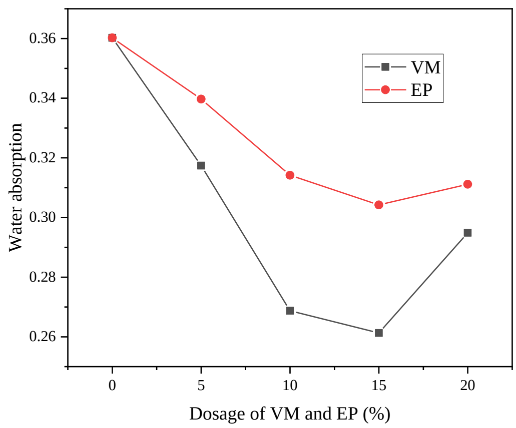
The variation of the effect of EP and VM addition on the flexural strength of gypsum-based lightweight mortar is demonstrated in Figure 4. From the condition at different ages of 3d and 14d,

ISSN: 2414-1895 DOI: 10.6919/ICJE.202406_10(6).0013

the flexural strengths of the lightweight mortar test samples with different mass proportions of lightweight aggregates (VM, EP) added to the GM-PO-S95 system showed different trends. From the 3d case, the addition of EP in the gypsum-based lightweight mortar samples produced a sustained and significant decrease in the flexural strength, from 3.70 MPa at 0% EP dosing to 1.87 MPa at 20% EP dosing, a decrease of about 49.5%; the addition of VM resulted in different degrees of increase in the flexural strength of the lightweight mortar samples, from the initial 3.70 MPa to the 5.30 MPa at the highest, which is 43.2% higher compared to the blank group samples, and still reaches 4.15 MPa at 20% VM dosing. From the 14d case, the addition of EP showed a similar trend to that at 3d, decreasing from 3.30MPa at 0% dosing to 2.00MPa, but the flexural strength only showed a weak trend at 5%-20% dosing of EP; while the addition of VM in different amounts caused the flexural strength of the lightweight mortar samples to change differently, decreasing from 3.30MPa initially and then increasing 15% at 3.30MPa at VM admixture and then a small decrease at other admixtures. It can be seen that the addition of VM has brought a positive effect on the flexural strength of gypsum-based lightweight mortar, and the flexural strength can still reach about 3.0 MPa when the density decreases to 750 kg/m³ at 14 d. The main reason is that the EP strength is low and the open holes cause it to be churned; the closed structure of VM causes it to have a certain strength. The main reason is that, during the mixing process of light mortar, the EP strength is low and the open holes cause it to be stirred up; the closed structure of VM causes it to have a certain degree of strength, which plays a certain role in the mechanical properties of gypsum-based lightweight mortar, and it is still able to maintain the strength of gypsum-based lightweight mortar while the density decreases significantly.

3.4 Water Resistance

(a)



(b)

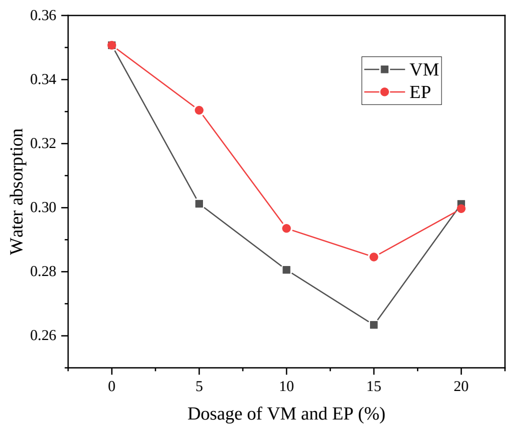


Figure 5. Water absorption of Lightweight gypsum mortar (a)3d, (b)14d

Volume 10 Issue 6, 2024
DOI: 10.6919/ICJE.202406_10(6).0013

The trend of water absorption of gypsum-based lightweight mortar by the addition of EP and VM is shown in Figure 5. From the condition of different ages of 3d and 14d, the water absorption of the test samples with different mass proportions of lightweight aggregate (VM, EP) added into the GM-PO-S95 system underwent different changes, with an overall trend of decreasing and then increasing. At 3d, the water absorption of gypsum-based lightweight mortar at different lightweight aggregate EP and VM dosages decreased from 36% to 31% and 26% at 15% dosage, respectively, compared to the blank group, and then produced a slight increase. Water absorption reached a minimum value of 26% at VM dosing of 15%. At 14d, the overall situation of water absorption was similar to the trend at 3d, also reaching a minimum value of about 26% at 15% VM. Overall, the decrease in the addition of VM compared to EP is more obvious reasons, mainly due to the presence of more open holes in EP is easy to break, resulting in more pores in the structure; and most of the closed pore structure in VM and fusion with gypsum crystals, to a certain extent, reduce the entry of water molecules, and correspondingly reduce the water absorption of the specimen.

3.5 LF-NMR Analysis

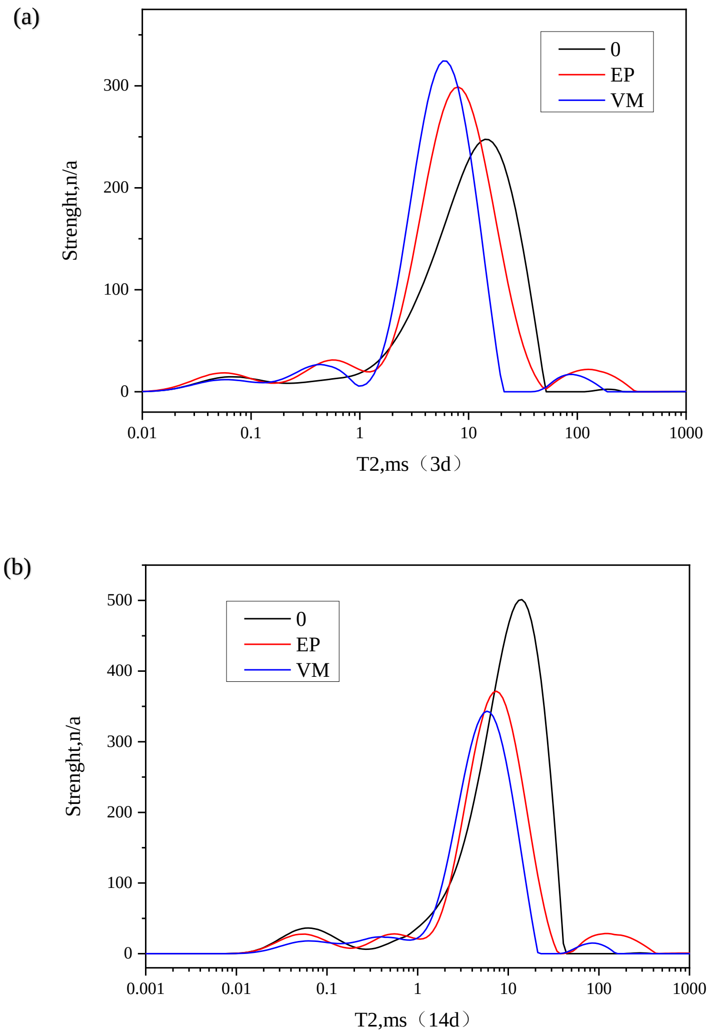


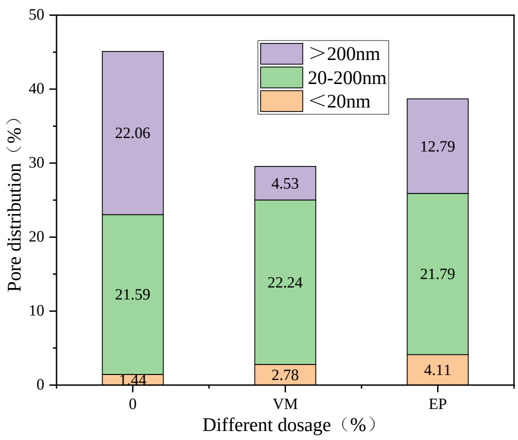
Figure 6. T2 of Lightweight gypsum mortar (a)3d, (b)14d

As shown in Figure 6 and 7, the pore structure relaxation time changes and pore size distribution ratio stacking of gypsum-based lightweight mortar after adding EP and VM. From the condition at different ages of 3d and 14d, the pore size distributions of the test samples with different mass proportions of

ISSN: 2414-1895 DOI: 10.6919/ICJE.202406_10(6).0013

lightweight aggregates (VM, EP) added to the GM-PO-S95 system all underwent different reductions, and the overall pore size distribution stacking was also reduced accordingly. In terms of relaxation time, at 3d, the main peak of the relaxation time of GM-PO-S95 system without light aggregate existed at about 2-52ms, and then after the addition of light aggregate (VM, EP), the main peak shifted to the left to 1.5-20ms and 1.5-40ms, respectively, and the peak area was also significantly reduced. At 14d, the main peak of relaxation time of GM-PO-S95 system without adding light aggregate existed around 1-30ms, and then after adding light aggregate (VM, EP), the main peak was shifted to the left to 1.2-20ms and 1.2-35ms, respectively, and the height of the peaks was also significantly decreased, and the area of the peaks was reduced[8]. In terms of the proportion of pore size distribution, at 3d, the proportion of multi-hazardous pores decreased from 22.06% at 0 to 4.53% (VM) and 12.79% (EP); the proportions of less-hazardous and hazardous pores did not differ much and remained around 21.79%, while non-hazardous and gelled pores increased from 1.44% to 2.78% and 4.11%. At 14 d, the proportion of multi-hazardous pores decreased from 21.83% at 0 to 4.13% (VM) and 9.91% (EP); the proportion of less harmful and harmful pores remained little different, maintaining at 21.5% up and down, and the non-hazardous and cementitious pores were also maintained at about 3.48% the change was not obvious. This is mainly because the addition of light aggregate absorbed the excess water after the reaction, making the light aggregate and gelling material fill more closely with each other, and the change in pore size structure further explains the changes in the mechanical properties and water resistance of gypsum-based lightweight mortar, which corresponds to the changes that occurred in the physico-mechanical properties and water resistance [9].

(a)



(b)

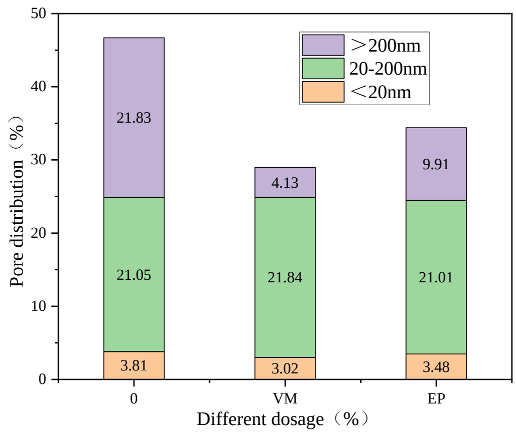


Figure 7. pore distribution of Lightweight gypsum mortar (a)3d, (b)14d

ISSN: 2414-1895 DOI: 10.6919/ICJE.202406_10(6).0013

3.6 SEM Analysis

As shown in Figure 8, the microstructural morphology in gypsum-based lightweight mortar and after adding EP (b) and VM (c) with the blank group (a). In the microstructure morphology of lightweight mortar with EP added (b), it is obvious to see that the expanded perlite EP in the figure becomes a fragmented mesh, with gypsum crystals interspersed in it, surrounded by more and more obvious pores, with a loose structure and disordered arrangement; In the micro-morphology c-plot of the added VM, the outer wall of the glass beads is thick, the shape is intact and not churned, and there are gypsum crystals into its internal structure, which are closely connected and interact with each other, and together they provide a positive effect on the mechanical properties of the gypsum-based lightweight mortar. It can be seen that different light aggregates bring large differences to the gypsum-based lightweight mortar, which is readily apparent in the microstructure. The combination of glass beads VM and gypsum crystals with each other jointly supports the mechanical properties and water resistance of gypsum-based lightweight mortar, which, together with the previous pore size distribution, explains the reason why the density decreases dramatically but the performance is still better.

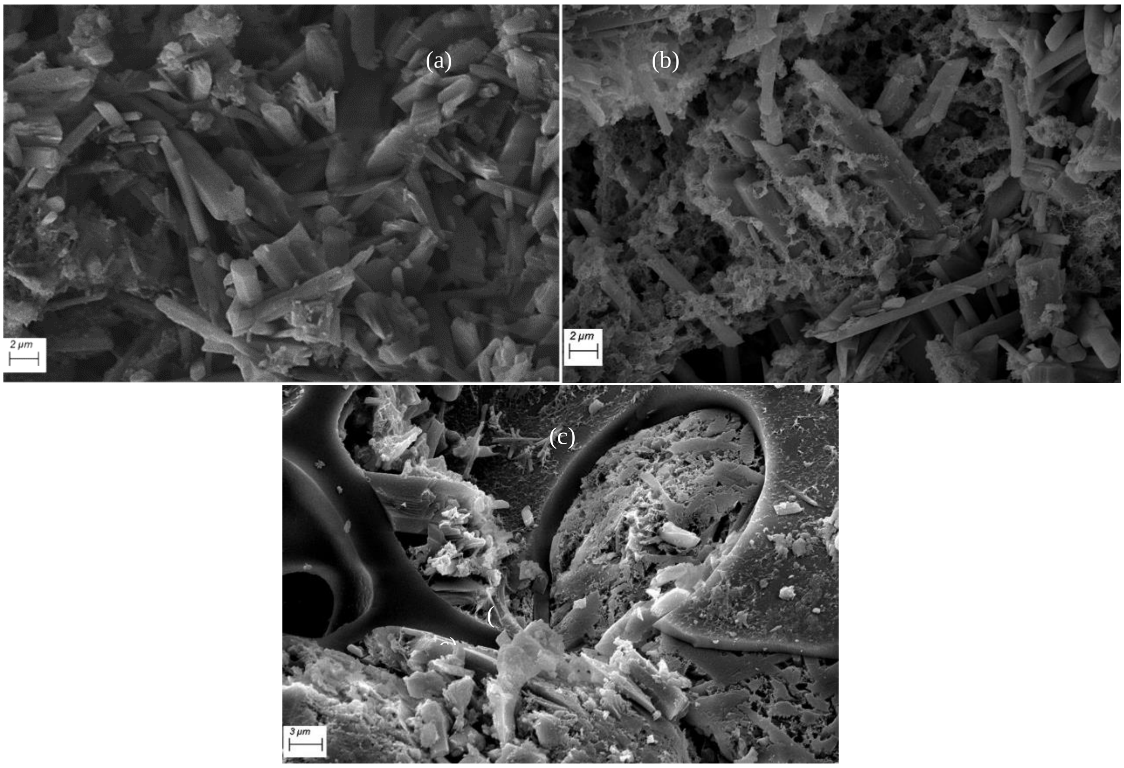


Figure 8. SEM of Lightweight gypsum mortar (0(a), EP(b), VM(c))

4. Conclusion

In this chapter, the change rule of performance of lightweight gypsum mortar jointly prepared by EP and VM mixed into GM-PO-S95 system in different proportions was investigated, and the mechanical properties, density, water resistance, and microscopic morphology and pore size distribution of lightweight gypsum mortar were analyzed, and low-density and high-performance lightweight gypsum mortar was prepared. The following conclusions were mainly drawn:

Lightweight gypsum mortar with different lightweight aggregates was prepared with different proportions of EP and VM, and the density of the specimens decreased significantly after the addition of lightweight aggregates, and at 20% VM admixture, the density decreased to 715 kg/ m^3 at 3d, and to about 750 kg/m^3 at 14d, both of which decreased by more than 62%.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202406_10(6).0013

While the density of the lightweight gypsum mortar decreased to about 750 kg/m³, the mechanical properties remained good, with the compressive strength maintained at 12 MPa, the flexural strength maintained at 2.8 MPa, and the water absorption rate decreased to about 26%.

The addition of EP and VM in different proportions to the GM-PO-S95 system changed the internal structure of lightweight gypsum mortar, especially the addition of VM, which worked together with the gypsum crystals after the hydration of the GM-PO-S95 system, which not only reduced the proportion of the pore size distribution, but also gypsum crystals entered into the interior of the VM, and interacted with the VM, and together propped up the internal structure of the lightweight gypsum mortar, which corresponded to the change of the physico-mechanical property situation.

Acknowledgments

The authors gratefully acknowledge the Science and Technology Project of Henan Province (232102321145) and the Key Public Welfare Special Project of Henan Province (201300311000).

References

[1] X. Xin, G. Chen, X. Zhang, et al. Progress of gypsum solid waste recycling[J]. China Powder Technology, 2023, 29(01): 10-18.

[2] H. liang, L. Xiang, Y. Wu, Guangzhou Chemical Industry[J], 2016, 44(21), 86.

[3] D. Zhang, D. Wang, J. Zhao, et al. Building materials development orientation (below) [J], 2016 (12), 72.

[4] S. Liao,Z. Zhao,L. Wu,et al. Effect of lightweight ceramic granules on thermal insulation performance of phosphorus building gypsum_Liao Shixiong[J]. New Building Materials, 2021, 48(02): 142-145.

[5] A. San-Antonio-Gonz´ alez, M.D.R. Merino, C.V. Arrebola, P. Villoria-S´ aez, Lightweight material made with gypsum and extruded polystyrene with enhanced mechanical strength, Constr. Build. Mater. 93 (2015) 57–63.

[6] Z. Jin, C. Cui, Z. Wan, et al. Preparation of eco-friendly functional lightweight gypsum: Effect of three different lightweight aggregates[J]. Construction and Building Materials, 2023, 400: 132875.

[7] Z. Jin, B. Ma, Y. Su, H. Qi, W. Lu, T. Zhang, Preparation of eco-friendly lightweight gypsum: Use of beta-hemihydrate phosphogypsum and expanded polystyrene particles[J]. Construction and Building Materials, 2021,297:123837.

[8] L. Liu, Z. He, X. Cai, S. Fu, Application of Low-Field NMR to the Pore Structure of Concrete[J]. Appl Magn Reson 2021,52: 15–31.

[9] W. Shen, X. Li, G. Gan, L. Cao, C. Li, J. Bai, Experimental investigation on shrinkage and water desorption of the paste in high performance concrete[J]. Construction and Building Materials, 2016,114: 618–624.