Effect of matrix components on performances of cement-EPS/VM insulation mortar

Mingxu Chen, Shoude Wang, Lingchao Lu*, Wen Zong, Piqi Zhao, Chenchen Gong

[1]Shandong Provincial Key Lab. of Preparation and Measurement of Building Materials, University of Jinan, Jinan 250022, China.
*corresponding author, Email: mse_lulc@ujn.edu.cn

ABSTRACT

Cement-EPS/VM insulation mortar (CEV) was prepared by using suphoaluminate cement as main matrix, VM (vitrified microsphere) and EPS as insulation aggregates. Moreover, the effects of polypropylene fiber, paper sludge ash (PSA), ordinary Portland cement (OPC) and SCM as part of matrix on the mechanical and insulation performance of CEV were investigated. The experimental results showed that 0.3w% fiber would result in the increase of mechanical strength and water resistance of CEV mortar. 20w% OPC and 10w%PSA could decrease the cost of CEV mortar and improve its water resistance with some loss of mechanical strength.

Keywords: Insulation mortar; Polypropylene fiber; SAC; PSA

1 INTRODUCTION

In present, the world is facing a grim situation of energy conservation and emission reduction. The building sector is known to contribute largely in total energy consumption and CO_2 emissions [1] and the external insulation technology has become one of the most direct and scientific way of energy saving [2-3]. The production of appropriate materials for insulation materials is of great importance.

Now, the category of cement-based insulation material is varied such as cement-based polyurethane foam insulation materials, foam cement insulation materials [4] and cement-based EPS insulation mortar [5-8]. The introduction of Insulation ingredient, such as polyurethane foam, redispersible latex powder, EPS, vitrified microsphere, even for gas bubble, could endow cement-based insulation material with good insulation performances and low dry density. But it also brings out some drawbacks (such as poor stability of slurry, easy to crack and poor toughness). In order to solve these problems, many types of materials are added into cement-based insulation, such as aerogel [9], rice straw [10], wood shavings [11], paper sludge ash [12], sunflower, polymers electric wires and rice husk ash. In particular, adding the optimal amount of fiber in thermal insulation mortar can improve the toughness and increase the splitting tensile strength.

In this paper, the CEV mortar is prepared by suphoaluminate cement (SAC), small aggregate of VM with size of several millimeters and big aggregate of EPS with high porosity consisting essentially of 98%air. Some experimental results about CEV mortar have been obtained that the ratio of VM to the whole insulation aggregate and its addition content, also the influence of emulsified asphalt and redispersible latex powder on properties of mortar and their addition content. In the next step, the effects of matrix components, such as fiber, PSA and OPC content, on the performances of CEV will be investigated.

2 EXPERIMENTAL

2.1 Specimen Preparation

OPC (42.5 grade, Shanshui Cement, CHN) was used in CEV mortar, whose initial setting time and final setting time was 40min and 135min, respectively. SAC (42.5 grade, Zhonglian Cement, CHN) is a kind of special rapid-hardening cement, which was used as a cementitious material in CEV mortar. Also, its initial and final setting time was 9min and 15min, respectively. The detail material behavior of OPC and SAC were shown in Table 1. The properties of EPS and VM were shown in Table 2. Paper sludge ash was obtained from Huatai Company, whose chemical components were shown in Table 3. First, SAC cement was mixed with HMPC and Polypropylene fiber while water was mixed with air-entraining agent. Then EPS and VM particles were added to the mortar when the mixture was stirred well-distributed by mortar mixer. After that, the mixture was put into 40 *40 *160 mm^3 moulds. It was cured at 20℃ for 24 h, and its relative humidity was 95%. At last, CEV mortar was demoulded when the curing time was up to the specific age.

2.2 Testing Method

Mechanical properties of cured CEV mortar were tested by using a flexural and compressive testing machine (CDT1305-2), whose capacities was 300KN. The specimens were carried out in testing machine until it was damaged at a loading speed of 0.3KN/s. The water of CEV

mortars were carried out following JC/T 1042-2007. The mortars were kept in vacuum drying oven at 60℃ until no longer changes in weight. The dry specimen completely immersed in water for 48h until a constant weight was reached. After the mortar was dried, the dry density is accurate ensured by using scales.

Cement type	Density/kg/m^3	Setting time/min		Compressive strength/MPa		
		Initial	Final	3d	7d	28d
Sulphoaluminate cement	2.83	9	15	45.1	—	50.7
Portland cement	3.12	40	135	—	35.8	46.8

Table 1: Physical properties of cement

Insulation aggregate	Particle size /mm	Bulk density / kg/m^3	Thermal conductivity /W/(m·K)	Water absorption /%
EPS	2.0－5.0	8.9	0.041	—
VM	0.15－0.50	120	0.048	38.5

Table 2: Properties of insulation aggregate

element	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Loss
PSA /wt%	25.12	23.99	3.54	28.5	1.17	8.37	5.39

Table 3: Complete chemical analysis of mineral

3 RESULTS AND DISCUSSION

3.1 Polypropylene Fiber

The shortcomings of easy to crack and brittleness of cement-based insulation materials can be overcome by adding chopped fibers. In particular, polypropylene fiber is one of widely used fibers with low cost, which could play the role of better bonding to cement hydrates and decrease the plastic shrinkage and micro-cracking of surface. In this experiment, the mechanical strength of CEV mortar with different fiber content cured for 3days and 7days is shown in Fig.1. It is seen that the compressive and flexural strength increases gradually with the rise of fiber content regardless of cured days. Apparently, the compressive and flexural strength of CEV mortar reaches its maximum value when fiber addition is 0.30%. The compressive strength of cured for 3days and 7days increased about 31% and 42%, respectively. The possible reason is that the fiber with high elastic modulus forms a three-dimensional network, which reinforces the structure of CEV mortar. Also, the change trend of flexural strength for 3days and 7days is in accordance with the compressive strength. Due to big contact surface between fiber and cement matrix, which is benefit to consume much energy in the destroy process of CEV mortar. This results in the flexural strength of CEV mortar with fiber higher than that of reference specimen. In addition, the better fracture elongation of polypropylene fiber can obviously improve deformation ability of CEV mortar after cracking. After that, the compressive and flexural strength decreases slowly, the reason is that extra content of fiber in mortar would be cluster, resulting in a decline in the mechanical properties of CEV mortar.

As for pressure off ratio of CEV mortar, the fiber addition of 0.10% endows mortar with low value, which is better to improve the mechanical performance of insulation material. And the more addition of fiber has no obvious influence on the pressure off ratio. Water resistance is one of the most important performances to characterize CEV mortar. The softening coefficient is shown in Fig.1. Regardless of fiber addition, softening coefficient of CEV mortar is almost stable and keep a better water resistance due to the softening coefficient is greater than 0.8. Fig.2 shows that the dry density, water absorption and moisture content of CEV mortar with different fiber content. With the rise of fiber content, water absorption and moisture content are of CEV mortar slightly decreases compared with the reference specimen, also, the dry density increased until fiber content reached 0.30%. Due to the presence of polypropylene fibers, CEV mortar is able to resist the propagation of internal crack in the later cured ages. This results in low porosity of CEV mortar. Consequently, CEV mortar has low water absorption and moisture content. Naturally, low porosity of CEV mortar will cause the increase of its dry density.

3.2 Paper Sludge Ash

Paper sludge ash (PSA) is a kind of problematic waste materials with main composition of $Ca_2Al_2SiO_7$ and $CaSO_4$, whose XRD pattern was shown in Fig.3. The size of PSA particle is so small (its particle size analysis was shown in Fig.4) that it can be used to fill the pores between EPS and VM. Fig.5 shows a slight decrease in compressive strength from 0.811 to 0.697 MPa and flexural strength from 0.786 to 0.625 MPa on increasing the PSA content from 0% to 40% for CEV mortar. Furthermore, the decrease trend of mechanical strength was observed for mortars with the amount of PSA increased to 10%. Also, in this case, the pressure off ratio and softening coefficient were the best. Fig.6 shows that volumetric water absorption and moisture content are found to be in the range of 6.88%~11.69% and 10.78%~12.80%, respectively, when PSA content increases from 0% to 40%. So, the optimal result, 8.43% and 10.78%, were observed for mortar when PSA content increased to 10% in terms of mechanical strength. In addition, dry density increased to 401 kg/m^3, which results in a better water resistance. The presence of PSA in CEV mortar caused mechanical strength loss is inevitable tend, this case is due to the low activity of $Ca_2Al_2SiO_7$ and $CaSO_4$ was not able to provide strength. PSA with has particle size distribution ranging from 3μm-80μm, which results in a better water resistance and the structure of CEV mortar more compact.

3.3 OPC

It is known that the high amount of $Ca(OH)_2$ is formed in the process of OPC hydration, which results in the high alkalinity in pore solution of hardened cement paste.

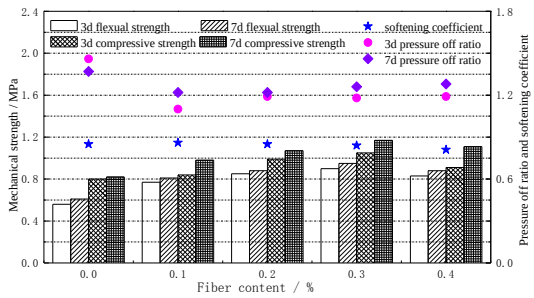

Fig.1. Pressure off ratio, softening coefficient and mechanical strength of CEV mortar with different fiber content

The effects of OPC content on mechanical strength and softening coefficient of CEV mortar are illustrated in Fig.5. As shown from Fig.5, it is seen that the mechanical strength of every specimen with OPC is lower than those of reference specimen. When the addition of OPC is 20%, the decrease aptitude of mechanical strength of CEV mortar is the smallest among all specimens with OPC. Although the hydration process of SAC and OPC can promote each other, the mechanical strength is not a simple superposition. As for softening coefficient, the appropriate content of OPC corresponding to its high value is also 20%.

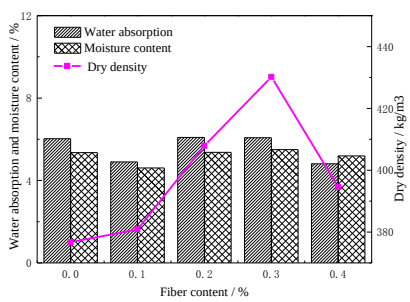

Fig.2. Dry density, water absorption and moisture content of CEV mortar with different fiber content

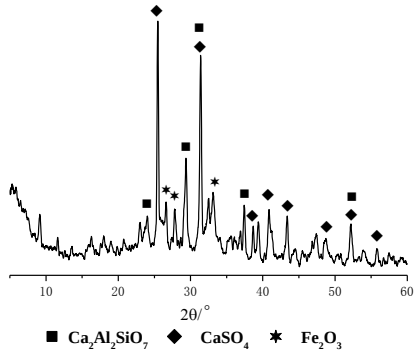

Fig.3 XRD pattern of PSA

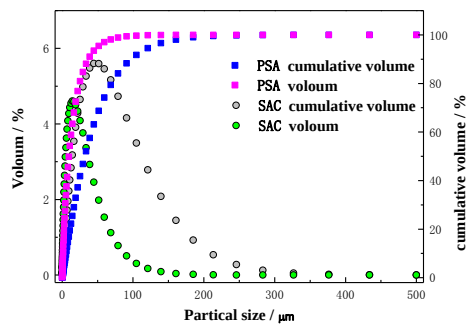

Fig.4 particle size analysis of PSA and SAC

Fig.6 shows the variation in dry density and water resistance with different OPC content for CEV mortars. The volumetric water absorption and moisture content at 7d are found to be in the range of 7.77%~12.05% and 6.4%~7.7%, respectively, when OPC content increases from 0% to 30%. It is observed that the optional results were 7.77% and 6.4% when the dosage of OPC was 20%. At this time the dry density of CEV mortar increased to 325 kg/m^3, which results in the increase of the water resistance. Therefore, replacing SAC with OPC in CEV mortar is crucial to ensure the mechanical strength of cementitious material and reduce the cost of thermal insulation material. In the following study 20% OPC is employed to replace SAC.

4 CONCLUSIONS

The experimental results showed that the mortars have a better property as the polypropylene fiber content of the CEV mortar reached 0.30%. The 3d compressive and flexural strength achieves 1.05MPa and 0.90Mpa respectively. Meanwhile, with the rise of fiber content, water absorption and moisture content are of CEV mortar

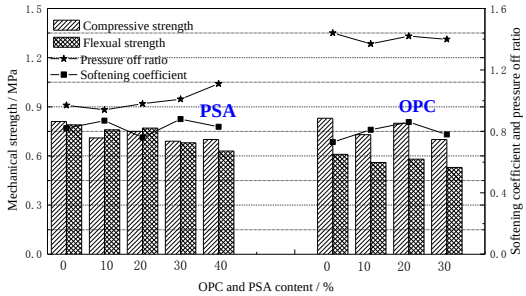

Fig.5 Pressure off ratio and mechanical strength of CEV mortar with different OPC and PSA content

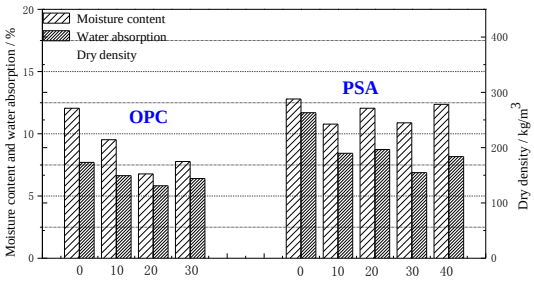

Fig.6 Dry density, water absorption and moisture content of CEV mortar with different OPC and PSA content

slightly decreases compared with the reference specimen. When the addition content of PSA was 10%, the water resistance, pressure off ratio and softening coefficient of CEV mortar would get its high value, only with small loss in mechanical strength. It is contributed to the small size of PSA is ranging from 3μm-80μm. In addition, although the mechanical strength of every specimen with OPC is lower than those of reference specimen, the decrease aptitude of mechanical strength of CEV mortar is the smallest among all specimens with OPC when the addition of OPC is 20%. Meanwhile, it can reduce the cost of CEV mortar at the extreme.

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