

Development of Cement-based Relief Coatings

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Abstract. In this paper, the application of microsilica and mine tailings in cement-based relief coatings is introduced, the synergy effect mechanism of microsilica and re-dispersible glue-powder in improving the early water-resisting strength, wear and adhesive performance of coating, and the effect of the mixture of mine tailings with natural sand on initial dry cracking-resistance and spray ability are studied.

1. Introduction

Relief coating is a three-dimensional multi-layer coating for architecture, which is sprayed or roll coated to show concave-convex pattern, multi-layer pattern or orange peel pattern, and form a finish with distinctive levels and good texture. Relief coating has excellent adhesive property and performs well in water, alkali and weather resistance, so it is widely used to protect internal and external walls of various buildings. At present, relief coatings in the market are mainly made of synthetic resin emulsion binding agent, which is poor in cold & heat cycle resistance, alkali resistance and weather resistance, inconvenient in storage and transportation, and is costly; cement-based relief coating as a kind of dry powder decorative mortar is made of cement, re-dispersible glue-powder, aggregate and addition agent. With polymer glue powder and cement as cementing materials, cement-based relief coating is characterized by: (a) high cohesive strength and convenient to use: before using, add a certain amount of water and stir until it becomes a uniform paste; (b) excellent adhesive property and performs well in water, alkali and weather resistance, and is applicable to wet base; (c) low in cost and performs well in durability; (d) convenient in production, construction, storage and transportation, and is more applicable to wet base. Therefore, cement-based relief coating enjoys strong market competitiveness and good prospect of application.

Cement-based relief coating is a kind of dry powder mortar, which is made of cement, aggregate and admixture. Before using, add a certain amount of water and stir to form a paste and then spray or roll coat to form concave-convex pattern, multi-layer pattern or orange peel pattern, thus creating a finish with three-dimensional pattern. Microsilica and mine tailings, as industrial wastes, can partly replace cement and natural fine sand which are used as raw materials in producing cement-based relief coating. Micro silica fume (scientific name "microsilica") is a kind of fly ash collected from smoke dust generated during ferro-silicon alloy or industrial silicon smelting process, and particle size of microsilica is around 0.1 μ m. Addition of microsilica in cement-based relief coating contributes to higher strength and durability of coating. Natural fine sand has small fineness modulus, so cement consumption and water demand is large; on the contrary, mine tailings has distinctive grain corner and large roughness, so a mixture of mine tailings and natural sand based on a certain proportion, if applied in cement-based relief coating, can reduce consumption of both cement and water and enhance initial dry cracking-resistance and sprayability. On the one hand, large-scale excavation of natural



sand will damage river course, affect shipping, bring hidden safety danger on flood control of river embankment, besides, immoderate excavation of natural sand will inevitably damage ecological environment; on the other hand, in order to stockpile bulky industrial solid waste and industrial mine tailings, a lot of land are occupied, which directly pollute environment and water resource. These industrial solid wastes and mine tailings are the best sources of dry powder mortar, Hence, application of microsilica and mine tailings in cement-based relief coating can not only lower cost, but also reduce natural sand excavation volume, recycles industrial waste, realizes comprehensive utilization of resources and makes a great contribution to environment and resources conservation.

2. Composition of cement-based relief coatings

2.1 Cementing material

Cementing material is an important component of cement-based relief coating, serving as adhesion agent.

2.1.1 Inorganic cementing material-cement. Cement is an inorganic cementing material for cement-based relief coating. On the one hand, cement as a kind of hydraulic cementing material can improve cohesive strength of coating and a mixture of cement and powder can further improve water resistant performance of relief coating under synergy effect of active cation and hydrophilic anion in powder. On the other hand, cement as the main filler of relief coating can enhance both fullness and three-dimensional decorative effect of such coating. Considering a balance between coating strength, spray ability and the influence of different types of cement on comprehensive performance of relief coating, and upon test, 425# white ordinary Portland cement is selected as the inorganic cementing material for cement-based relief coating.

2.1.2 Selection of re-dispersible glue-powder. The types, structural forms and distribution of re-dispersible glue-powder can significantly affect structure and performance of hardened polymer cement-based relief coating. Polymer-cement-based relief coating is generally divided into three parts: set cement, polymer and pore. Hardened coating is mainly composed of set cement and polymer, which are bonded on interface between inorganic particle and polymer particle in coating structure. Performance of polymer depends on binding form of polymer glue powder and cement as well as their mutual cementation. At present, main types of glue powders adopted include ethylene- acetate ethylene powder and polyvinyl alcohol powder. Table 1 compares their performances in cement-based relief coating.

Table 1. Performance comparison table of several powder glues

Type		MCP-801	2488	PV-23	5603P	150S
Cohesive strength (Mpa)	Original strength	0.50	0.62	0.8	0.89	0.90
	Water-resisting strength	0.41	0.48	0.92	1.20	1.16
Cost		Low	Relatively low	Moderate	Moderate	Relatively high

According to Table 1, PV-23, 150S and 5603P shows good original strength and water-resisting strength, of which, the first two are inferior while prices of the latter two are higher, so 5603P has the best performance-to-price ratio. 5603P is a kind of re-dispersible vinyl acetate-ethylene copolymerized emulsion powder, which is of low verification temperature and higher flexibility, so it is applicable to cement-based relief coating.

2.1.3 Influence of different polymer-cement ratios on performance of cement-based relief coating. Influence of different polymer-cement ratios on performance of cement-based relief coating under the same test conditions. Figure 1 shows that larger polymer-cement ratio will lead to a significant increase of cohesive strength and improvement of initial dry cracking-resistance of coating, polymer-

cement ratio then is 0.3-0.4. The reason is that hydrophilic polymer and liquid phase of cement permeate into base holes and pores, polymerize to form film, and firmly absorb on the base surface, thus guaranteeing good and firm bonding between coating and base. Polymer modified cement involves two processes: cement hydration and film formation of polymer. Cement hydrates firstly, and then condensate and harden, while dehydrated polymer will form a film attached to hydrated cement particles and realize a linear polymerization between pores which constitutes mutual continuous phase with set cement. It has two functions: firstly, to block pores in cement-based relief coating, slow down water evaporation speed and reduce evaporation volume so as to inhibit the generation of crack; secondly, once microcrack is formed, polymer film can serve as a bridge and filler under polymer bonding effect, inhibiting development and enhancing initial dry cracking-resistance of such coating.

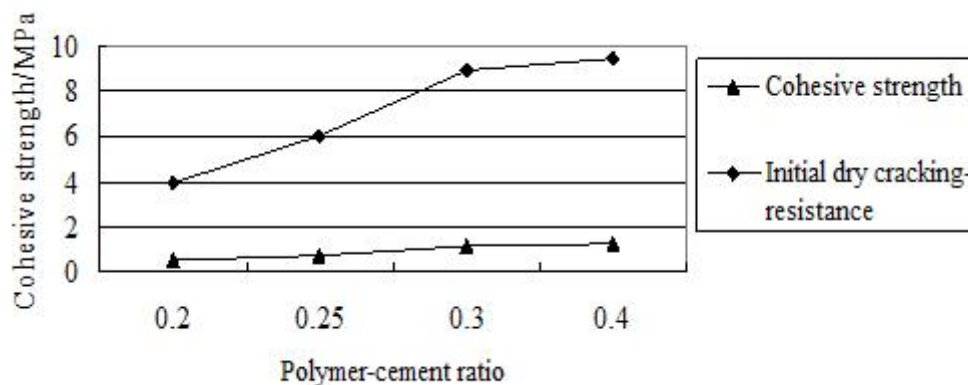


Figure 1. Influence of different polymer-cement ratios on performance of cement-based relief coating. (Note. 10 levels are classified based on initial dry cracking of coating. The larger the value, the better crack resistance)

2.1.4 Influence of synergy effect of microsilica and re-dispersible glue-powder on early water-resisting strength of coating. Due that top coating is generally applied 24 hours after relief spray coating is dried; relief coating shall have good original strength and early water-resisting strength. Test proves that the synergy effect of microsilica and emulsion powder can significantly improve early water-resisting strength of relief coating. The synergy effect mechanism of emulsion powder and microsilica is physical and chemical reactions on surface, which is a complex process, and is manifested in two aspects: firstly, surface active agent is absorbed onto super mineral powder surface, electric potential is enhanced and such actions as water reduction, dispersion, plastification, filling and homogenization on cement mortar of relief coating can be improved. The combination of surface active agent and super mineral powder contributes to form a compact microstructure of cement-based relief coating. In addition, the introduction of glue powder and super mineral powder-microsilica can greatly reduce weepage and improve pore structure; secondly, microsilica can fill internal void and defect in cement-based relief pulp structure and reduce the quantity of glue powder used to fill void and defect, so that glue powder can be used to fully wrap mineral powder and cement particle surface, facilitating net forming when glue powder dosage is low, and better inhibiting formation and expansion of crack. The combined action of the two aspects can not only improve efficiency of glue powder and mineral powder, but also enhance early stage water resistant performance of polymer cement-based relief coating with a low polymer-cement ratio. Beyond that, as average particle size of microsilica is only 1% of that of cement, microsilica added in cement-based relief coating will fill cement particle void to make coating more compact. Microsilica will combine with free $\text{Ca}(\text{OH})_2$ to form a stable hydrate of calcium silicate ($2\text{CaO} \cdot \text{SiO}_2 \cdot n\text{H}_2\text{O}$) with jelly strength higher than that of $\text{Ca}(\text{OH})_2$ crystal, thus improving water-resisting strength of coating. Table 2 shows the relationship between its dosage and early water-resisting strength (soaked in water for 48 hours after being formed for 3 days) of relief coating.

Table 2. The relationship between volume of microsilica addition and relief coating strength

Volume of addition %	0	0.5	1	2	3
Initial water-resistant cohesive strength (MPa)	0.28	0.40	0.52	0.74	0.60

According to Table 2, if microsilica dosage is 1%-2%, cement-based relief coating has good early water-resistant cohesive strength, so microsilica is selected as cement reinforcing material.

2.2 Selection and application of aggregate

Relief coating is featured by uneven finish, distinctive layers and strong relief perception, so coating with cement as the sole addition material will be poor in sprayability and constructability; besides, relief coating strength is affected by small point and rapid drying process, so a certain amount of natural sand or mine tailings must be added to enhance fullness and anti-crack resistance and to achieve a good decoration effect. Meanwhile, rational grading must be adopted to improve sprayability and crack resistance of relief coating.

2.2.1 Influence of mine tailings on sprayability and cold & heat cycle resistance performance of cement-based relief coating. Mine tailing is a kind of solid waste generated during mining and mineral separation, which is randomly discharged, leading to serious pollution on ecological environment. Therefore, by replacing mine tailings with natural sand in producing cement-based relief coating and other types of dry-mixed mortar products, excavation volume of natural sand will be reduced, river course and land protected, environmental and resource better conserved and product cost greatly reduced. Relief coating is applied on the site by means of air pump and special spraying gun, so it shall have good sprayability, and cold & heat cycle resistance performance if applied on external wall.

Table 3. Influence of Mine Tailings-Natural Sand Mixture Ratio on Sprayability and Cold & Heat Cycle Resistance Performance of Coating

SN	White cement /kg	Microsilica/ kg	Admixture/ kg	Fiber/ kg	Mine tailings/ kg	Natural fine sand/kg	Sprayability	Cold-heat cycle resistance (10 cycles)
1	420	22	18	40	150	350	Good	Blistered and cracked
2	420	22	18	40	200	300	Good	Blistered and cracked
3	420	22	18	40	250	250	Good	No blistering and crack
4	420	22	18	40	300	200	Weak	No blistering and crack

According to Table 3, under the same condition, coating performs well in sprayability and cold & heat cycle resistance if mine tailings/natural fine sand ratio is 1:1, the reason is that nearly spherical natural sand particle has "ball rolling" effect, surface area/volume ratio of spheroidal particle is small, cement mortar required to wrap particle is also small, and the remaining cement slurry is sufficient to enhance constructability of coating; polygonal mine tailings have mechanically interlocked particle surface, internal friction is thus increased and constructability of coating is degraded. However, stone powder in mine tailings can fill voids, wrap sand particle surface and reduce internal resistance between aggregates, thus enhancing workability, compactness and cold & heat cycle resistance of coating.

2.2.2 Influence of mine tailings on sprayability and cold & heat cycle resistance performance of cement-based relief coating. Cohesive strength is an important indicator which guarantees strength of

intermediate material and avoids hollowing and cracking. 14d tensile strength tests on relief coatings with different mine tailings/natural sand mixture ratios are conducted under standard curing condition, and the results are listed in the table below.

Table 4. Cohesive Strength and Failure Mode

SN	White cement/kg	Microsilica /kg	Admixture/kg	Fiber/kg	Mine tailings/kg	Natural sand/kg	Cohesive strength/Mpa	Failure form
1	420	22	18	40	150	350	0.52	Coating
2	420	22	18	40	200	300	0.65	Coating
3	420	22	18	40	250	250	0.92	Mortar
4	420	22	18	40	300	200	0.86	Mortar

According to Table 4, cement-based relief coating prepared by a mixture of mine tailings and natural sand (1:1) is well adhered onto test base material, with test failure surface occurring on the test base material. This is because that an appropriate amount of stone powder contained in mine tailings can improve workability of coating, increase its compactness, serve as filler, and improve adhesive performance of coating as a result of weak chemical reaction on its surface in a high concentration calcium hydroxide; mud contained in natural sand will reduce strength of cement-based relief coating, so mud content shall be strictly controlled.

2.3 Selection of anti-crack fiber

Relief coating is thick, so spraying point shall be large enough to generate good perception of relief, but crack will also occur during drying, to this end, grading of aggregate shall be adjusted, and a certain amount of anti-crack fiber shall be added to improve initial dry cracking-resistance of coating. Commonly used fibers and their performances are summarized in Table 5.

Table 5. Types and performance of commonly used fiber

Items	Functions
Wood fiber	Good dispersibility but ordinary crack resistance
Asbestos wool	Bad dispersibility, sprayability and crack resistance
Polypropylene fiber	Moderate dispersibility, bad sprayability and moderate crack resistance
Dula fiber	Bad dispersibility, moderate sprayability and good crack resistance
Wollastonite fiber	Good dispersibility, sprayability and crack resistance

Based on crack resistance test (under the temperature of 32°C -36°C, at wind speed level of 2-4, and air humidity is 40-55%), wollastonite fiber is selected as the anti-crack material for its performance in crack resistance and sprayability and price advantage.

By adding a certain amount of fiber, initial dry cracking-resistance of relief coating can be greatly improved, but sprayability will be lowered as fiber amount increases: coating is prone to have wiredrawing and not in a dotted layout. See Figure 2 for the relationship.

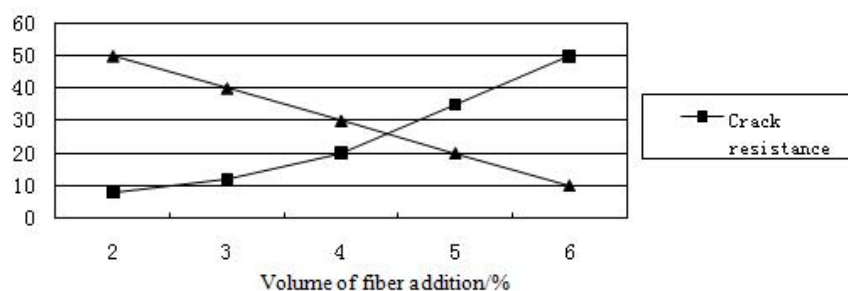


Figure 2. the relationship between volume of fiber addition and coating crack resistance and sprayability

2.4 Selection of water retention agent

On the one hand, dry powder relief coating as a cement-based product shall have good water retention property to ensure that cement in the system contains sufficient amount of water of hydration, so as to improve relief strength; on the other hand, it shall also have appropriate setting time to guarantee sufficient operable time. Therefore, different types and performance of water retention agents are of importance to physical property and workability of relief relief. Main types of water retention agents include cellulose derivative, stuff ether, bentonite, etc. Water retention rates of different water retention agents are measured utilizing vacuum suction method at differential pressure of 400 ± 5 mm mercury column, and draft filtering time is 30min.

Table 6. Water-intention rate of different water retention agents

Water retention agent	HPMC	MC-1	MC-2	Starch ether	Bentonite
Water-retention rate (%)	95.1	95.3	94.1	88	80

According to Table 6, MC-1 (viscosity: 30000CP) is selected as water retention agent of cement-based relief coating for its high water-retention rate.

3. Results and discussions

In this paper, sampling test on raw materials of coating is conducted and the role of microsilica as a kind of industrial waste and mine tailings in improving performance of cement-based relief coating is studied, and cost-effective dry powder relief coating is developed. All performance indexes are proved to meet the standard of Multi-layer Coatings for Architecture (GB/T9779-2005) upon inspection by Beijing Building Materials Quality Supervision and Testing Station, and the following conclusions are summarized:

(a)Rationally graded mine tailings and natural sand contribute greatly to better performance of cement-based relief coating in crack resistance and sprayability. Stone powders in mine tailings fill pores in coating, thus making coating more compact and workable.

(b)Thanks to the synergy effect of microsilica and glue powder, early water-resisting strength of cement-based relief coating is improved; a mixture of microsilica of cement can improve water-resisting strength and crack resistance of coating.

(c)Water retention agent, if utilized rationally, can change thixotropy, water retention property and sprayability of relief coating. Low viscosity MC performs well on this regard.

(d)Initial dry cracking-resistance and constructability of relief coating will be affected by types and dosages of different anti-cracking materials. 1mm long wollastonite fiber is generally adopted; low dosage of fiber leads to poor crack resistance, but high dosage will affect sprayability, so wollastonite fiber dosage is generally 4% and 5%.

4. References

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