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Effect of Adding Redispersible Polymer Powder to Cementitious Tile Adhesive: A Literature Review

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ABSTRACT

Modern advancements in structural and construction materials have prompted researchers to focus on the adaptation of these innovations. Particularly, ceramic tiles have garnered attention due to their aesthetic appeal in various indoor and outdoor settings, alongside their simplicity of installation. The utilization of ceramic tiles isn't only geared towards providing structural integrity, but similarly towards enhancing their visual attributes, which hold significant value. In terms of affixing these tiles onto surfaces, the conventional approach entails the employment of sand-cement grout. Nonetheless, this method presents certain limitations such as inadequate water retention, rigid surfaces, extended drying periods, lack of pliability, and thicker paste application, among other issues. These obstacles can be effectively addressed through the incorporation of redispersible polymer powder (RPP) in conjunction with additional cementitious elements. Through their combined application, polymers synergize with cement constituents to bolster physical and mechanical characteristics, thereby improving adhesion strength, minimizing shrinkage, and reducing water absorption. The main goal of this review article is to highlight the significance of ceramic tile adhesive while offering a thorough explanation of cementitious tile adhesive (CTA) and all of its components. We focused emphasis on the commercially available RPP and its incorporation into CTA formulation.

1. INTRODUCTION

1.1 General snippets

Inside and outdoor structures of various kinds have utilized tiles for decoration for millennia Decorative tiles were first used in construction about 575 BC, on the Assyrian and Babylonian-built Ishtar Gate of Babylon. Decorative tiles were popular with the Egyptians, Romans, and Greeks. Ceramic tiles are one of the oldest ornamental art forms, and their durability and exquisite beauty have made them highly sought for over the years. Tiles made of ornamental ceramic were widely utilized as architectural ornaments throughout the Islamic period. Decorative ceramic tiles are still widely employed today, both indoors and out, to create eye-catching displays in buildings of all types. Modern tiles come in many color of hues and may be rented for use in any indoor or outdoor space, including swimming pools, walls, kitchens, bathrooms, and even artwork [1]. Three interacting layers make up the ceramic tiling system: adhesive, substrate, and tile all have important roles [2, 3]. Adhesives are any compound in a liquid or semi-liquid condition that may permanently bond to another surface. When two objects of contrasting natures are positioned in close proximity, they have the ability to transfer mechanical force or energy through their interface, which is known as adhesion [4]. An inexpensive adhesive made of cement and sand has long been used extensively and popularly in the Indian subcontinent for the outside cladding of ceramic tiles. The thick bed technique is used to apply grout, which traditionally entails combining water with regular Portland cement and sand. The grout bed should be 10-25mm thick from the base to the adhering. It takes a lot of work and time to complete this procedure. One potential answer to all the issues with conventional cement-sand grout is to use a thin bed tile adhesive that has been enhanced with polymers. Cement may have its adhesion, strength, waterproofing, durability, flexibility, and deformation improved by adding polymer-based adhesives as a modifier. Mixing a powdered or liquid polymer or monomer with cement and other additives, then curing, is the fundamental process of polymer modification. When working with monomers, it is necessary to do in-situ polymerization [5]. The durability of tiled surfaces depends heavily on the bond formed between ceramic tiles and mortar. To establish this bond, there are various physical and chemical factors to consider when creating interfaces with polymer modified cement mortar. Key variables that impact the resistance at the interface encompass the ceramic tiles' water absorption capacity, the quantity and composition of cement employed, the type and quantity of polymer employed as a cement modifier, the installation technique, and the water-cement proportion [6]. Shear strength and resilience to a harsh environment are two qualities that structural adhesives must have in plenty. Because of its low cost and high availability, a cement-sand composition is commonly used as an adhesive for exterior cladding of ceramic tiles in the Indian subcontinent [7]. The addition of polymer-based adhesives to cement serves to enhance its adhesive properties, strength, waterproofing abilities, durability, flexibility, and malleability [8]. This study will provide an overview of the materials used to make ceramic tile adhesive, with an emphasis on the role of RPP polymer powder in different cementitious compositions, such as cement modifiers and tile adhesives.

1.2 Classifications of polymer based admixture

A lot of people are interested in studying the idea of changing a polymer-based additive. In 1923, the first patent pertaining to the alteration of polymers was acquired. The earliest patent pertaining to the idea of using polymers to alter concrete and cement mortar was issued in 1924 [9]. There are typically three kinds of admixtures that are based on polymers:

1. PIM and PIC, or polymer-impregnated mortar and concrete,
2. Polymer mortar (PM)
3. Polymer modified mortar (PMM)

1.3 Typical formulation of a CTA

In accordance with the European standard, tile adhesives are classified into two categories: C1 class and C2 class [10]. C1 class adhesives are restricted in their use, being unsuitable for fully vitrified tiles or high thermal stress areas like terraces, rooftops, and balconies. Conversely, C2 class adhesives offer the advantage of compatibility with all types of tiles and substrates. The key distinguishing parameter between C1 and C2 class tile adhesives is the proportion of RPP in conjunction with other constituents. The formula outlined in Table 1 functions as a reference for producers and manufacturers, tailored to the dimensions and components nature chosen. At this time, a least of 15 different component variations is employed in the manufacturing of cementitious tile adhesives [5].

Cementitious tile adhesives are classified according to the mechanical requirements that they must achieve. Technical Committee CEN/TC 67 been prepared many European Standards, among them DIN EN 12004 [11] standard recognizes two main classes based on their adhesion determined by the tensile strength is C1: greater than 0.5 N/mm^2 and C2: greater than 1 N/mm^2. On the other hand, EN13007-2 [12].

Table 1. Standard formulation of a CTA [5]

Component Name	Example	Dosage%	
		C1 Class	C2 Class
Binder	Portland cement	30-50	30-40
Aggregates	Silica sand	45-70	45-60
Co filler	Calcium carbonate	5-10	5-10
Redispersible polymer powder	SBR, EVA, SAE, PAE, VA/VeoV.	0-3	3-6
Water Retention Agents	HPMC	0.2-0.5	0.2-0.5
Accelerator	Calcium formate	<1	<1

2. COMPONENTS OF RPP MODIFIED CTA

2.1 Binder

A binder, true to its name, plays a crucial role in holding all materials together through cohesion, creating a connection between the surface and the adhesive. Cement stands out as the most commonly employed binder in construction projects. As a crushed substance, cement achieves adhesion by merging various solid fragments into a cohesive mass [13]. Apart from its primary role in concrete production, it is also utilized in creating ceramic tile adhesives alongside other additives. The diverse compositions of its constituents result in the existence of different types of cement [14]. In the realm of tile adhesive production, three main types of cement are extensively employed: Portland pozzolan cement (PPC), Portland cement (PC), and high-alumina cement (HAC) [5].

2.2 Aggregates

In construction materials, aggregates play a critical role in enhancing strength, density, and durability. Their shape, size, and composition significantly influence the overall mass of the mixture. To ensure a high-quality outcome, aggregates must be clean, free of contaminants like clay, and chemically inert with respect to the cement components. Common types of aggregates include gravel, quartz, sand, crushed stone, and limestone.

Silica sand, as highlighted by Dr. Felixberger, is extensively used in thin bed tile adhesive due to its size range (= 0.05 mm - 0.5 mm) [5]. Using recycled aggregates (RA) is a sustainable option, contributing to environmental conservation. Research indicates that RA, compared to natural aggregates (NA), has higher porosity, impacting the overall concrete porosity. Incorporating RA in concrete offers significant mechanical and physical benefits. The aggregate size is crucial for enhancing resistance to chemical attacks. Studies suggest that the aggregates of nano-sized improve impermeability to chemical attacks like chloride diffusion, thereby increasing the durability of concrete structures [15].

2.3 Chemical admixture

2.3.1 Accelerators

Accelerators are mixed into the paste or grout to speed up the setting and hardening process. These accelerators can be organic or inorganic. Organic additives such as diethanolamine, triethanolamine, propionate, glyoxal, urea, and formate are used, while inorganic additives mostly consist of fluorides, aluminates, borates, silicates, nitrites, chlorides, and others. Among these, calcium chloride stands out as the most commonly utilized and effective accelerator, supported by well-documented evidence of its accelerating properties [16].

2.3.2 Retarders

The key role of retarders is to delay the setting of cement, allowing enough time for the grout or paste to solidify [5]. Inorganic retarders such as oxides of Zn and Pb, magnesium, phosphates, salts, borates and, fluorates are commonly utilized for this purpose. On the other hand, organic retarders include Ca, Na, and NH_4 salts of lingnosulfonic acids, as well as citric acid, gluconic acid, adipic acid, heptonic acid, carbohydrates, succinic acid, and tartaric acid. Research extensively explored the effects of sugars on retardation, leading to numerous hypotheses, for example nucleation adsorption, precipitation, and complexation [17]. Among different types of sugars, those that do not reduce were discovered to be more effective at slowing down a chemical process compared to the reducing ones, primarily due to their influence on the quantity of silica present in the solution. Citric acid not only speeds up the initial phases of the process but also prolongs the following phases by creating a compound with monosulfates. Lignosulfonates were observed to delay the reaction of tricalcium-silicate (C_3S) and tricalcium-aluminate (C_3A), with both commercially available and sugar-free lignosulfonates demonstrating impressive outcomes. In the category of inorganic substances that slow down reactions, ZnO was found to have no impact on the reaction of C_3A and gypsum but does hinder the reaction of C_3S. The presence of $Ca(OH)_2$ went unnoticed owing to the development of calcium hydroxyzincate resulting from its interaction with ZnO [16].

2.3.3 Agents of water retention

Water is initially introduced into the cement mixture to initiate the hydration process of the cement. Subsequently, additional water is supplied as the initial water evaporates to guarantee complete hydration of the cement. The utilization of water retention agents has proven to be effective in sustaining the required water levels for optimal hydration and enhancing the non-slump properties of the adhesive. The integration of water retention agents has become indispensable due to the transition from thick to thin layers of tile adhesive, resulting in accelerated dehydration [5]. Cellulose ethers stand out as the most frequently employed water retention agents, contributing to the improvement of polymeric powder adhesion. Among the different cellulose ethers, four are predominantly utilized: hydroxyethyl cellulose (HEC), hydroxyethylmethyl cellulose (HEMC), hydroxypropyl methyl cellulose (HPMC) and Methyl cellulose (MC) [18]. When compared to hydroxyethylmethyl cellulose and hydroxypropyl methyl cellulose, methyl cellulose demonstrates superior water retention, reduced air entrapment, and increased solubility. These aspects validate the preference for hydroxyethylmethyl cellulose (HEMC) over other options in tile adhesive formulations.

2.3.4 Redispersible polymer powders

Since the year 1953, when RPPs were first introduced by Wacker Chemie, they have brought about a significant transformation in contemporary tile cladding technology [19]. These Reactive Polymeric Powders (RPPs) are instrumental in augmenting different characteristics of cement grout. They enhance qualities such as plasticity, tensile strength, flexural strength, and resistance to abrasion, while also increasing the flexibility of cement mortar by modifying its elastic modulus according to the ratio of cement-polymer. Furthermore, a polymeric film is formed by these powders, which seals off crevices and pores in the solidified grout, rendering it impermeable to substances as water and alkali. Moreover, RPPs contribute to improving the workability and buildability of the grout, providing water retention capabilities, as well as imparting slip and impact resistance to prevent the formation of cracks. Figure 1 Shows the market which offers two primary types of RPPs: elastomeric powders that contain materials like styrene butadiene rubber (SBR), and thermoplastic powders that include poly (vinyl acetate-vinyl versatate) (VA/VeoVa), poly (ethylene-vinyl acetate) (EVA), polyacrylic ester (PAE) and poly (styrene-acrylic ester) (SAE) [20]. A summary of commercially available RPPs and their chemical structures is presented in Table 2. Initially utilized in tire production, Styrene Butadiene Rubber (SBR) has become a frequently used polymer, with its industrial applications commencing during World War II as a substitute for natural rubber [21]. Its utilization expanded to the concrete sector as a polymer modifier, where it has remained in use since [22, 23]. The construction of SBR, characterized by stiff styrene chains and flexible butadiene, has exhibited enhanced adhesion, durability, mechanical properties, and water resistance in concrete mortars [24-27]. Another commonly employed RPP, Poly (ethylene-vinyl acetate) (EVA), is renowned for its exceptional compatibility with cement-based systems, making it a preferred option in dry-mix mortars [28-30]. Research is also being conducted on Poly (vinyl acetate-vinyl versatate) or (VA/VeoVa). The inclusion of the versatate group presents three elongated α-alkyl molecule side chains into the polymer, providing exceptional qualities such as outstanding alkali resistance [31-34]. Poly (styrene-acrylic ester) (SAE), a member of the acrylic polymer family, has been utilized in the modification of cement mortars. Augmenting the SAE/cement ratio enhances effects like water retention, compressive strength, water reduction, waterproofing and flexural strength, [35-38]. Polyacrylic ester (PAE) has demonstrated enhanced workability and improved mechanical properties, establishing it as a valuable component in the production of modified mortars. Various studies have substantiated these findings [39-44]. Table 3 shows typical properties of RPPs.

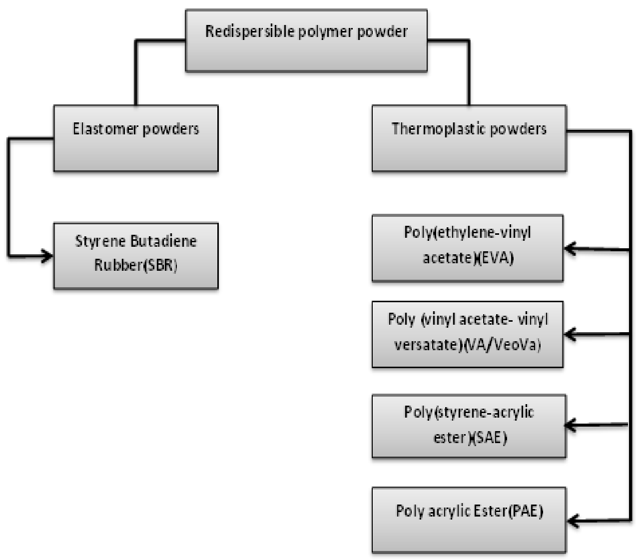


Figure 1. Categorization of commercially accessible RPP

Table 2. Chemical structures and abbreviations of commercially accessible RPP [16]

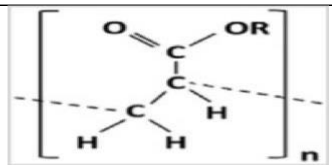
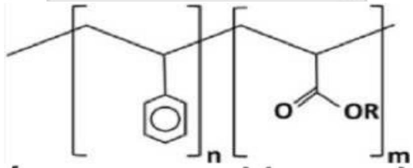
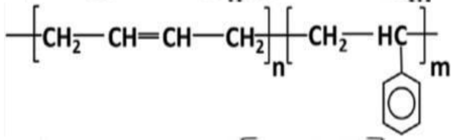
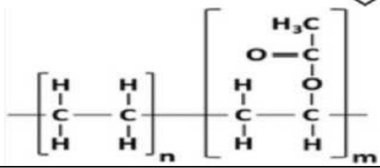
Polymer Type	Chemical Structure	Abbreviation
poly acrylic ester		PAE
poly (styrene-acrylic ester)		SAE
styrene butadiene rubber		SBR
poly (ethylene-vinyl acetate)		EVA

Table 3. Typical properties of RPPs

Type of RPP	Appearance	Average Particle Size (µm)	Bulk Density (g/cm^3)	pH (Redispersed, 50% Solid)
VA/VeoVa	White powder	10-250	0.54-0.64	4
EVA	White powder	70	0.40	5-6
PAE	White powder	45-75	0.31-0.51	10-12
SBR	White powder	5-50	0.40	7-8

2.3.5 Anti-foaming agents/defoamers

When water is combined with cement and admixtures by means of agitation, it has the capability to generate foam that entraps air. In order to avert this occurrence, a variety of chemical substances recognized as defoaming agents or anti-foaming agents are employed. Examples of commonly utilized defoamers encompass polydimethylsiloxanes, non-soluble oils on a carrier of silica, specific alcohols, polyalkylene glycols, and stearates [5]. A study carried out by J. Xing and colleagues scrutinized the impacts of four distinct categories of anti-foaming agents, namely mineral oil, emulsified silicone oil, polyether, and polyether modified silicone - on concrete. The outcomes of the investigation pinpointed polyether modified silicone as the most efficacious anti-foaming agent among these alternatives [45].

2.4 Preparation of cementitious tile adhesive

The cementitious tile adhesive is a blend of organic additives, hydraulic binding agents, and aggregates. Before use, it is mixed with water. The initial step involves preparing the cement and sand. These components are then combined with other dry constituents in a container, operating at a speed of 140 (rev/min) for 10 minutes. During this mixing process, the operator must wear gloves and a mask to avoid inhaling dust from the sand, cement, or any other volatile materials. After proper mixing, the product is ready for packaging. To prepare the adhesive, the mixture is poured into a clean stainless-steel bowl containing normal water. The ratio of dry components to water is 3:1. A mechanical mixer equipped with a stainless-steel paddle operates at a low speed of 140 rev/min. Initially, the mixture is mixed for 30 seconds, followed by gradual disappearance of the powder. After another 30 seconds, a final mix is performed for 1 minute at a higher speed of 160 rev/min. If necessary, the product may be allowed to rest and cure before an additional 15-second mix. The water-to-admix ratio remains consistent across all tests. Based on various research findings, the researcher arrived at a formula with specific percentages [45-47].

3. METHODS TO EVALUATE RPP MODIFIED CTA

3.1 Characterization and analysis of microstructural properties of RPP modified CTA

Microstructural cement characteristics have been the subject of much research using methods such as scanning electron microscopy (SEM), multi-inspection polarization (MIP), transmission graphite (TG), and Fourier transform infrared spectroscopy (FT-IR) in recent years [9].

3.2 Experimental methods

3.2.1 Adhesion strength

When evaluating the impact of Reactive Powder Concrete (RPC) on cement-sand mortar or grout, one of the commonly utilized approaches involves the assessment of bond strength, adhesion strength, or tensile strength via mechanical testing. Adhesion strength denotes the highest strength per unit surface area and can be assessed using shear (EN 12003:1997, EN 1324:2007) or strength of tension (EN 1348:2007) [48-50]. These assessments adhere to the European standards DIN EN 12004:2007 or ISO13007-1:2006 [51, 52]. Schulze and Killermann [53] conducted an extensive 10-year investigation on the adhesion force of RPC in mortars. This study examined the impacts of altering cement (CEM 1 32.5R) and sand mixtures with (Poly (Styrene-Acrylic Ester)) (SAE) and (Poly (Ethylene-Vinyl Acetate)) (EVA) in comparison to a control sample containing only cement and sand. The research was conducted under varying outdoor and indoor weather conditions. In outdoor settings, the adhesion force of EVA-modified mortar initially surpassed that of SAE-modified mortar after 28 days, which, in turn, exceeded that of the standard cement-sand combination. A progressive enhancement in adhesion strength was noted across all grouts, with the peak bond strength reached after a decade. By the end of this timeframe, the unaltered sample (a fundamental blend of cement and sand) displayed adhesive strength lower than the original value of the EVA-enhanced mortar. Under controlled indoor conditions, the unmodified mortar failed to exhibit improvement, maintaining levels under 0.5 N/mm^2. Both SAE and EVA alterations demonstrated comparable performance, indicating a marginal enhancement in adhesion strength over the 10-year duration. The inability of the unaltered sample or plain mortar to strengthen over time could be attributed to its incapacity to retain adequate water for cement setting. The inclusion of EVA and SAE powders served as binders, augmenting the cohesion of the aggregates and resulting in superior adhesion.

3.2.2 Flexural strength

Flexural strength, a material's resistance to bending deformation [54], is measured by the maximum load a sample can withstand before permanent deformation. Standard EN 12808-3:2002 outlines the determination of flexural strength for cementitious tile adhesives [55].

The addition of polymeric resins or redispersible polymer powder (RPP) to the cement-sand mix significantly improves early-stage flexural strength [56, 57]. This enhancement is attributed to polymer infiltration and reinforcement of the pore system within the adhesive. Afridi's study [57] demonstrated a clear increase in flexural strength when EVA, VA/VeoVA, and SBR RPP have been combined into the mortar. Similarly, Barluenga and Hernández-Olivares [58] observed a positive correlation between latex content and flexural strength in latex-modified mortars (LMM).

3.2.3 Water-retention rate

Having a good rate of water-retention is highly beneficial for construction as it enhances specific characteristics of the mortar. This rate serves as a numerical measure to assess how well the mortar retains water [32]. The rate of water-retention could be evaluated according to the standards set by DIN18555-7 [59]. When mixed with water, VA/VeoVa powder becomes challenging to separate from the system.

3.2.4 Shrinkage

Shrinkage in grout, a reduction in length due to water evaporation and chemical reactions, is measured according to European standard EN 12808-4:2002 [60]. Weng [61] examined the influence of RPP type and water-cement ratio on shrinkage. At a ratio of water-cement of 0.5, adding 8% EVA powder increased drying shrinkage from the reference value of 0.0128% to 0.0224%. In comparison, 8% VA/VeoVa powder addition resulted in a slightly lower increase to 0.0159%. Notably, using a higher water-cement ratio of 0.6 with EVA addition yielded even better shrinkage control compared to VA/VeoVa.

3.2.5 Water absorption

Water absorption significantly impacts the performance of cementitious tile adhesives. European standard EN 12808-2:2002 outlines the water absorption test method [62].

The typical test involves drying a sample to a constant weight, followed by immersion in water for a particular period of time. The sample is then reweighed to determine the water absorption percentage relative to its dry weight [63-65]. The standard formula for calculating this percentage is:

$$\text{Water Absorption\%} = \frac{\text{Wwet} - \text{Wdry}}{\text{Wdry}} * 100\%$$

where, Wdry=The dry sample weight, Wwet=The wet sample weight.

3.2.6 Compressive strength

The thin layer of polymer layer that developed on the grout slightly enhanced its strength of compression. However, in the case of (VA/VeoVA) modified mortars, the compressive strength decreased slightly due to its high air content. Research performed by Schulze and Killermann [53] on SAE and EVA modified mortar revealed a decrease in strength of compression. In outdoor and indoor conditions, the unmodified mortar without polymer powder exhibited the highest strength of compression compared to SAE and EVA improved mortars, from 28 days to 10 years of exposure. The soft nature of the RPPs, in contrast to the cement-sand aggregates, caused a reduction in strength of compression of the modified mortar. An experiment by Barluenga and Hernández-Olivares [58] led to reasonably consistent strength of compression for LMM with SBR at 28 days.

In concrete research, compressive strength is a critical parameter indicating a material's ability to withstand compressive loads without fracturing or significant deformation. Defined by EN 13888:2002, it's measured as the maximum load a grout prism can bear before failure under compression applied at two opposing points [66]. The evaluation procedure is further detailed in European standard EN 12808-3:2002. Afridi et al. [57] investigated the impact of RPP on strength of compression in cement-sand mixtures. He observed an increase in strength with both powdered and aqueous polymer modifications. This enhancement is attributed to a lower water-cement ratio, leading to reduced capillary porosity and a finer pore size distribution. Additionally, a slim polymer film formation on the grout slightly improved strength.

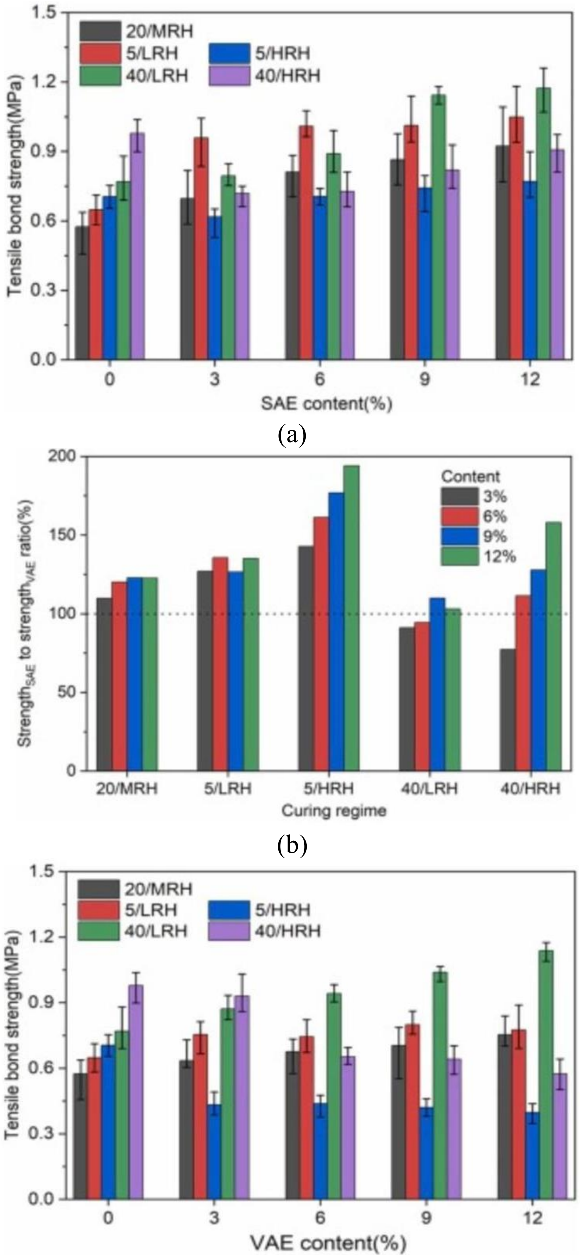
While a thin polymer film on the grout slightly improved compressive strength, the inclusion of RPP can have mixed effects. VA/VeoVA modifications showed a decrease due to high air content, and research by Schulze and Killermann [53] observed similar reductions with EVA and SAE modifications. Unmodified mortars consistently exhibited higher strength of Compression compared to SAE and EVA mortars across both initial and long-term (up to 10 years) exposure conditions. This is likely because the softer RPPs, compared to the harder cement-sand aggregates, contribute to a decrease in overall strength. However, Barluenga and Hernández-Olivares [58] reported relatively consistent strength for SBR-modified mortars at 28 days.

4. RESEARCH RESULTS AND DISCUSSION

Table 4 shows the chemistry-related impacts of redispersible latex powder (RDP) of different ratios (2, 2.75, 3) and formulation components.

Table 4. The formulation components

Raw Material	Wt%
Cement type II-V	36.8
Siliceous sand	55.5
$CaCO_3$	5.17
Modified hydroxyl ethyl methyl cellulose	0.33
Calcium formate	0.2
Va/VeoVA or EVA-based RDP	2, 2.75, 3
Water	23



(a)

(b)

(c)

Figure 2. (a) Tensile bond strengths of the SAE modified mortars; (b) The ratios of the strengths of SAE modified mortars against the strengths of the corresponding VAE modified mortars; (c) Tensile bond strengths of the VAE modified mortars [68]

Increased redispersiable polymer powder (RPP) rate plasticized spherical micro-size polymer droplets to lower the viscosity of ceramic tile adhesive polymer modified mortars, however it only influenced shear stress values early in dry curing. RPPS from VA/VeoVA increased cementitious tile adhesives' wet shear stress due to their lengthy -alkyl side chains. VA/VeoVa powder-reinforced cement mortars with organic binders vinyl acetate and versatate copolymer. Results were best at 2.75 wt% [67].

Figure 2 shows the tensile bond strength of polymer-modified mortar and cementitious tile adhesive which relies on curing applicable research. Durability of polymer-modified mortar-tile tensile bonds depends on curing cycle. Project employs Portland cement. Latex powders VAE and SAE weigh 0.55 and 0.47 g/cm^3. Lowest film-forming temperatures are 14℃ and 0℃. Used quartz sand with particle sizes range from 117 to 381 µm. For mixing, use tap water. We used tiles with water absorption < 0.1% per Chinese standard GB 3810.3-2016. The tile back adhesive used was SB emulsion, with an average particle size of 0.166 µm, pH of 7.0-9.0, lowest film forming temperature of 14℃, and solid content of 52%. Masonry-tile connections are strengthened by tile-back glue. Four artificial cyclic curing regimes with predefined conditions approximated natural curing and a constant curing reference in this investigation. Back-glued tiles were evaluated for tensile bond strengths of VAE (vinyl acetate-ethylene) or SAE (styrene-acrylic ester) modified mortar with 0, 3, 6, 9, and 12% VAE or SAE. Better polymer concentration improves low-RH cyclic curing strength but not high-RH. Low-RH cyclic curing enhances polymer-modified mortar strength, whereas high-RH curing decreases it. SEM indicates that the extra polymer develops a continuous film network structure at the mortar-tile interface, enhancing strength during low RH cycle curing. Cycles also change the structure and distribution of the film network, which impacts the tensile bond strength of cured mortars, especially VAE modified mortars. In hydration products, the cyclic treatment decreases AFt but raises CH [68].

Portland cement, high alumina cement (HAC), vinyl acetate ethylene (EVA), calcium formate, and polycarboxylate were tested to see how they influenced ceramic tile adhesive adherence. These components influenced mortar adherence, thus it's necessary to identify the appropriate amounts of each to produce the greatest adhesion. The research showed that adding polymer to mortar increased its tensile strength. Microstructural testing showed the polymer was equally distributed in the mortar. The appropriate amount of high-alumina cement was 3%. Increasing accelerator and super plasticizer increased ceramic tile adhesive tensile strength by 20-30% [69].

Nicolini et al. [70] proved that poly (styrene-acrylic ester) latex may be used as a binding agent in aqueous-based polymeric mortars, and that limestone can be used as a filler in lieu of quartz sand. When making a substitute for cementitious mortar, the binder content is an important consideration. Surface morphology and porosity distribution changed with change in resin amount, as shown by scanning electron microscopy and optical microscopy.

Pre-packed polymer-modified cementitious mortars from marble and granite refuse are made by this effort. Numerous polymer-modified mortar compositions were tested for marble and granite sludge waste's cementitious adhesive properties. The mortar compositions' raw components and 28-day hardened mortar specimens were X-ray fluorescence and diffraction-tested. Viereck IR. In mortars, marble and granite sludge replaced 0%, 5%, 10%, 15%, 20%, 25%, and 30% silica sand. Marble and granite sludge waste contains calcite and quartz particles which average 4.86 μm. Finding the optimal proportion of sludge to add to the produced polymer-modified cementitious adhesive mortar formulation improved its workability, performance, and adhesion strength. In addition, the experimental findings demonstrate that increasing the sludge content of the created mortar formulations improved their compressive and flexural strengths [71].

Cementitious tile adhesives (CTA) play a crucial function in ensuring the longevity and functionality of tiled surfaces. However, achieving successful tiling systems presents numerous challenges, with a primary focus being the reduction of failures, especially in outdoor environments. Ceramic tiles exposed to various weather conditions are susceptible to damage [72]. Chew [73] identified several factors that contribute to tiling system failures, including: a) Mortar deformation: Shrinkage in the mortar layer beneath the tiles can lead to deformation and potential cracking, b) Differential movement: Thermal expansion and contraction, moisture fluctuations, or other external influences can cause movement between the tiles, CTA, and the substrate, ultimately leading to failure, c) Underlying cement issues: Problems with the cement rendering layer beneath the adhesive can compromise the overall system's integrity, d) Inadequate surface preparation: Improper keying (roughening of the surface to improve adhesion) or insufficient cleaning can negatively impact bonding, e) Structural movements: Settlement of the building or vibrations can cause stress on the tiling system, f) Incorrect material selection: Choosing inappropriate materials based on size, workability, or compatibility can lead to failure. To address these challenges and ensure successful tiling systems, Wetzel et al. [74] proposed several key steps: a) Material selection: Selecting appropriate CTAs based on the size and workability of the tiles is crucial, b) Structural design: Implementing a compatible structural design that incorporates water drainage and flexible waterproofing is essential for managing moisture and preventing damage, c) Installation practices: Following proper installation practices, including proper pretreatment of the substrate and tiles, is vital for optimal bonding and long-term performance.

A pioneering study by Yiu et al. [75] marked the first in-depth laboratory investigation of how external tiling systems are affected by harsh weather conditions like rain, moisture, wind, and pollutants. Their findings revealed a crucial aspect: a significant 50% reduction in strength of shear after the initial 100 exposure cycles. This highlights the importance of developing CTAs with superior durability for withstanding the rigors of outdoor environments.

Manufacturers and users alike are increasingly prioritizing sustainable practices and eco-friendly materials in the development and application of CTAs. A recent innovation by an RPP manufacturer demonstrates this commitment. They introduced a vinyl acetate co- and terpolymer derived from renewable resources, offering a significant reduction in reliance on fossil fuels [76]. Similarly, research into alternative binders for CTAs presents promising results. Sulfoaluminate cement (CSA) is being explored as a potential replacement for traditional Portland cement. This alternative material has the potential to halve the carbon dioxide emissions associated with its production, making it a more environmentally friendly option [77].

5. CONCLUSIONS

The incorporation of redispersible polymer powder (RPP) into cementitious tile adhesive (CTA) effectively addresses the limitations inherent in traditional cement-sand pastes or grouts. This results in improved flexural strength, water retention, adhesion, abrasion resistance attack, and resistance to chemical, among other quality aspects. The formulation of CTA is cost-effective as it requires a smaller quantity of polymer powder. This tile adhesive is perfect for home tiling projects due to its simple preparation and application process, indicating a promising future for CTA due to its flexibility.

There are a variety of RPPs available today, each with its own distinct physical and chemical makeup that gives it better qualities including resistance to abrasion, water, adhesion, and flexibility.

One suggestion for future work is the inclusion of the recycled material in the formulation of pre-blend polymer-modified cementitious adhesive, also promoting environmental sustainability.

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