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Research Progress on the Application of High-Mica-Content Manufactured Sand in Concrete and Performance Enhancement Techniques: A Review

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Abstract

In recent years, the scale of the infrastructure sector has continued to expand， the supply-demand gap for natural sand has continued to widen. Mica-rich parent rocks such as granite and gneiss are abundant, and the manufactured sand produced from them offers notable advantages for water conservancy and hydropower projects because it is locally available, requires short transport distances, and is low in cost. However, excessive free mica introduced during the crushing of the parent rock degrades concrete performance and threatens engineering safety, restricting the efficient utilization of this material. Clarifying the degradation mechanisms of mica and proposing performance enhancement pathways are therefore essential for promoting the safe and efficient application of such manufactured sand. This study systematically reviews the occurrence characteristics and test evaluation methods of mica in manufactured sand, discusses the mechanisms by which mica degrades concrete from the three aspects of workability, mechanical properties, and durability, and summarizes research progress in three categories of performance enhancement techniques: physical separation, surface chemical modification, and mineral admixture regulation. The review indicates that current research still has shortcomings, including inadequate physical separation methods and poor engineering adaptability of chemical modification. Future work should develop more adaptable physical mica-removal equipment, elucidate the synergistic regulation mechanism between the molecular structure of silane-based admixtures and mica surfaces, enhance the bonding between mica and cement paste through interfacial chemical bonding, and optimize the targeted filling and modification of the interfacial transition zone (ITZ) by multi-component cementitious materials, thereby promoting the safe and efficient application of high-mica-content manufactured sand in engineering practice.

Keywords: Manufactured sand; Free mica; Concrete; Interfacial transition zone; Performance enhancement

1 Introduction

With the continuous advancement of infrastructure construction, natural sand resources are becoming increasingly depleted, and manufactured sand has become the core substitute for fine aggregate in concrete. According to official data released by the Price Department of the National Development and Reform Commission of China, manufactured sand and gravel account for approximately 70% of the sand and gravel used for construction in China [1](Fig. 1). The lithology distribution of registered sand and gravel mines nationwide is shown in Fig. 2, which indicates that many projects produce aggregate from locally available tunnel-excavation waste of high-mica metamorphic rocks such as gneiss [2]. However, mica commonly occurring in the parent rock of manufactured sand enters the finished sand in large quantities during crushing, and excessive free mica content occurs frequently: the mica content of manufactured sand produced from common source rocks such as granite and gneiss often exceeds the 2% limit specified in the Specification for Construction of Hydraulic Concrete[3], which directly restricts the wider application of manufactured sand. Therefore, clarifying the mechanisms by which mica degrades concrete performance and developing economical and efficient performance enhancement techniques are the key issues that must be resolved for the engineering application of high-mica-content manufactured sand. To address this engineering challenge, researchers in China and abroad have carried out extensive and productive research on mica detection and evaluation, the revelation of degradation mechanisms, and performance enhancement techniques, laying a solid foundation for the effective utilization of high-mica-content manufactured sand; however, existing studies still have certain shortcomings and have not effectively resolved these problems.

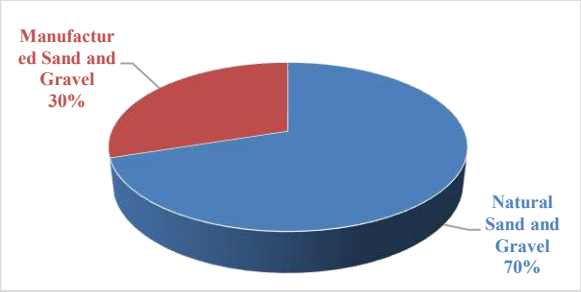


Fig. 1 Sources of construction sand and gravel in China. (data from Ref. [1])

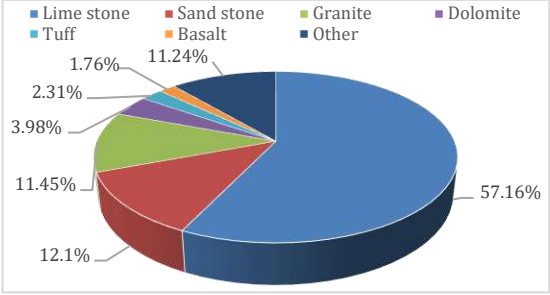


Fig. 2 Lithology distribution of registered sand and gravel mines in China in 2025. (data from Ref. [2])

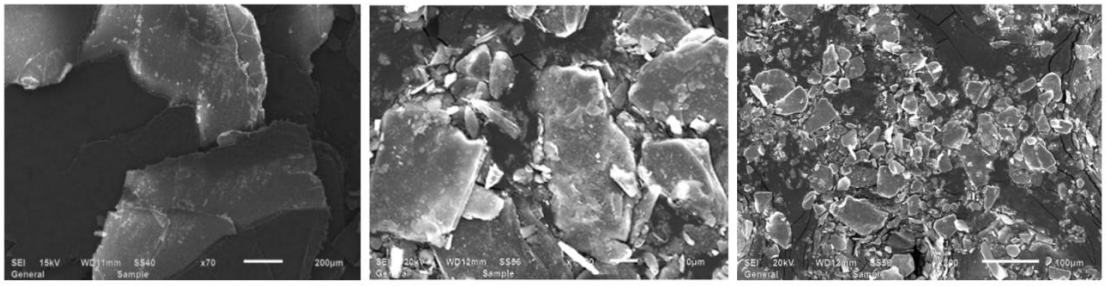
Mica is a typical layered silicate mineral (including muscovite, biotite, etc.) whose crystal structure exhibits perfect cleavage; after mechanical crushing it forms thin flaky or scaly particles with smooth surfaces, weak interlayer bonding, and a tendency to peel off [4,5]. In the fresh state, the flaky structure and high specific surface area of mica adsorb free water and chemical admixtures, leading to increased water demand, reduced fluidity, accelerated slump loss, and segregation and bleeding of concrete; in the hardened state, the smooth surface, low elastic modulus, and weak interfacial bonding with the paste disrupt paste continuity and form weak interfaces, causing significant strength reduction and increased porosity and microcracking, which in turn reduce durability properties such as impermeability, erosion resistance, and freeze–thaw resistance[6].

To address these adverse effects of high-mica-content manufactured sand, existing research has proceeded mainly along three technical routes. The first is physical separation: based on the differences in density, morphology, and magnetism between mica and its associated minerals, dry magnetic separation and industrial air classification technologies have developed rapidly[7]. The second is surface chemical modification: organ silane coupling agents are used to modify the surfaces of mica and cementitious materials; the hydrolysable groups of silane form chemical bonds with hydroxyl groups on the surfaces of aggregate and mica, while the organic functional groups bond with the cement paste to form long-chain networks, constructing “molecular bridges” on the aggregate surface that optimize wettability, reduce water absorption, and markedly improve the microhardness and porosity of the interfacial transition zone (ITZ)[8]. The combined use of silane-modified aggregate with highly dispersing polycarboxylate superplasticizer can also produce synergistic effects that improve cement particle dispersion and paste fluidity[9], although the compatibility among admixtures and their concentration adaptability within the mica–cement system still requires particular attention. The third is mineral admixture regulation: silica fume and fly ash exert dual effects of micro-filler packing and pozzolanic reaction, which can reduce the thickness of the aggregate ITZ and lower its porosity to a level close to that of the bulk paste[10]. The long-term hydration of fly ash complements the early reactivity of silica fume, forming a dense microstructure while blocking macroscopic cracks induced by freeze–thaw and ionic erosion, making this an effective approach to improving the weak ITZ of high-mica-content concrete.

Overall, existing research has made considerable progress in detection and evaluation, degradation mechanisms, and modification technologies; however, problems remain, including the deterioration of fineness modulus and gradation caused by physical separation, insufficient compatibility between admixtures and the mica–cement system, and the poor engineering adaptability of chemical modification. Against this background, this paper systematically reviews research progress on the occurrence characteristics and test evaluation methods of mica in manufactured sand, the mechanisms by which mica degrades the workability, mechanical properties, and durability of concrete, and performance enhancement technologies including physical separation, surface chemical modification, and mineral admixture regulation; it further analyzes the problems existing in current research and proposes solutions, with the aim of providing a reference for the safe and efficient application of high-mica-content manufactured sand.

2 Occurrence Characteristics and Test Evaluation Methods of Mica in Manufactured Sand

Mica minerals are widely distributed in rocks such as granite and gneiss, where they exist in the original rock as flaky, easily exfoliated crystals[11]. During the production of manufactured sand, high-mica-content source rock is crushed by ball milling, rod milling, and other processes, after which mica particles are predominantly flat in morphology[12]; SEM images of mica particles of different sizes are shown in Fig. 3[13], and, similar to mined mica flakes, they all exhibit a thin flaky shape. This morphological characteristic is the main reason for the poor fluidity, high viscosity, and strong thixotropy of cement mortar incorporating mica powder[14]. Regarding limits, China's current Specification for Construction of Hydraulic Concrete explicitly stipulates that the free mica content in sand shall not exceed 2%[15]. The Indian standard IS 383:2016 specifies a mica content limit of 1% in fine aggregate when strength and durability tests are not conducted; when workability, strength, and durability are verified by testing, the limit may be relaxed to 3% for muscovite and to 5% when muscovite and biotite coexist[16]. Other international standards mostly do not explicitly specify mica limits in manufactured sand, which are generally determined by testing according to the performance requirements of the actual engineering structure.



(a) 0.3~5 mm (b) 0.16~0.3 mm (c) <0.16 mm

Fig. 3 SEM images of mica particles of different sizes

Reprinted from Zheng et al[13].

At present, relatively few studies have addressed test methods for mica content in manufactured sand. China's current Test Code for Sand and Gravel Aggregates of Hydraulic Concrete specifies manual picking of mica under a 3–5× magnifying glass and calculation of its mass fraction[17]. For manufactured sand, however, part of the mica has been ground to a fine powder state and is difficult to sort manually under a magnifying glass: fine mica either adheres to the surfaces of larger particles or is lost during sieving because its particle size is smaller than 0.315 mm, so the mica content measured by the picking method differs considerably from X-ray diffraction (XRD) results[18]; the method is therefore only suitable for lithological verification of coarse particles.

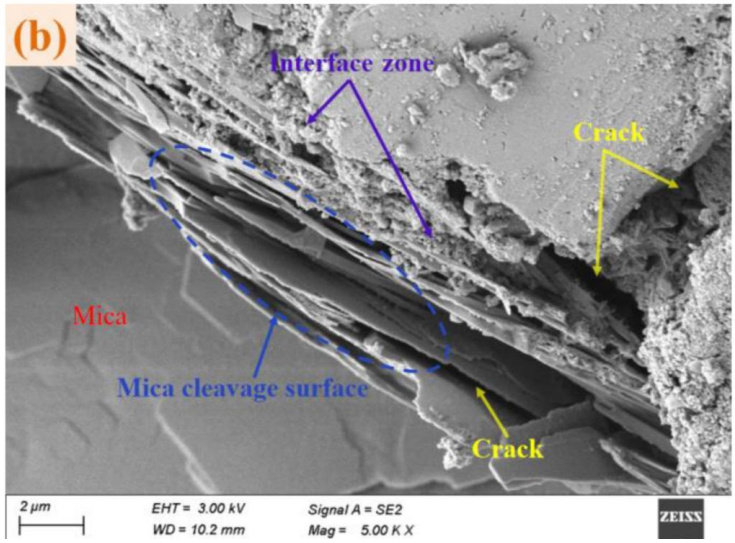
X-ray diffraction (XRD) is currently the mainstream technique for determining the free mica content in manufactured sand, but different detection approaches differ in accuracy and applicable scenarios. The results of the petrographic method are closely related to the ore samples collected, and the mica contents measured among

groups fluctuate considerably, so it is only suitable for roughly estimating the mica content in rock. When the XRD internal standard method is used to determine the mica content in stone powder of manufactured aggregate, the measured value is higher than the mica content of the parent rock because the relatively soft mica is enriched in the stone powder size fraction after grinding, and the results differ from petrographic analysis and image calculation results by approximately 15%[19]. In addition, when the raw material contains two or more types of high-mica-content rock, the total mica content measured by XRD differs essentially from the concept of "free mica" in traditional specifications: analysis of five phyllites and three gneisses from the dam site of a hydropower station showed that the characteristics of mica contained in the two types of crushed rock differ significantly[20].

For high-mica-content manufactured sand samples, a rapid mica content detection method based on digital image analysis can control the detection error within 5%[21]. Compared with the traditional manual picking method, this method does not rely on the large-scale equipment required for XRD detection and avoids the risk of X-ray radiation contamination, giving it good prospects for engineering application.

Studies outside China have used field-emission scanning electron microscopy (FE-SEM) to obtain high-resolution backscattered electron (BSE) images, which can identify the typical acicular morphology of mica; combined with energy-dispersive spectroscopy (EDS) and high-magnification image analysis software, the content of free mica fines can be accurately identified and quantitatively determined[22]. This method offers high detection accuracy, but its operating cost is high and the sampled fraction is small, so the results cannot cover an entire batch of manufactured sand, making it suitable only for high-precision analysis scenarios. In addition, a semi-quantitative prediction of mica content in minerals can also be achieved by first determining the mineral composition of the ground raw ore by XRD (e.g., biotite), then applying strong alkali leaching and observing the degradation behavior of each component and of mica in the aggregate in alkaline solution by SEM, which simultaneously allows a visual assessment of the degree of alkali attack on the cement paste[23]. The typical micromorphology of mica particles in hardened cement-based materials is shown in Fig. 4 and Fig. 5.

In summary, the free mica content in manufactured sand is mainly governed by the mineral composition of the parent rock and the crushing process, and the limits on mica content required by different engineering scenarios also differ. The degree to which mica degrades concrete performance is closely related to its content and the service environment, and targeted research should be carried out in light of actual engineering conditions.



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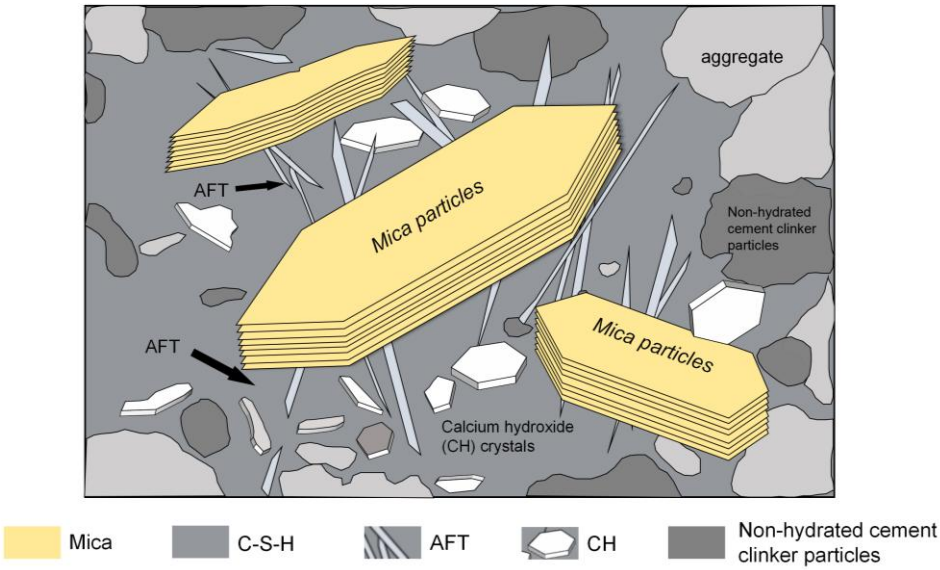
143 **Fig. 4 Micromorphology of mica particles in hardened cement-based materials**

144 Reprinted from Liu et al [21]



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146 **Fig. 5 Microscopic schematic diagram of mica particles in hardened cementitious materials**

147 **Table 1 Comparison of mica content detection methods**

Method	Principle	Advantages and limitations	Applicability
Manual picking method	Mica flakes are manually picked from the sample under a magnifying glass and weighed to calculate the content.	Simple instruments, low cost, and intuitive results; however, it is labor-intensive, subject to large subjective errors, and difficult to apply to fine particles.	Rough detection and lithological verification of samples with little fine powder and relatively coarse particles[17,18] .
XRD petrographic method	Combines XRD mineral phase identification with polarizing-microscope petrographic analysis for quantitative/semi-quantitative analysis of mica content.	Effectively identifies mineral species and crystal structures; limited sensitivity to low mica contents (<5%), with severe overlapping-peak interference when fine particles are interwoven.	Rough qualitative analysis and lithological background identification of manufactured sand [17,18].
XRD internal standard method	A known proportion of a standard substance (e.g., zinc	No manual picking required, high testing efficiency, and more	Phase analysis of batch samples and quantitative

	oxide) is mixed into the sample to quantitatively calculate the mica phase content.	accurate than conventional XRD; demanding sample preparation, and extremely fine particles and strong preferred orientation readily produce fitting errors.	detection of medium-to-high contents[19,20].
Digital imaging method	High-resolution particle images are collected, and mica is automatically identified and quantified by image processing algorithms based on differences in color, luster, and flaky morphology.	Fast detection and high automation, avoiding subjective fatigue errors of manual picking; identification of powder-scale particles is limited, and lighting conditions and particle overlap can affect interpretation.	Rapid batch screening of medium-to-coarse free mica particles, online monitoring, and automated quality inspection[21].
FE-SEM method	Field-emission SEM combined with energy-dispersive spectroscopy (EDS) and image recognition performs morphological and elemental quantitative analysis of microscopic particles.	Extremely high resolution and excellent identification of micron-sized free mica, unaffected by preferred orientation; expensive equipment, high cost, and a very small sampling area per measurement.	High-precision research analysis, characterization of powder-scale mica, and standard calibration[22].

3 Effects of Excessive Mica on the Properties of Concrete

3.1 Effects on the Workability of Cement Concrete

Although excessive mica poses performance risks, the local utilization of high-mica-content manufactured sand can significantly reduce the cost of long-distance aggregate transport and engineering carbon emissions, and clarifying its influence on workability is the primary prerequisite for safe utilization. In general, manufactured sand with excessively high mica content significantly degrades the workability of fresh cement-based materials, the most direct manifestations being substantial increases in unit water demand and admixture demand. Mica is an inert mineral that does not participate in cement hydration; organic carbon determination and scanning electron microscopy (SEM) observations have confirmed at the microscopic level that mica powder particles are predominantly flat in morphology[24,25], which is the main reason for the poor fluidity, high viscosity, and strong thixotropy of cement mortar incorporating mica powder.

To clarify the correspondence between the degradation effect of mica and particle size ranges, studies on stone powder systems with particle sizes smaller than 0.315 mm have shown that, at the same water–binder ratio and the same MB value, stone powder with low mica content can enhance mortar fluidity[26], indicating that the influence of free mica on paste fluidity exhibits a threshold effect, whereas the special morphology of large-size mica with high specific surface area is the main cause of fluidity degradation. Further research found that, at the same mica content, the negative effect of mica on mortar fluidity is significantly greater than its effect on concrete workability, because the incorporation of coarse aggregate in concrete intensifies rheological resistance and amplifies the degradation effect of free mica in the paste[27]. A comparison of the synergistic differential effects of biotite and granite stone powder showed that the unique lamellar structure of mica and its stronger

adsorption capacity for polycarboxylate superplasticizer (PCE) significantly increase the plastic viscosity of cement paste and the frictional resistance between particles, resulting in more pronounced deterioration of rheological properties[28]. Taken together, these studies indicate that the degradation of workability by mica essentially originates from the coupling of its flaky morphology, high specific surface area, and admixture adsorption characteristics, and that this effect exhibits complex nonlinear characteristics as particle size decreases and system scale increases.

The high specific surface area of free mica also weakens the dispersing performance of polycarboxylate superplasticizer, leading to increased concrete water demand and reduced effective adsorption of the superplasticizer; the dry–wet state of the sand likewise affects paste fluidity, because minerals such as feldspar and mica in the sand and gravel lose moisture and destroy the original framework spatial structure, thereby weakening the adsorption of superplasticizer[29]. It can thus be seen that the degradation of the workability of cement-based materials by mica stems from the interference of its special structure with free water flow and admixture adsorption in the paste.

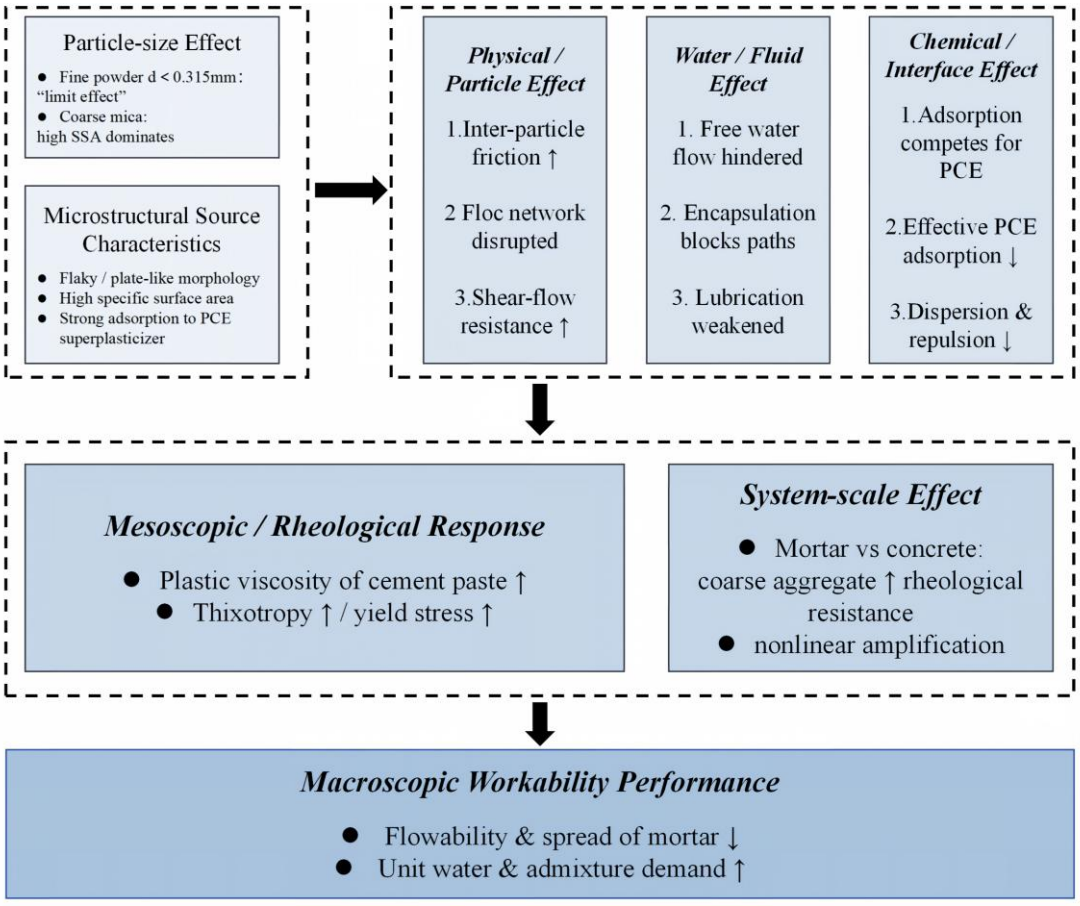

Fig. 6 Schematic diagram of the effect of mica on the workability of cementitious materials

3.2 Effects on the Mechanical Properties of Cement Concrete

The compressive and flexural strengths of cement mortar both decrease significantly with increasing mica content[13,27], and dfferent types of mica degrade mortar to a similar degree[13]. Taking the 28d compressive strength as an example, when the mica content increased from 0 to 4.5%, the mortar strength decreased from 27.7 MPa to 19.9 MPa, a reduction of approximately 28%[13](Fig. 7). The direct reason is that, in the middle and late stages of hydration, the layered structure of mica hinders the escape of gas from the paste, and the resulting pores significantly increase porosity, thereby severely reducing compressive and flexural strengths[13].

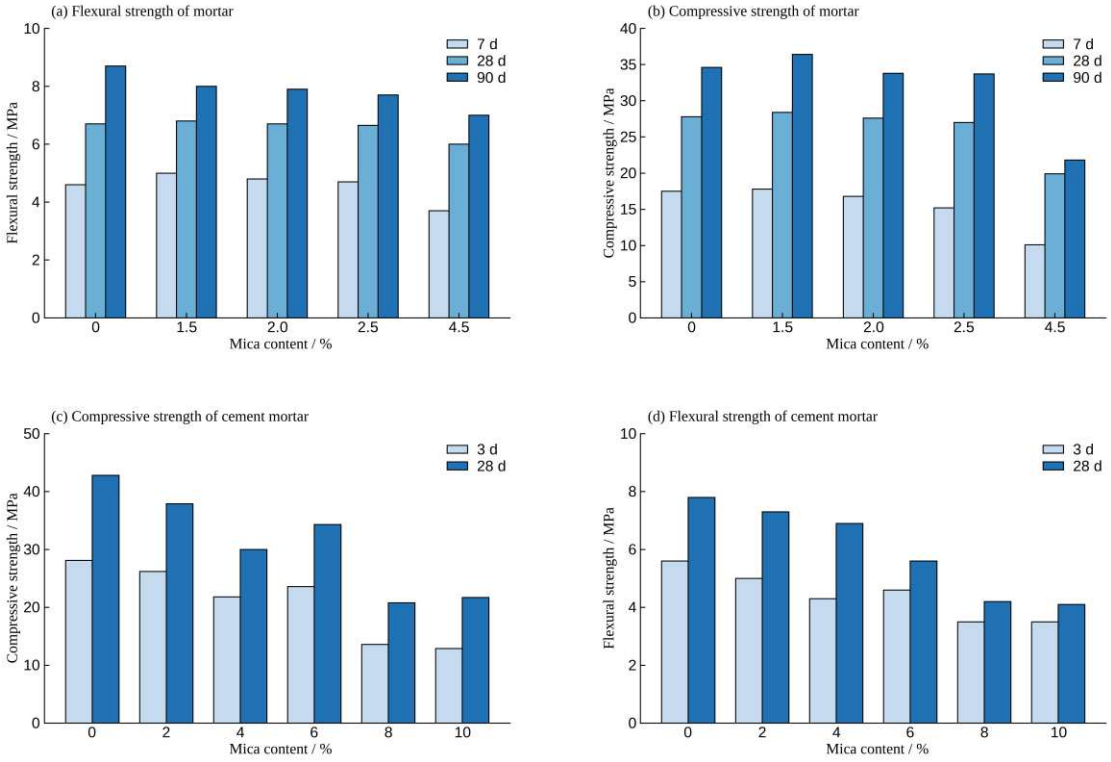

Fig. 7 Flexural and compressive strengths of mortar at different mica contents

Data from Liu et al[27]and Zheng et al[13].

At the concrete scale, the mica content of manufactured sand shows a significant linear negative correlation with the 28d strength of concrete (linear fitting correlation coefficient of 0.97), and at the same mica content, mica degrades mortar more strongly than concrete[27]. Tests on free mica contents (2.7%–6.0%) in manufactured sand also showed that, with increasing mica content, the axial tensile strength of concrete decreased from 2.79 MPa to 2.52 MPa and the ultimate tensile strain decreased from 1.43×10^{-4} to 1.33×10^{-4} [30](Fig. 8), consistent with the degradation law observed in mortar systems. A systematic review for pumped-storage power station engineering summarized, in micro-to-macro logical order, the mechanism by which the poor bonding between mica and cement paste degrades the performance of mortar and concrete, and proposed that the application of high-mica-content manufactured sand should focus on the influence of mica in stone powder, adopting stricter

mica content requirements than current standards when necessary[25], which corroborates the conclusions of the above experimental studies.

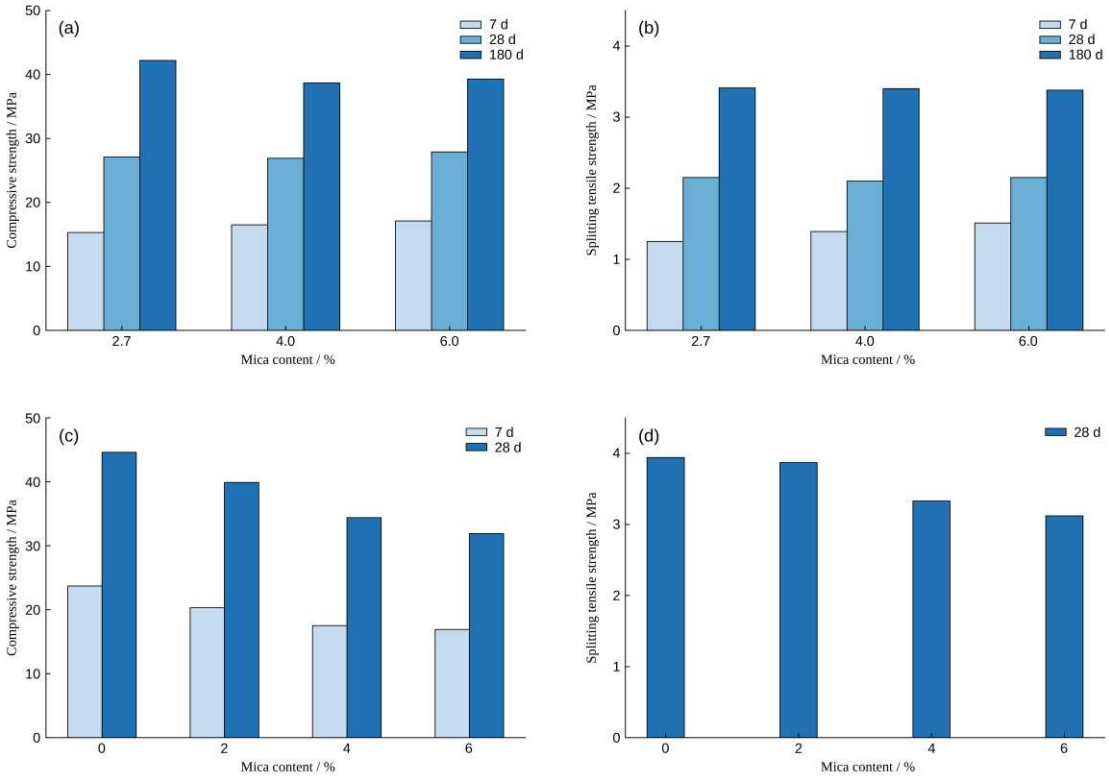

Fig. 8 Compressive and splitting tensile strengths of concrete at different mica contents

Data from Liu et al[27] and Wu et al.[30].

The above studies consistently show that the special morphology and surface physicochemical properties of mica are the main reasons for the deterioration of the mechanical properties of cement-based materials; from the perspective of microscopic mechanisms, the performance evolution of the interfacial transition zone (ITZ) is the core dimension for revealing this degradation process.

Comparative studies of transition zones between different aggregates and cementitious materials have shown that the ITZ generates numerous microcracks owing to the “wall effect” and water enrichment, in which the C–S–H gel content is significantly lower than that of the bulk cement paste, and the deterioration of this weak interfacial region is the direct cause of the decline in macroscopic strength of manufactured sand concrete [31]. When the ITZ strength is low, the fracture process of concrete is mainly manifested as the initiation, propagation, interaction, and eventual bridging-through of microcracks within the ITZ[32]; cracks in the ITZs of adjacent aggregates also produce an overlapping effect, increasing the local cracking susceptibility of the mortar [33].

Interface studies of lightweight aggregate concrete provide corroborating evidence: porous, high-water-absorption lightweight aggregates significantly weaken the concrete interface[34], which is consistent with the

mechanism by which free mica adsorbs free water and causes ITZ deterioration. In addition, the microstructure and mechanical properties of the ITZ at different positions around an aggregate are non-uniform, and the ITZ thickness at the upper surface of the aggregate is significantly smaller than that at the lower surface [34]. Tests with different water–cement ratios showed that at a water–cement ratio of 0.3 the ITZ thickness increases with increasing coarse aggregate size, whereas at a water–cement ratio of 0.4 there exists an optimal coarse aggregate size that minimizes ITZ thickness and maximizes strength[35]. Simulation of the redistribution of calcium hydroxide (CH) crystals in a porous medium showed that the closer to the aggregate, the looser the inner structure of the ITZ[36].

These ITZ characteristics explain why microcracks always initiate at aggregate surfaces and provide a microscopic basis for understanding the degradation of high-mica-content manufactured sand: mica itself has a flaky cleavage structure, and if the thickness and structure of the interfacial transition zones on its two sides differ significantly, mica is more likely to peel away from the cement paste along cleavage planes, inducing stress concentration and accelerating crack propagation. This microscopic degradation mechanism is likewise the root cause of the decline in the durability of cement concrete materials.

3.3 Effects on the Durability of Cement Concrete

It should be noted that high-mica-content manufactured sand concrete also possesses exploitable performance characteristics: the thermal conductivity of mica is lower than that of common rock-forming minerals such as quartz, and the apparent density of concrete decreases with increasing mica content[37]. Research on temperature control and crack prevention of super-high arch dams in high-altitude cold regions showed that variation in the mica content of manufactured sand affects the peak concrete temperature by only about 0.7 °C[38], suggesting potential utilization value in engineering scenarios with high temperature-control requirements or certain thermal insulation needs. In general, however, mica in manufactured sand not only degrades the various properties of fresh concrete but also significantly reduces the long-term durability of concrete. Free mica has a smooth surface and poor bonding, making it difficult to form an effective interfacial bond with cement-based cementitious materials, and it readily induces microcracks and pore defects in the interfacial transition zone, thereby accelerating the deterioration of durability.

Among various rock types, the problem of excessive free mica is particularly prominent in granitic manufactured sand. As the mica content in manufactured sand increases, the electric flux of concrete increases, the resistance to chloride ion penetration decreases, and the mass loss rate after sulfate dry–wet cycling also increases relatively[39]. The reason is that the incorporation of large-size mica is unfavorable for air bubble

discharge and increases harmful pores, and the microcracks near the mica surface become transport channels for sulfate ions, accelerating mass loss.

Studies on concrete containing high-mica-content stone powder showed that a high mica powder content has little effect on the early shrinkage deformation of concrete but significantly aggravates its later shrinkage deformation[39]: during early hydration, the mica in the stone powder can still coexist stably with the paste and free water; after entering the later shrinkage stage, the free water around the mica is gradually consumed, eventually forming penetrating microcracks that significantly affect the shrinkage deformation of concrete. The derivation and propagation of such microcracks often act on the weakest structural regions of concrete, further triggering deeper levels of performance deterioration.

The interfacial transition zone between aggregate and cement paste is precisely such a weak link naturally present in the composite structure of concrete, and the decline in concrete durability is likewise closely related to the ITZ. This region is formed by the non-uniform hydration of cement particles and is approximately 10–50 μm thick; it readily induces crack formation and reduces the mechanical strength of concrete, and it is also a channel through which aggressive media invade the interior of concrete. The numerous microcracks formed by abundant free mica further accelerate the deterioration of concrete durability[40].

International engineering cases also provide empirical evidence. Microstructural, chemical, and thermodynamic modeling analyses of thousands of damaged concrete block houses in Donegal, Ireland, showed that the damaged aggregates contained high mica and iron sulfide in the form of pyrrhotite; the concrete deterioration was caused by internal sulfate attack (ISA) triggered by pyrrhotite oxidation, and the mica in the concrete aggravated the sulfate attack[41]. In cement paste, mica can serve as a transport channel for harmful ions because of the weakness of its bonding surface with cementitious materials; the poor interfacial bonding between mica and cement paste is the main cause of the performance deterioration of mortar and concrete[42].

Similar to Donegal, Ireland, reflected-light microscopy, mineral chemistry, and electron probe microanalysis (EPMA) chemical mapping of concrete aggregates damaged by internal sulfate attack in the Trois-Rivières region of Canada showed that natural biotite is intimately intergrown with pyrrhotite; although the chemical composition of biotite was unchanged, its layered cleavage readily cracks and acts as a mass-transport channel during pyrrhotite oxidation, accelerating the ingress of oxygen and moisture and significantly speeding up concrete failure[43].

When manufactured sand contains large amounts of smooth-surfaced, layer-exfoliated mica particles, the local water–binder ratio around the aggregate increases and the ITZ porosity rises significantly; directionally

arranged hexagonal plate-like $Ca(OH)_2$ and needle-like ettringite (Aft) are enriched in large quantities, resulting in insufficient intracrystalline interlocking in the interfacial transition zone. Under external load or drying shrinkage stress, cracks readily propagate rapidly along the mica–paste interface, leading to an overall decline in macroscopic strength and durability (Fig. 9). Therefore, to solve the problem of excessive mica content in manufactured sand, in addition to physically separating and removing mica, optimizing the compactness of the concrete interfacial transition zone through admixture regulation or adjustment of cementitious material composition is also an important research direction.

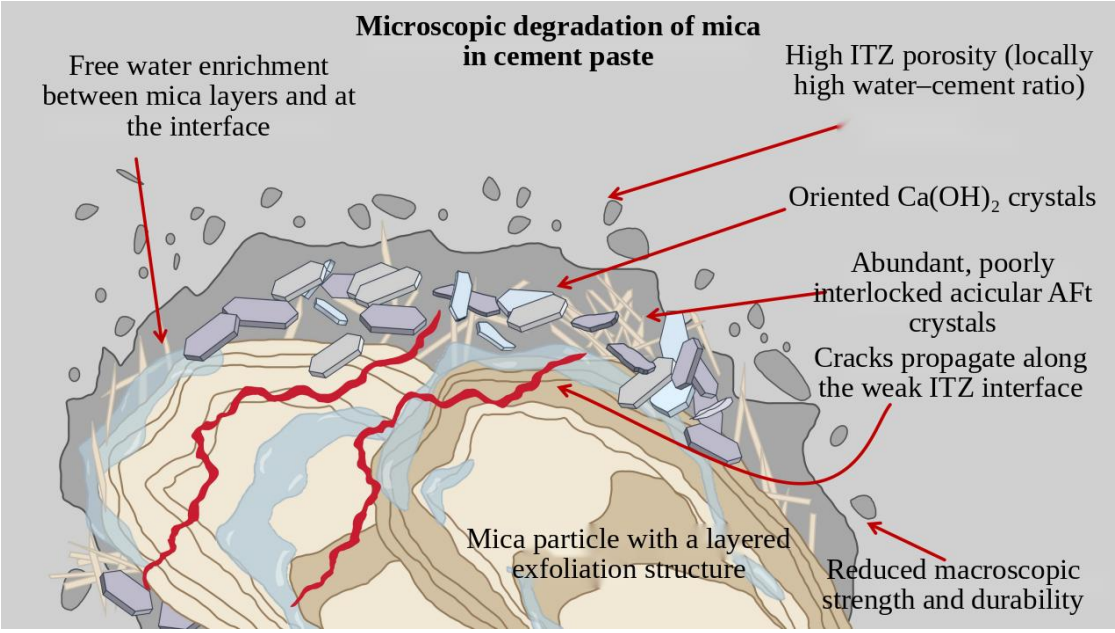

Fig. 9 Schematic diagram of the microscopic degradation of mica in cement paste

4 Comprehensive Solutions and Modification Techniques for High-Mica-Content Manufactured Sand Concrete

4.1 Physical Separation and Mica Removal Techniques

Controlling the free mica content is the core link in the engineering application of high-mica-content manufactured sand, and physical separation is currently the only source-control means with conditions for large-scale implementation. Its technical logic lies in exploiting the differences in density, morphology, magnetism, and surface properties between mica and its associated minerals to achieve selective separation of mica during the crushing and screening stage. In engineering practice, part of the flaky mica is usually first stripped during crushing of the source rock by means such as rod milling, and the mica content of the finished sand is then regulated step by step by combining air classification, magnetic separation, flotation, and other processes; a

typical process flow is shown in Fig. 10. The separation accuracy, processing scale, and gradation influence of each process differ significantly, which directly determines the applicable boundaries of physical methods in the production of high-mica-content manufactured sand.

Screening machinery is generally divided into two categories: trommel screens and vibrating screens. When a vibrating screen with two or more layers of different apertures is used to separate crushed mica ore, small mica pieces and gangue fall to the second layer after the raw ore enters the screen, and finally the gangue falls through the screen while the mica remains on the screen surface, completing the separation[44]; however, this method usually performs only preliminary screening and cannot effectively remove the excessive mica in manufactured sand. Based on the principle of selective crushing of mica, a combined separation flowsheet using a jaw crusher, roller mill, rod mill, and bar screen showed that mica in the ore can be effectively extracted by crushing the raw ore with a roller mill followed by re-screening with a rod mill[45]; however, crushing and screening machinery has difficulty handling excessively fine particle sizes, and mica smaller than a certain size still cannot be effectively extracted. According to the characteristic that mica and its associated minerals have similar densities but markedly different morphologies (mica being flaky and the others granular), the raw ore is ground to a specified mesh size and fed to a shaking table, where mica is enriched in the light-mineral zone because of its thin flake diameter while the other minerals accumulate in the heavy-mineral zone, completing mica separation [46]; however, shaking-table separation relies on gravity and screens out fine substances in the ore together, which may cause loss of fineness modulus.

Air classification is a gravity separation method using air as the separation medium; it has a wide range of application and can separate ores of different densities, particle sizes, and shapes in a moving air stream. Effective removal of free mica can be achieved by controlling the air volume, but the loss of fine particles increases the fineness modulus of the finished sand; back-blending high-quality material smaller than 0.3 mm from the discarded material can regulate the fineness modulus to the engineering gradation range[47]. Regarding magnetic separation, exploiting the weak magnetism of biotite, a magnetic separation process can reduce the mica content in manufactured sand from 10% to 2%[48]; dry rare-earth magnetic separation can effectively remove various paramagnetic minerals unsuitable for mortar, such as amphibole, among which the removal efficiency for biotite reaches 85%–93%, playing a significant role in removing harmful components from fine aggregate[49]. However, magnetic separation of mica requires precise control of the magnetic separation intensity: both the fine particle content and the mica content decrease with increasing magnetic separation intensity, a drawback similar to that of air classification. Moderate magnetic separation can reduce the

superplasticizer dosage and increase concrete strength, whereas excessive magnetic separation removes ultrafine stone powder, degrading the gradation of manufactured sand and causing segregation and bleeding of concrete [50].

The Yebatan Hydropower Station adopted a combined water washing–magnetic separation process, reducing the mica content in manufactured sand by an average of 1.1%[51]. Flotation mainly exploits differences in the surface physicochemical properties of minerals to achieve selective separation: in a solution with pH 2.0–2.5, the mica surface is negatively charged[52] and becomes hydrophobic after electrostatic adsorption of ammonium cations, floating with the froth and thereby being separated from minerals such as quartz[53~57]. Although the combined flotation–magnetic separation process can significantly reduce the mica content in manufactured sand, in actual engineering, facing the huge volume of manufactured sand to be processed, the sequential process of flotation, magnetic separation, and then drying can hardly meet engineering requirements; this combined process is therefore mostly used for mica beneficiation and is not yet suitable for manufactured sand processing in water conservancy and hydropower engineering.

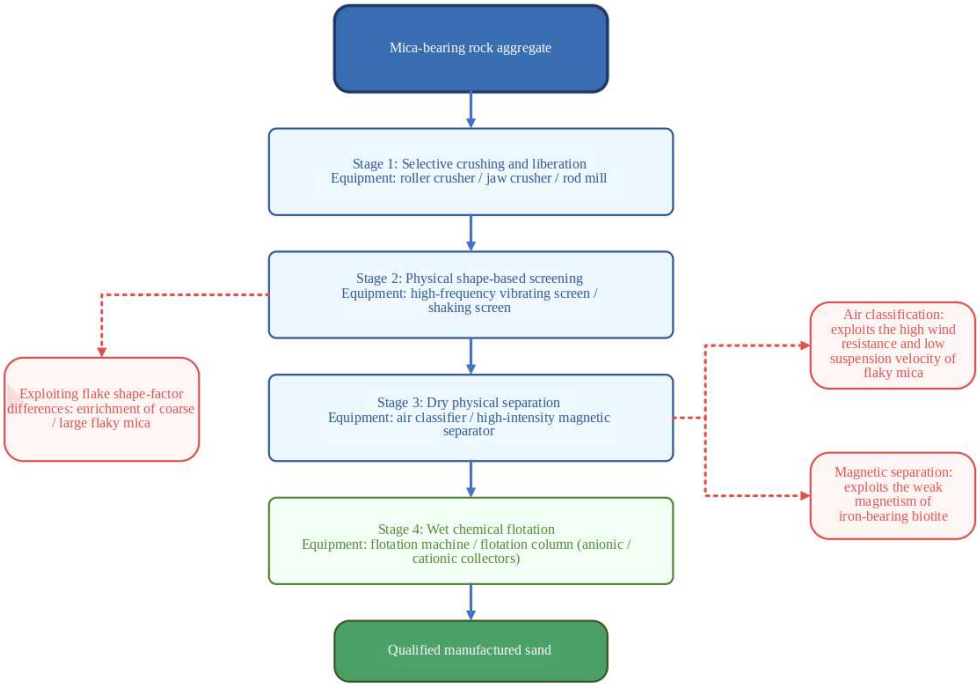

Fig. 10 Process flow of mica separation

4.2 Admixture Regulation and Surface Chemical Modification

4.2.1 Surface Chemical Modification of Aggregates with Silane Coupling Agents

A silane coupling agent is a bifunctional interfacial modification material: the hydrolysable groups at one end generate active silanol groups upon contact with water, which can combine with hydroxyl groups on the surfaces of aggregates (including mica particles in high-mica-content manufactured sand) to form stable Si–O covalent bonds; the organic functional groups at the other end react with the hydration products in the cement paste, building a "molecular bridge" between the aggregate and the cement-based material[58], and its mechanism of action is shown in Fig. 11. The active groups in silane coupling agents undergo hydrolysis and condensation reactions under alkaline conditions to generate silyl groups that can effectively couple to the surfaces of hydration products, and the silane coupling agent distributed at the aggregate–paste interface forms a cross-linked structure that can inhibit microcrack propagation, thereby reducing the water absorption of concrete specimens[59,60]. KH550 exhibits a significant retarding effect at early ages[61]; in the middle and late stages of hydration, the silanol generated by its hydrolysis can interact with Ca^{2+}, Al^{3+}, and other ions in the paste, providing additional nucleation sites and promoting the uniform deposition of hydration products. Although it does not change the types of final hydration products of the cement paste system, it promotes the formation of amorphous gel and significantly increases the volume of gel pores with diameters smaller than 10 nm, optimizing the skeleton densification effect of pore refinement and filling[62]. This bidirectional bonding can greatly enhance the interfacial bond strength, optimize the microstructure of the interfacial transition zone, and reduce pores and microcracks, thereby improving the mechanical properties and durability of concrete.

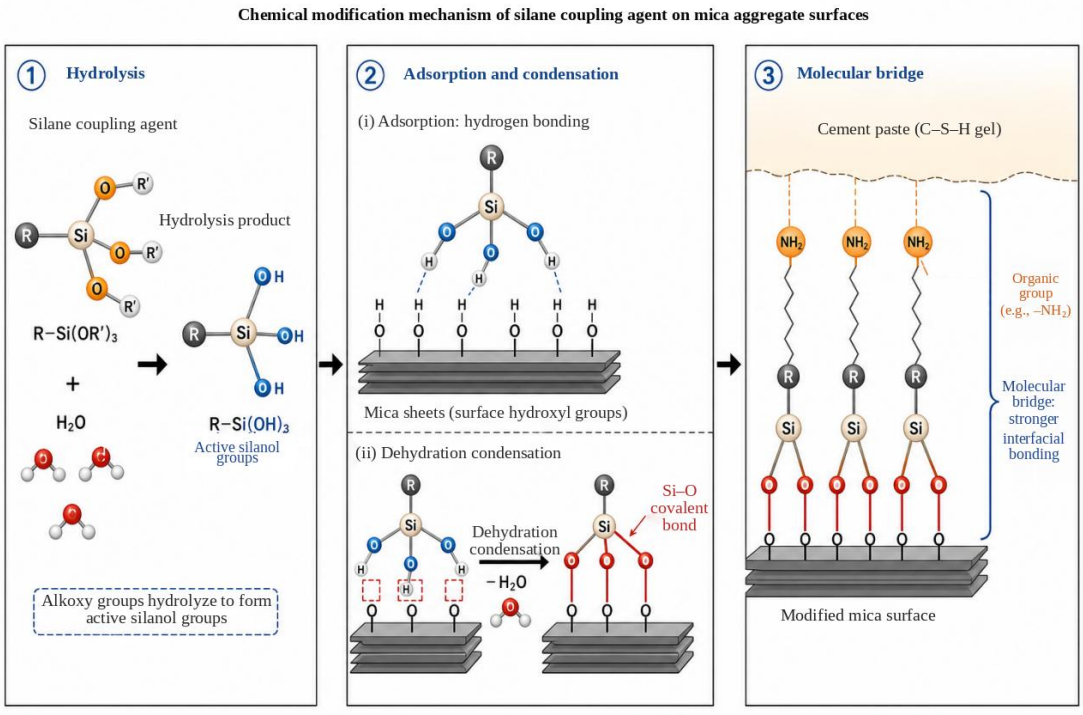

Fig. 11 Chemical modification mechanism of silane coupling agent on mica aggregate surfaces

In ultra-high-performance concrete, hydrolytically modified silane can solve the problem of poor fluidity caused by the high specific surface area of cementitious materials, and after modification by hydrolyzed silane, each component is adsorbed on the component surfaces through chemical reactions, which can improve material dispersibility[63], providing an idea for ameliorating the dispersion failure of admixtures such as superplasticizers in high-mica-content systems.

KH550 modification can increase the compressive strength of mortar by 10%, reduce the porosity of the interfacial transition zone by 8.4%, and increase the elastic modulus by 42.3% by alleviating the ITZ edge effect, greatly optimizing the cement hydration environment[64]. Its working principle is mainly to improve the interfacial compatibility between the mica surface and the cement paste through chemical bonding, reduce the pores and microcracks formed by water accumulation at the interface, and optimize the microstructure of the interfacial transition zone[65]; while improving the numerous harmful pores formed by mica, it effectively weakens the negative effect of mica's own low bond strength on the aggregate–paste interface, thereby enhancing the overall performance of concrete.

For rubber aggregate, which has similar interfacial bonding defects, infrared spectroscopy and contact angle tests showed that modified silane can introduce polar groups such as hydroxyl groups onto the rubber aggregate surface, improving its bonding performance with the interfacial transition zone of the cementitious material and significantly enhancing the macroscopic mechanical strength of concrete[66]. This modification concept is equally applicable to mica particles with inert surfaces: the silanol groups generated by hydrolysis of the alkoxy groups at one end of the silane molecule can form hydrogen bonds with the hydroxyl groups already present on the mica surface or undergo dehydration condensation to form covalent bonds, while the functional groups at the other end can combine with the hydration products in the cement matrix, building a molecular bridge between the two, strengthening the microscopic connection, and thereby improving concrete performance.

Different types of silanes carry different molecular chain structures, and their modification effects also differ. Research based on the boundary nucleation and growth (BNG) model combined with XRD, FTIR, TG, and SEM characterization found that short-chain silanes promote early nucleation, whereas long-chain silanes retard the hydration process[67]. This indicates that, in cement-based material systems prepared with high-mica-content manufactured sand, relying solely on the single modification means of silane coupling agents can hardly fully offset the negative effects of mica or comprehensively improve the weakness of the interfacial transition zone caused by mica cleavage planes[68]; it is therefore necessary to combine other modification technologies to form a synergistic regulation system.

4.2.2 Combined Effects of Modified Silanes

Owing to the high specific surface area and high cleavage of mica-like substances, they exert a significant inhibitory effect on polycarboxylate superplasticizer: mica minerals such as sericite strongly adsorb polycarboxylate superplasticizer and significantly reduce the spread of the mixture, constituting one of the key factors causing the loss of superplasticizer efficacy and the deterioration of concrete workability[69].

Accordingly, research has been carried out on regulating interfacial properties through modified silanes. The results show that the combined use of silane-modified aggregate and polycarboxylate superplasticizer can exert a synergistic enhancement effect[70]: using silane-modified aggregate alone readily causes peeling of the concrete matrix, whereas with increasing polycarboxylate superplasticizer dosage, the workability and mechanical properties of concrete are significantly improved, and the aggregate peeling defect is ameliorated by the effective dispersion of the matrix by the superplasticizer; however, how the two admixtures achieve optimal grafting on the mica surface remains to be further explored.

Modified ettringite crystal nuclei (Aft) prepared with silane-modified polycarboxylate superplasticizer as the dispersant change in morphology from fibrous to fine acicular, with reduced particle size, increased number, and shortened formation time; they can promote the bonding of cement particles, reduce microscopic cracks, and significantly enhance the early strength of concrete[71], confirming the enhancing effect of polycarboxylate-modified silane on the performance of hydration products.

Related research has further proposed the mechanism of action of silane-group-containing polycarboxylate superplasticizer (SPC)[72]: compared with the physical complexation of PCE on cement particle surfaces, the silane groups on the SPC molecular chain can form covalent-bond adsorption with the surfaces of cement hydration products, and this covalent adsorption force is much stronger than the electrostatic adsorption force of traditional PCE and its intercalation adsorption force on clay fines; meanwhile, SPC adopts an extended configuration on cement particle surfaces, which can increase the steric hindrance between cement particles and thereby optimize the adsorption coverage of the superplasticizer on cement particle surfaces[73]. The synergistic action of SPC can give full play to the dispersion effect of PCE and the interfacial modification advantages of silane, and its core reaction path is as follows: the active silanol groups generated after silane hydrolysis undergo dehydration condensation with hydroxyl groups on the mica surface to form stable Si–O covalent bonds, effectively suppressing the free dispersion tendency of mica particles and achieving stable anchoring of mica in the cement-based composite system (Fig. 12).

Amino-modified silane coupling agents are an effective approach to improving the interfacial degradation problem between high-mica-content manufactured sand and the cement matrix: the amino functional groups at the ends of their molecular chains can undergo coupling reactions with active functional groups such as carboxyl and ether groups of polycarboxylate superplasticizers, cooperating with cement hydration to generate a highly dense three-dimensional C–S–H gel network. Through the interfacial chemical bonding strengthening mechanism, the bond strength of the interfacial transition zone of concrete with excessive mica is significantly improved, thereby enhancing macroscopic mechanical properties such as compressive and flexural strength[74]. Given the wide application of polycarboxylate superplasticizers, subsequent research should prioritize the graft copolymerization reaction kinetics between polycarboxylate molecular chains and different types of silane functional groups, the regulation mechanism of grafting rate, and the optimization of engineering application technical parameters.

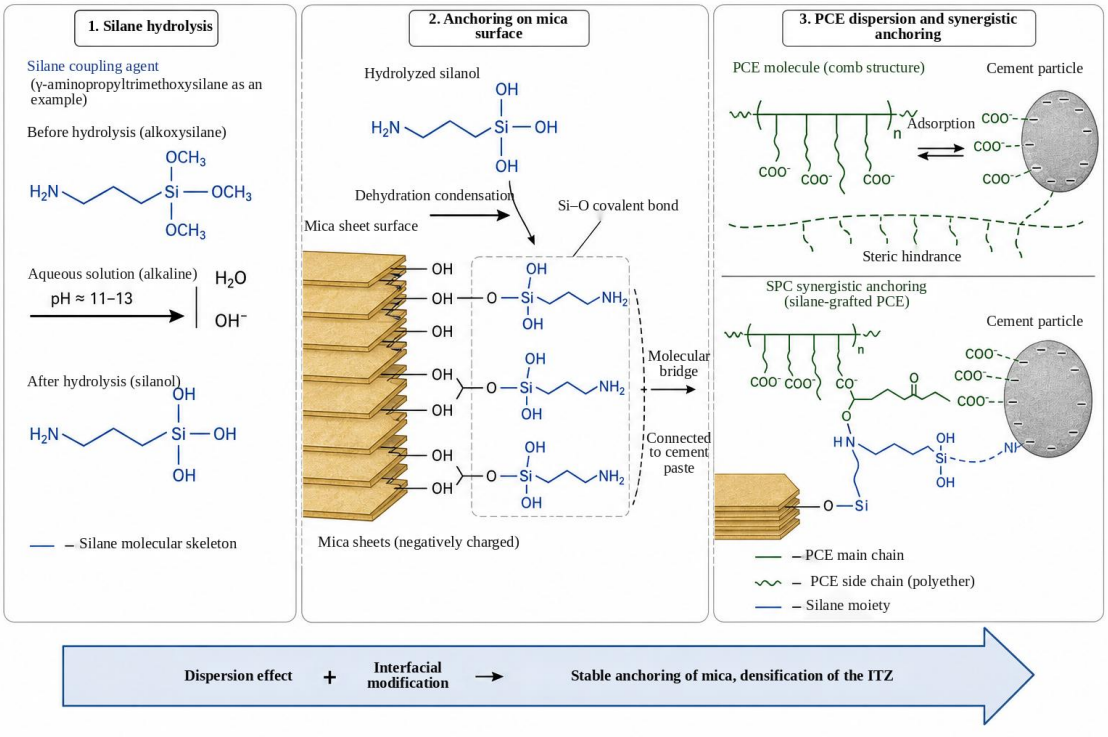

Fig.12 Mechanism of the synergistic action of polycarboxylate and silane

4.3 Synergistic Improvement of Weak Interfacial Zones by Mineral Admixtures

Exploiting the micro-filler filling effect and high-efficiency pozzolanic reaction of high-quality mineral admixtures is another core technical scheme for eliminating the ITZ interfacial degradation caused by mica and achieving structural densification.

Nano-silica can exert pozzolanic and filling effects in cement paste, accelerate cement hydration, and enable manufactured sand concrete to generate more hydrated cementitious products, significantly improving the performance of the interfacial transition zone [75,76]; it can effectively promote the formation of the C–S–H gel phase and consume the CH phase, generating more hydration products such as C–S–H and AFt through secondary hydration, filling interfacial pores, refining CH crystals, and improving interfacial compactness and microscopic mechanical properties[77,78]. Surface modification of nano-SiO_2 with the silane coupling agent KH560 can also promote the hydration process of cement and generate more calcium silicate hydrate gel favorable to the development of the mechanical properties of cement-based materials[79,80]. Although nano-SiO_2 has been proven to significantly improve the compactness of the interfacial transition zone[81], its application in actual engineering is limited by factors such as cost and construction workability, and using silica fume as a substitute material is more in line with actual engineering needs.

In the aforementioned study on the concrete interfacial transition zone, the introduction of slag and silica fume into the cementitious material can significantly increase the compactness of the ITZ and reduce its thickness: compared with no admixture, the ITZ thickness decreases by 31% at a slag content of 15% and by as much as 37% at a silica fume content of 15%, indicating that silica fume and slag have an extremely strong ability to reduce the thickness of the weak interfacial zone. To better exert the interfacial improvement effect of silica fume, the “aggregate surface wrapping modification” method emerged[82], in which the aggregate surface is pre-wrapped with silica-fume-modified cement paste and dried at room temperature before preparing high-volume fly ash concrete, achieving targeted enrichment of silica fume in the ITZ. Studies show that under the optimal parameters of a water–binder ratio of 0.30 and a silica fume content of 9%, the ITZ porosity of concrete decreases to 21.2% (a reduction of 54.54%); this regulation pathway can effectively reduce the porosity of high-mica-content concrete, optimize the gradation distribution of pores, and significantly improve the compactness and macroscopic performance of the interfacial transition zone of cement-based systems.

Research on the durability of concrete with a combined silica fume–fly ash system showed that the best comprehensive frost resistance is achieved at a total content of 30% and a mass ratio of 2:1, with the mass loss rate and various strength losses during freeze–thaw cycling controlled at the lowest levels[83] indicating that an appropriate combination of the two can significantly improve the long-term frost resistance and impermeability of hardened concrete and enhance its compressive, tensile, and abrasion resistance.

Adding both silica fume and fly ash during the preparation of cement-based materials can exploit the micro-filler filling effect of silica fume and the long-term hydration characteristics of fly ash to generate a compact

calcium silicate hydrate gel network on the smooth surfaces of mica-bearing manufactured sand and in the weak regions where paste and aggregate bond. This gel network tightly wraps the mica cleavage particles and fills the gaps between the mica surfaces and the cement paste, thereby ameliorating the degradation of interfacial transition zone performance caused by high-mica-content manufactured sand (Fig. 13).

Taken together, the above three categories of modification measures each have their own emphasis in improving concrete performance: in terms of workability, physical separation reduces the mica content at the source[48~52], while silane hydrolysis modification combined with polycarboxylate superplasticizer can improve particle dispersion and paste fluidity[69,70]; in terms of mechanical properties, silane coupling agents strengthen the mica–paste interface through chemical bonding[64], and admixtures such as silica fume and slag reduce ITZ thickness and porosity through filling and pozzolanic effects[31,82]; in terms of durability, the combined silica fume–fly ash system shows the most prominent improvement in freeze–thaw and penetration resistance[83]. Overall, however, no single measure can fully offset the negative effects of mica, and multi-technology synergistic regulation is the future development direction.

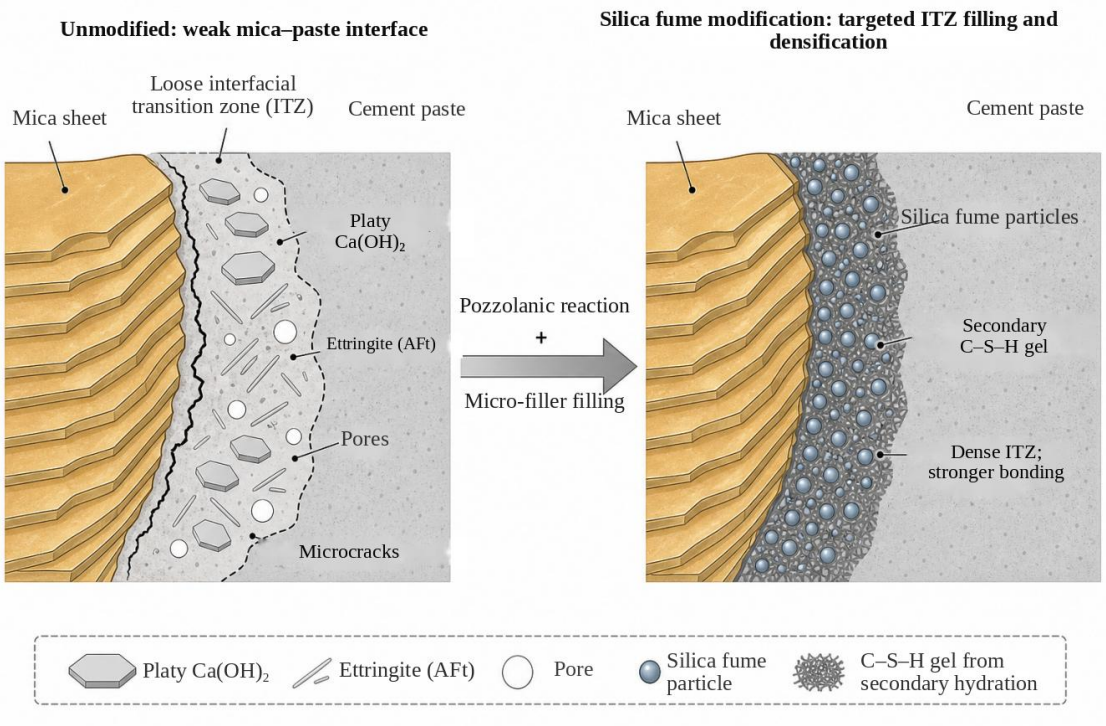

Fig. 13 Schematic diagram of silica fume improving the interfacial transition zone

5 Existing Problems in Current Research and Proposed Solutions

Although research on high-mica-content manufactured sand has made considerable progress, a gap remains between existing achievements and large-scale engineering application. Reviewing the existing literature, the main problems and proposed solutions are shown in Fig. 14 and elaborated as follows.

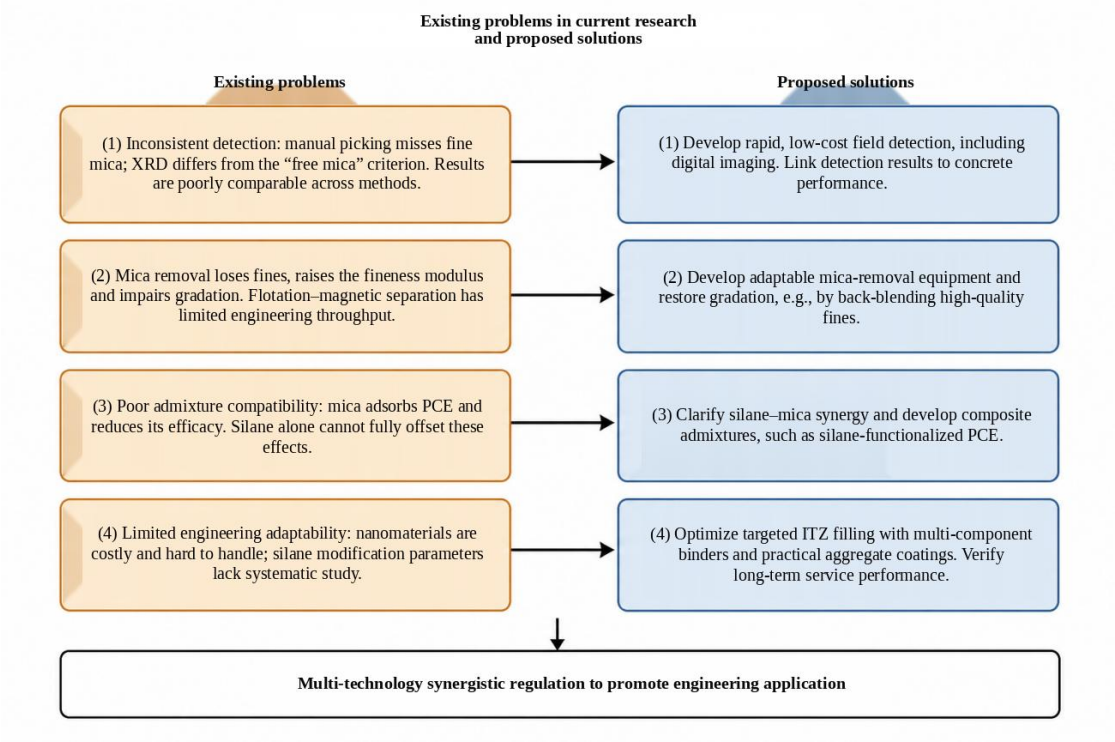

Fig. 14 Existing problems in current research and proposed solutions

(1) The detection and evaluation system is not yet unified. The picking method cannot identify mica in the fine powder state[17,18], and the total mica content measured by XRD deviates from the concept of "free mica" in the specifications[19]; the poor comparability of detection results among different methods leaves limit research without a unified evaluation benchmark. Developing rapid, low-cost, and engineering-deployable detection technologies such as digital image analysis[21] and establishing the correspondence between detection results and concrete performance are the foundation for subsequent research.

(2) Physical separation and gradation regulation are difficult to reconcile. Air classification and magnetic separation lose fine particles while removing mica, leading to an increased fineness modulus and degraded gradation of the finished sand, and even segregation and bleeding of concrete[49,51]; the combined flotation–magnetic separation process can hardly meet the processing demand of large-volume engineering[54]. Developing highly adaptable physical mica-removal equipment, together with supporting gradation regulation technologies such as back-blending high-quality fines, is the key to the engineering application of physical methods.

(3) The compatibility between admixtures and the mica–cement system is insufficient. The strong adsorption of polycarboxylate superplasticizer by mica causes loss of superplasticizer efficacy[69], and single silane modification can hardly fully offset the negative effects of mica[67]; the interactions among admixtures and their concentration adaptability remain unclear. Deeply revealing the synergistic regulation mechanism between silane molecular structure and the mica surface and developing composite functional admixtures such as silane-group-containing polycarboxylate superplasticizers are the key directions of chemical modification.

(4) The engineering adaptability of chemical modification and admixture technologies needs to be improved. Nanomaterials are costly and difficult to handle in construction, and the engineering application parameters of silane modification lack systematic study. Optimizing the targeted filling and modification effects of multi-component cementitious materials on the interfacial transition zone, developing engineering-friendly technologies such as aggregate surface wrapping modification[82], and carrying out long-term service performance verification are the necessary paths to promote the translation of these achievements.

6 Conclusions and Prospects

This paper has systematically reviewed research progress on the occurrence characteristics and test evaluation methods of mica in manufactured sand, the mechanisms by which mica degrades concrete performance, and performance enhancement techniques. The development and utilization of mica-bearing manufactured sand can not only effectively alleviate the pressure of natural sand resource shortages and reduce construction costs, but also has important practical significance and application value for promoting the resource utilization of construction solid waste and supporting the sustainable development of the green building materials industry.

The main conclusions are as follows:

(1) Free mica in manufactured sand mainly originates from the occurrence in the parent rock and the crushing process. The picking method, XRD method, digital imaging method, and FE-SEM method each have their applicable scenarios, and the comparability and engineering applicability of detection results still need to be improved.

(2) Mica degrades the workability of concrete by adsorbing free water and admixtures, reduces mechanical properties through weak interfacial bonding and interfacial transition zone defects, and accelerates the deterioration of durability by serving as a transport channel for aggressive media; the mica content is significantly negatively correlated with concrete strength.

(3) Physical separation, surface modification with silane coupling agents, and mineral admixture regulation can improve the performance of high-mica-content manufactured sand concrete from different links, but each single measure has limitations, and multi-technology synergistic regulation is the development trend.

Multiple studies have shown that even when the mica content exceeds the current 2% limit, concrete prepared with manufactured sand can still meet structural design requirements, and the current content limit restricts the wide application of manufactured sand to a certain extent. Regarding the problem of excessive mica

content in manufactured sand, future research is recommended to: (1) optimize the crushing and screening process flow and further improve mica removal efficiency and equipment level on the basis of ensuring production applicability; (2) strengthen research on the performance of silane coupling agents in concrete systems, explore the adsorption and bonding mechanisms between silane molecules and cement particles and mica surfaces, and develop modified admixtures more suitable for manufactured sand with excessive mica; (3) deeply reveal the filling and modification mechanisms of cementitious materials on the interfacial transition zone at mica surfaces, and establish quantitative correlations between microstructure and macroscopic performance, providing theoretical and technical support for the safe and efficient application of high-mica-content manufactured sand.

Declarations

Availability of data and materials. The datasets supporting the conclusions of this article are included within the article and its cited references.

Competing interests. The authors declare that they have no competing interests.

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References

[1] Price Department of National Development and Reform Commission. Official responsible person of the Price Department of National Development and Reform Commission answers reporters' questions on the Guiding Opinions on Promoting the Healthy and Orderly Development of Sand and Gravel Industry. https://www.gov.cn/zhengce/2020-03/27/content_5496209.htm (2020).

[2] China Aggregate Association, 2025 annual economic operation report of China's sand and gravel industry, https://www.zgss.org.cn/zixun/zhuti/17808.html (2026)

[3] DL/T 5144, Specification for construction of hydraulic concrete, China Electric Power Press, Beijing, 2014.

[4] H.W. Ma, Industrial minerals and rocks, 4th ed., Chemical Industry Press, Beijing, 2018.

[5] Wenjun Lv, Y. Zhou, Z.G. Tao, Z. Shi, Q.Y. Liang, Z.Z. Li, M.C. He, B. Li, Weak-link minerals in crystalline rock: how mica cleavage orchestrates fracture propagation, J. Rock Mech. Geotech. Eng. (2026). https://doi.org/10.1016/j.jrmge.2026.06.019

[6] X.Y. Li, J.M. Ren, Y.H. Chen, Experimental study on the performance of concrete with high-mica-content stone powder, J. Hydroelectr. Eng. 31 (2012) 211–215.

[7] W. Chen, H. Tong, Y.X. Xiao, et al., Current status of mica separation technology in China and its application prospects in the sand and gravel industry, Water Power 47 (2021) 90–93, 131.

[8] H.Q. Liu, X.Q. Yang, L.H. Jiang, et al., Study on the effect of interfacial modification on the properties of super standard mica sand cement-based materials, Buildings 14 (2024) 1665. https://www.mdpi.com/2075-5309/14/6/1665
[9] Y. He, X. Zhang, M.D. Gu, et al., Effect of silane-modified polycarboxylate superplasticizer on the fluidity and hydration process of cement paste, J. Chin. Ceram. Soc. 44 (2016) 1166–1172.
[10] S. Gao, S.L. Ban, J. Guo, et al., Effect of silica fume on the interfacial transition zone of recycled concrete, Mater. Rep. 37 (2023) 97–103.
[11] G.B. Song, T.J. Peng, F.S. Liu, et al., Study on the mineralogical characteristics of major muscovites in China, Acta Mineral. Sin. (2) (2005) 123–130.
[12] J. Chand, D.P. Gupta, A. Dewangan, How does mica contents in sand affects characteristics of concrete, Int. J. Appl. Eng. Res. 5 (2010) 1325
[13] S.X. Zheng, Y. Yan, R.Y.J. Wang, et al., Study on the effect of mica characteristics of manufactured sand on mortar performance, J. Hydroelectr. Eng. 41 (2022) 117–123.
[14] Y.L. Mao, X. Shu, Q.Q. Zhang, et al., Effect of mica powder on the rheological properties of cement mortar, New Build. Mater. 47 (2020) 33–36.
[15] DL/T 5144, Specification for construction of hydraulic concrete, China Electric Power Press, Beijing, 2014.
[16] Bureau of Indian Standards, Coarse and fine aggregates for concrete—specification: IS 383-2016, Bureau of Indian Standards, New Delhi, 2016.
[17] DL/T 5151, Test code for sand and gravel aggregates of hydraulic concrete, China Electric Power Press, Beijing, 2001.
[18] Y.J. Zhang, W.J. Luo, J.T. Zhang, et al., Study on the application of biotite quartz schist aggregate in the Batang Hydropower Station project, Sichuan Water Power 43 (2024) 103–105.
[19] J.Q. Xing, S.L. Zhan, X.Y. Li, et al., Study on the test method for mica content in stone powder of manufactured sand and its influence on concrete properties, New Build. Mater. 42 (2015) 7–9, 32.
[20] Z.L. Wang, Y. Bai, J.T. Ding, et al., Analysis method for mica content in manufactured aggregate based on X-ray diffraction, Water Resour. Power 35 (2017) 150–153.
[21] H.Q. Liu, X.Q. Yang, Y.Z. Chen, Rapid detection method for mica content in concrete fine aggregate, New Build. Mater. 48 (2021) 18–21.
[22] L. O'Connor, R. Goodhue, Methodology for the determination of <63 μm free mica fines in sand and within the cement matrix of hardened concrete blocks using scanning electron microscopy and energy dispersive spectroscopy, Q. J. Eng. Geol. Hydrogeol. 53 (2020) 425–430. https://doi.org/10.1144/qjegh2019-063
[23] P. Venyite, J. Giogetti Deutou Nemaleu, R. Cyriaque Kaze, et al., Alkali-silica reactions in granite-based aggregates: the role of biotite and pyrite, Constr. Build. Mater. 327 (2022) 126259. https://doi.org/10.1016/j.conbuildmat.2021.126259
[24] Y.Z. Shang, Z.L. Cui, Y.J. Li, Y.N. Zhang, Y.H. Cheng, Strength and Microscopic Mechanism of Cement–Fly Ash–Slag–Desulfurization Gypsum Solidified Mica Schist Weathered Soil, Materials 16 (2023) 6957. https://doi.org/10.3390/ma16216957
[25] H.D. Gao, X.W. Zhang, S. Wang, X.Y. Liu, G. Wang, L.Y. Gou, Morphology-dependent behavior of micaceous residual soils: A micro-macro experimental investigation into size and exfoliation effects, J. Rock Mech. Geotech. Eng. (2026). https://doi.org/10.1016/j.jrmge.2026.02.037
[26] Q. Zhang, H. Fan, X.Q. Yang, et al., Study on the rheological behavior and drying shrinkage of high-mica-content granitic manufactured sand mortar, New Build. Mater. 52 (2025) 40–45.
[27] H.Q. Liu, X.Q. Yang, Y.Z. Chen, Experimental study on the effect of mica content in manufactured sand on the properties of cement-based materials, J. North China Univ. Water Resour. Electra. Power 42 (2021) 60–65.
[28] H. Fan, S.X. Guo, Z.P. Wang, et al., Study on the effect of mica in manufactured sand on the rheological behavior and hydration hardening of cement paste, J. China Foreign Highw. (in press).
[29] X.W. Jiang, Effect of light substance content in fine aggregate on the dispersion performance of polycarboxylate superplasticizer, Jiangsu Build. Mater. (1) (2025) 24–26.

[30] W.B. Wu, J.J. He, H.T. Wang, et al., Effect of free mica content in manufactured sand on concrete performance, J. Yangtze River Sci. Res. Inst. 41 (2024) 148–152.
[31] S.C. Chen, Study on the structure and mechanical properties of the interfacial transition zone of lightweight aggregate concrete, Doctoral dissertation, Xi'an University of Architecture and Technology, Xi'an, 2024.
[32] Q.L. Yu, T.H. Yang, C.A. Tang, Numerical simulation of the effect of interfacial strength on the tensile fracture of concrete, J. Build. Mater. 12 (2009) 643–649.
[33] Z.S. Peng, Q.X. Xiong, X.M. Zhou, et al., A porosity-based mechanics model for studying crack evolution from ITZ to mortar matrix in concrete, Comput. Methods Appl. Mech. Eng. 444 (2025) 118085. https://doi.org/10.1016/j.cma.2025.118085
[34] H.Z. Cui, F. Xing, Study on the interfacial transition zone of lightweight aggregate concrete by SEM and FT-IR, Concrete (1) (2010) 18–20.
[35] D.S. Yin, M.K. Zhang, B.B. Xiong, et al., Study on the physical and mechanical properties of concrete interfacial transition zones (ITZ) with consideration of positional effects, Constr. Build. Mater. 486 (2025) 141985. https://doi.org/10.1016/j.conbuildmat.2025.141985
[36] Y.L. Wang, W.Y. Zhang, J.J. Wang, et al., Effects of coarse aggregate size on thickness and micro-properties of ITZ and the mechanical properties of concrete, Cem. Concr. Compos. 154 (2024) 105777. https://doi.org/10.1016/j.cemconcomp.2024.105777
[37] Y.T. Chu, Q.J. Yu, Y. Yu, et al., Characteristic analysis of innermost layer of ITZ of cement paste based on modelling the spatial distribution of calcium hydroxide, Mater. Des. 256 (2025) 114249. https://doi.org/10.1016/j.matdes.2025.114249
[38] Y. Xia, L. Zhang, G.Y. Du, C. Zhang, J.F. Zhang, Z.Y. Zhu, et al., Study on the effect of mica content in manufactured sand on temperature control and crack prevention of super-high concrete arch dams in high-altitude cold regions, Water Resour. Hydropower Technol. 56 (S2) (2025) 144–148.
[39] S.K. Li, M.T. Qin, Q.L. Liao, et al., Effect of mica content in granitic manufactured sand on the durability of concrete, J. Guilin Univ. Technol. (in press).
[40] X.Y. Li, G.S. Xie, J.M. Ren, et al., Study on the effect of high-mica stone powder in manufactured sand on the performance of abrasion-resistant concrete, Water Power 42 (2016) 106–110.
[41] H.S. Shi, D.D. Sun, K. Wu, Research progress on the microstructure of the interfacial transition zone of concrete and its numerical simulation methods, J. Chin. Ceram. Soc. 44 (2016) 678–685.
[42] A. Leemann, B. Lothenbach, B. Münch, et al., The "mica crisis" in Donegal, Ireland: a case of internal sulfate attack?, Cem. Concr. Res. 168 (2023) 107149. https://doi.org/10.1016/j.cemconres.2023.107149
[43] Y.P. Zhang, J.H. Wen, W. Wang, et al., Study on the effect of high-mica-content manufactured sand on the performance of concrete for pumped-storage power stations, Hydropower Pumped Storage 11 (2025) 43–47.
[44] B. Titon, J. Duchesne, B. Fournier, The role of biotite in the deterioration of pyrrhotite within concrete aggregates: Trois-Rivières case study, Cem. Concr. Res. 183 (2024) 107595. https://doi.org/10.1016/j.cemconres.2024.107595
[45] Y.C. Li, Preliminary study on the re-separation of tailings from air classification of crushed mica ore, Non-Met. Mines (2) (2002) 39–40.
[46] H. Long, Y. Huang, F.F. Wang, et al., Experimental study on the beneficiation of muscovite from granite in a locality of western Sichuan, China Non-Met. Min. Ind. Bull. (6) (2014) 28–31.
[47] C.F. Du, J. Ouyang, Y.G. Su, Processing and comprehensive utilization of non-metallic minerals, Chemical Industry Press, Beijing, 2018.
[48] Y.X. Xiao, J.G. Tang, W. Chen, et al., Experimental study on air classification of free mica in manufactured sand, Water Power 47 (2021) 83–86.
[49] H.L. Xiao, C.Q. He, M.L. Chen, et al., Improving mechanical properties of manufactured sand concrete with high biotite content: application of magnetic separation process and equipment optimization, Constr. Build. Mater. 350

(2022) 128861. https://doi.org/10.1016/j.conbuildmat.2022.128861
[50] H. Miceli, M.G. Rossi, R. Neumann, et al., Contaminant removal from manufactured fine aggregates by dry rare-earth magnetic separation, Miner. Eng. 110 (2017) 134–141. https://doi.org/10.1016/j.mineng.2017.07.017
[51] J. Qin, S.K. Li, Q.L. Liao, et al., Study on the effect of magnetic separation removal of mica from manufactured sand on concrete performance, Highway 67 (2022) 327–330.
[52] J.X. Yang, H.M. Li, Study on mica removal measures for manufactured sand at the Yebatan Hydropower Station, Des. Hydroelectr. Power Stn. 41 (2025) 43–45, 85.
[53] M.X. Jia, C.Y. Sun, Analysis of zero point of charge, floatability and bond valence of several silicate minerals, Nonferrous Met. (Miner. Process. Sect.) (6) (2001) 1–9.
[54] L. Wang, W. Sun, R.Q. Liu, Mechanism of separating muscovite and quartz by flotation, J. Cent. South Univ. 21 (2014) 3596–3602. https://doi.org/10.1007/s11771-014-2268-6
[55] L. Ren, T. Ma, S. Bao, Y. Zhang, Z. Jiao, X. Zhang, Enhanced flotation performance and adsorption mechanism on (0 0 2) crystal plane of fine muscovite powder, Adv. Powder Technol. 34 (2023) 104317. https://doi.org/10.1016/j.apt.2023.104317
[56] C. Korbel, I.V. Filippova, L.O. Filippov, Froth flotation of lithium micas – A review, Miner. Eng. 191 (2023) 107986. https://doi.org/10.1016/j.mineng.2022.107986
[57] Weiguang Zhou, J.J. Niu, W. Xiao, L.M. Ou, Adsorption of bulk nanobubbles on the chemically surface-modified muscovite minerals, Ultrason. Sonochem. 51 (2019) 31–39. https://doi.org/10.1016/j.ultsonch.2018.10.021
[58] Y.L. Li, X.H. Lu, Y.L. Feng, et al., Formation mechanism of the granite/silane coupling agent/cement paste interfacial layer, Chin. J. Mater. Res. (2) (2007) 140–144.
[59] J. Li, P. Li, F. Lin, et al., Inhibitory effect of silane coupling agent on carbonation erosion of alkali-activated slag concrete, J. Mater. Sci. Eng. 41 (2023) 497–501.
[60] M.J. Oh, I. Kownacki, J. Ortyl, “Silatranization”: Surface modification with silatrane coupling agents, Adv. Colloid Interface Sci. 338 (2025) 103649. https://doi.org/10.1016/j.cis.2025.103649
[61] B. Chen, M. Wang, H. Manzano, Y. Zhao, Y. Li, Molecular elucidation of cement hydration inhibition by silane coupling agents, Nat. Commun. 16 (2025) 1072. https://doi.org/10.1038/s41467-025-56877-9
[62] Y.K. Wei, N. Chen, S.Z. Feng, et al., Effect of silane coupling agent on the properties of alkali-activated slag–fly ash solidified expansive soil, J. Build. Mater. (in press).
[63] C.X. Li, S.J. Wang, Y.H. Xia, et al., Rheology and strength of silane-modified ultra-high-performance concrete, J. Chin. Ceram. Soc. 51 (2023) 2914–2923.
[64] H. Cheng, Z. Hai, Effect of silane coupling agent treatment of aggregates on mortar workability, strength and interfacial microscopic properties, Materials 16 (2023) 7458. https://doi.org/10.3390/ma16237458
[65] A. Stewart, B. Schlosser, E.P. Douglas, Surface Modification of Cured Cement Pastes by Silane Coupling Agents, ACS Appl. Mater. Interfaces 5 (2013) 1218–1225. https://doi.org/10.1021/am301967v
[66] Q.C. Tu, Y. Yan, Y.H. Bai, Experimental study on the properties and mechanism of silane coupling agent modified rubber cement-based materials, Fujian Build. Mater. (4) (2024) 1–5, 61.
[67] M. Yi, Z. He, Z. Long, et al., Chain-structure-dependent regulation of cement hydration by silanes quantified by boundary nucleation and growth modeling, Cem. Concr. Compos.9 173 (2026) 106719. https://doi.org/10.1016/j.cemconcomp.2026.106719
[68] J. Zhang, L. Kong, L. Yang, L. Zhang, G. Li, Long/short-chain silane co-modified nano-SiO_2 for robust superhydrophobic epoxy coating with enhanced concrete durability, Surf. Interfaces 48 (2026) 110768. https://doi.org/10.1016/j.surfin.2026.110768
[69] H. Wu, Z.M. Wang, Failure analysis of polycarboxylate superplasticizer in concrete with inferior sand and gravel, Concrete (6) (2012) 86–88.
[70] Y.L. Wang, C.F. Wang, Study on the combined effect of polycarboxylate and silane modification in recycled concrete,

Jiangxi Build. Mater. (3) (2022) 21–23.
[71] S.S. Qian, F. Chen, J.Y. Peng, et al., Effect of silane-modified ettringite crystal nuclei on cement hydration and strength, Polym. Mater. Sci. Eng. 41 (2025) 114–122.
[72] A. Lange, J. Plank, Contribution of non-adsorbing polymers to cement dispersion, Cem. Concr. Res. 79 (2016) 131–136. https://doi.org/10.1016/j.cemconres.2015.09.003
[73] B. Chen, H. Shao, B. Li, Z. Li, Influence of silane on hydration characteristics and mechanical properties of cement paste, Cem. Concr. Compos. 114 (2020) 103743. https://doi.org/10.1016/j.cemconcomp.2020.103743
[74] H. Feng, H.T.N. Le, S. Wang, M.-H. Zhang, Effects of silanes and silane derivatives on cement hydration and mechanical properties of mortars, Constr. Build. Mater. 129 (2016) 48–60. https://doi.org/10.1016/j.conbuildmat.2016.11.004
[75] S.B. Zhou, Z.M. Zhou, C. Ma, et al., Study on the effect of nano-silica on the performance of manufactured sand concrete, Concrete (11) (2020) 57–61.
[76] Hongmei Zhang, L.N. Cao, Y.F. Duan, Z.Z. Tang, F. Hu, Z.Y. Chen, High-flowable and high-performance steel fiber reinforced concrete adapted by fly ash and silica fume, Case Stud. Constr. Mater. 20 (2024) e02796. https://doi.org/10.1016/j.cscm.2023.e02796
[77] B. Li, Y.L. Jiang, J.X. Zhang, et al., Study on the effect of nano-SiO_2 on the mechanical properties of grouting interfaces and its modification mechanism, J. China Coal Soc. (in press).
[78] Mahmudul Hasan Mizan, T. Ueda, K. Matsumoto, Enhancement of the concrete-PCM interfacial bonding strength using silica fume, Constr. Build. Mater. 259 (2020) 119774. https://doi.org/10.1016/j.conbuildmat.2020.119774
[79] L.T. Bai, Q. Chai, Effect of modified nano-silica on the mechanical properties of building mortar and its mechanism, Contemp. Chem. Ind. 54 (2025) 347–352.
[80] Yemcy Calcina Flores, G.C. Cordeiro, R.D. Toledo Filho, L.M. Tavares, Performance of Portland cement pastes containing nano-silica and different types of silica, Constr. Build. Mater. 146 (2017) 524–530. https://doi.org/10.1016/j.conbuildmat.2017.04.069
[81] D.Y. Kong, X.F. Du, S. Wei, et al., Influence of nano-silica agglomeration on microstructure and properties of the hardened cement-based materials, Constr. Build. Mater. 37 (2012) 707–715. https://doi.org/10.1016/j.conbuildmat.2012.07.091
[82] E.M. Soufian, Study on the improvement of the interfacial transition zone of high-volume fly ash concrete by silica fume, Master's thesis, Yanshan University, Qinhuangdao, 2024.
[83] S.Z. Yan, Z.Y. Shi, Experimental study on the freeze–thaw performance of concrete with fly ash and silica fume, Fly Ash Compr. Util. 40 (2026) 52–57.