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Research Article

Nanocomposite Building Materials in Modern Architectural Design

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Architecture is the precipitation of history, not only the embodiment of technical level but also the inheritance of history and culture. Excellent architecture contains high historical value and emotional factors, and it continues to deepen over time. Nanotechnology is a new technology that was born in the late 1980s and is emerging. It mainly refers to the study of the laws of motion and interactions of electrons, atoms, and molecules in the composition system of matter in the range of 0.1 to 100 nm. Nanomaterials have special properties and structures, and the composite materials made of them have the effect of strengthening and toughening the polymer by virtue of their high-quality strength and toughness. Therefore, the aim of this text is to explore the application of nanocomposite building materials in modern architectural design and analyze the advantages and development trends of new building materials. The method in this paper is to use the method of experimental comparison to analyze the performance improvement effect of nanocomposite building materials on the current main building materials of concrete. By establishing a model to study the impact on the shrinkage and mechanical properties of cement-based materials, it can also improve the environmental performance and comprehensive evaluation of building materials. Corresponding conclusions are drawn through data comparison. When the amount of nanocomposite building materials is 1.5%, the chemical shrinkage value of the cement paste will increase by 58.2%, and the shrinkage strain will increase by 15.3%. When the fly ash content is 20%, the chemical shrinkage value of cement paste is reduced by 30.5%, and the shrinkage strain of concrete is reduced by 8.8%. Therefore, adding nanocomposite building materials to cement-based materials can promote cement hydration, optimize pore structure, and to a certain extent can make up for the shortcomings of mineral admixtures and achieve better improvement effects.

1. Introduction

Nanotechnology is a new technology emerging in the late 1980s. The emerging nanomaterial technology has been applied in many fields, especially in new building materials. Materials are the basic elements of architecture. As an important material carrier for the inheritance and development of modern civilization and cultural spirit, architecture carries decisive significance. Therefore, it is very important to construct elegant, beautiful, and practical buildings. The performance of materials is to integrate all buildings. Nanocomposite building materials have brought an unprecedented revolution to modern architectural design with their unique properties and unique characteristics of light, electricity, heat, and magnetism. Making an appropriate material design strategy has become an important part of modern architectural design.

The traditional building materials are mainly cement concrete, and the current consumption is about 2 billion cubic meters, which is an indispensable building material at present [1]. However, as people's requirements for building design become higher and higher, some problems in concrete itself have gradually expanded. After years of exposure to the air, cracks and damage will inevitably occur, and the rigidity of ordinary cement concrete is too high, and the flexibility is insufficient. The environmental protection is poor in the production process, which restricts the development of concrete in the future architectural design [2, 3]. As an indispensable part of building materials, the amount is considerable, and the requirements for stability and durability are very strict. The future development trend of modern architectural design is bound to be in line with the development of nanomaterials. Development is linked together [4]. Many scholars have done a lot of research on nanocomposites, and they all believe that nanomaterials are very important in new building materials, and they can get better development space in future special constructions [5]. In the research of foreign scholars, nano-conforming building materials are regarded as an unprecedented revolution. Combined with nanotechnology, many new materials can be developed, which are in line with today's architectural design concepts. The use of nanomaterials to shield ultraviolet rays can improve the antiaging yellowing performance of the wall, greatly improve the strength of plastic pipes, and increase the service life [6, 7]. Domestic research has also begun to explore the development and application of nanomaterials and nanotechnology in building materials and found that nano-conforming building materials also have a good self-cleaning function, which is useful for antibacterial and antimildew coatings in buildings and some conductive materials. Functionally developed conductive coatings have a positive guiding role [8]. Therefore, nano-building materials have great economic and social benefits in the field of building materials.

This article starts with the meaning and relationship between nanocomposite building materials and modern architectural design and explores the influence of different building materials on modern buildings. Through the experiment of improving the performance of concrete with nanomaterials, future solutions are proposed, so as to more accurately grasp the direction of modern architectural design and propose more optimized treatment plans. This will help promote the innovation and development of building materials. By comparing and analyzing specific experimental results, we can find out the balance between quality assurance and environmental friendliness and organically combine the two. Provide technical experience with reference value for future architectural design, obtain the similarities and differences of research directions through comparative advantage analysis, learn advanced experience, make suggestions for improvement in the selection of future building materials and in-depth understanding of more properties of nanocomposite building materials, strengthen the specialization and accuracy of architectural design, and provide theoretical basis for the field of materials science.

2. Theoretical Basis and Method

2.1. Core Concepts

2.1.1. Nanocomposite Materials. Nanocomposites are based on resins, rubbers, ceramics, and metals as the continuous phase and nanosized metals, semiconductors, rigid particles and other inorganic particles, fibers, carbon nanotubes, and other modifiers as the dispersed phase. The method uniformly disperses the modifier in the matrix material to form a composite system containing nanometer-sized materials in one phase, and the system material is called nanocomposite material. Since its inception, nanotechnology has gained the attention of the world. After more than 20 years of theoretical research, it has become one of the most promising technology industries [9, 10]. The use of nanotechnology can be applied to many industries, can greatly promote the development of productivity, and has achieved good results in medical, construction, military, and other aspects [11]. In the field of architecture, nanocomposite coating is the nanopowder used in the coating to get a kind of aging resistance, radiation resistance, high peel strength, or some special functions of the coating, in building materials which has been applied and has shown its unique charm. The same nanoparticle in different sizes will have different effects; different kinds of nanoparticles can also play the same role in the coating [12, 13]. Through this unique structure and excellent performance, it will be used in a wider range of fields, such as aerospace, transportation, culture, and sports. The development of new materials can determine the level of a country's industry, and all countries in the world have put nanocomposite materials in a priority development position and can be in a leading position in future international competition. There are many kinds of nanocomposites, including nanopolymer matrix composites, carbon nanotube functional composites, and nano-tungsten-copper composites [14].

2.1.2. Architectural Design. The so-called architectural design is the application of "virtual reality" technology in urban planning, architectural design, and other fields. Architectural design refers to a series of ideas and ideas about the building proposed by the designer according to the construction task before the building is built and then displayed through drawings or documents [15]. Excellent architectural design will consider various problems that occur during the entire building construction process and propose preparatory plans and emergency measures. Therefore, building construction is more of a holistic project. Architectural design must not only consider the construction requirements but also calculate the material preparation, construction organization work, and the conditions that various types of work rely on in production and construction [16, 17]. Only in this way can we coordinate and cooperate with each other, so that the entire project can be successfully completed within the predetermined investment limit and in accordance with the predetermined plan carefully considered. Architectural design in a narrow sense refers to the use of technology to turn virtual reality into reality, and design tools are becoming more and more advanced. It bids farewell to traditional drawing operations and uses human-computer interaction, real architectural space, and large-area 3D terrain simulation technology to make it more realistic. Accurately express the architectural design concept [18, 19]. Use dynamic interaction to meet the various requirements and uses expected by users and society, and conduct comprehensive and multiangle judgments and inspections of future buildings. At the same time, it can also achieve real-time switching and comparison of multiple environmental effects.

Observe the scene from any angle, distance, and degree of precision; accept customer experience feedback; and make timely adjustments, saving unnecessary cost and waste. With the development of society and the advancement of science and technology, the content of architecture and the problems to be solved are becoming more and more complex, and more and more related disciplines are involved.

2.2. Application of Nanomaterials in Building Materials

2.2.1. Application of Nanomaterials in Concrete Materials. Cement concrete is a general term for engineering composite materials that are mixed with water such as cement, sand, and stone to form a whole. Cement concrete has always played a pivotal role in the construction industry. As a traditional building material, it has made important contributions to the social industrialization and infrastructure construction of various countries. Its output and consumption are constantly increasing, but at the same time, the loss has always been high. [20]. Therefore, the use of nanomaterials to develop cement-based composite materials has become the focus of the material field. Under the new architectural design requirements, people's expectations for building materials are getting higher and higher, such as sound absorption, antifreeze, high strength, and high toughness. Nanomaterials have excellent characteristics such as small size effect, quantum effect, and surface and interface effects and combined with concrete can form very effective composite materials [21]. Use nanotechnology to develop new types of concrete, and use the excellent properties of nanomaterials to improve the strength, construction performance, and durability of concrete. In construction engineering, it can not only fill cement voids and increase concrete fluidity, but it can also improve the interface structure between cement stone and aggregate in concrete, improving the strength, impermeability, and durability of the concrete.

2.2.2. Application of Nanomaterials in Architectural Coatings. The core of the building is reinforced concrete, and the coating as the exterior of the building cannot be separated from the addition of nanomaterials. Traditional coatings always have various problems, such as poor scrub resistance, poor finish, and aging resistance. Nanocomposite coatings can be divided into nanomodified coatings and nanostructured coatings. Using some functions of nanoparticles to modify existing coatings to improve the performance of coatings, such coatings are called nanomodified coatings; for coatings prepared by some special processes, in which the fineness of a special component is in the nanometer range grade, such coatings are called nanostructured coatings [22]. The use of nanocomposite coatings can effectively improve the performance of concrete. When used in coatings, it will have antiaging, antiradiation, high peel strength, or some special functions, which greatly improves the use effect of coatings. Due to the particularity of its surface and structure, nanomaterials have excellent properties that are difficult to obtain with general materials. By combining with reinforced concrete materials, there is a great opportunity to obtain composite materials with excellent performance, so that the traditional coating function is modified, and macromaterials have many special and unprecedented excellent properties. Nanocomposite building materials can be used as composite materials for exterior decoration through nanocoating materials composed of nanoparticles, and traditional coatings can be modified by adding nanoparticles. The advantage of this method is that the cost is less and the preparation process is relatively simple. The actual use process is feasible and does not require a complete application of nanomaterials, which can improve the comprehensive performance of concrete. This is also the method of most current building material selection, and due to technical and cost issues, it is also in modern architectural design, one aspect to focus on.

2.2.3. The Application of Nanotechnology in Ceramic Materials. Due to the mechanical properties of the second phase, oxide nanomaterials have an artistic process that is different from ordinary ceramics. Relatively, the cost and consumption are naturally rising. Cermets containing 20% nano-cobalt powder are high-temperature-resistant materials for rocket jet nozzles. In this respect, they are superior to homogeneous traditional ceramic materials. In the field of building materials, ceramics have always been loved by people, so ceramic materials are added Nanomaterials are the development direction in modern architectural design. In recent years, the development and application of nanocomposite ceramics have been relatively mature. The introduction of nanodispersed phases into the micron-level matrix for compounding can greatly increase the fracture strength and fracture toughness of the material by 2 to 4 times and increase the maximum use temperature by 400°C~600°C; it can also improve the hardness, elastic modulus, creep resistance, and fatigue damage resistance of the material. Nanotechnology's porous ceramic (ceramic microporous material) material may filter and separate industrial waste gas. Porous ceramics provide strong heat resistance and chemical corrosion resistance, as well as being long lasting and low maintenance.

3. Experiment on the Influence of Nanomaterials on Concrete Materials

3.1. Experimental Materials. The main raw materials used in this article are cement, mineral admixtures, and nanocomposite silica. Cement is an ordinary Portland cement used in construction and meets the national safety and health standards. Since its inception, cement concrete has been the most important structural material in construction engineering and has been widely used. For cement-based materials, in order to better compare the effects, mineral powder and fly ash are also used to restrict the concrete by using its compressive strength and elastic modulus. Table 1 shows the performance of the cement used this time.

The performance data of the experimental materials are shown in Table 2. Among them, the average particle size of fly ash is 4.10 μm, the median diameter is 3.08 μm, and its specific surface area is 600 square meters per kilogram;

Table 1: Properties of cement.

Setting time		Stability	Compressive strength (MPa)		Flexural strength (MPa)	
Initial setting	Final coagulation	Qualified	3 d	28 d	3 d	28 d
2 h 30 min	3 h 42 min		22.3	50.1	5.4	8.9

Table 2: Physical properties of mineral blends.

Nature	Fine aggregate	Coarse aggregate
Specific weight (t/m^2)	2.62	2.6
Bulk density (t/m^2)	1.50	1.58
Void ratio (%)	42	38
Water absorption (%)	2.2	0.6
Crushing value (%)	1.2	0.35
Silt content (%)	2.9	1.1
Fineness modulus	2.5	1.3

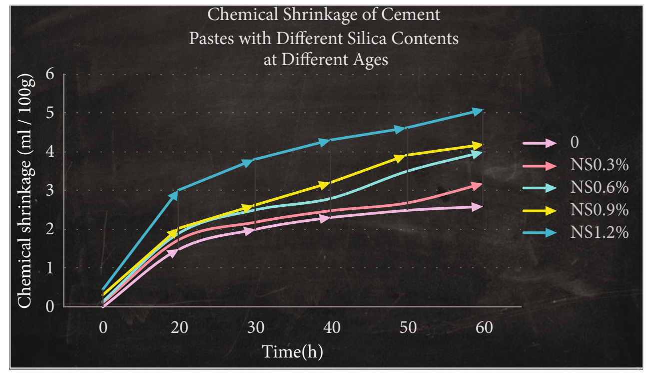

Figure 1: Chemical shrinkage of cement paste with different silica content at various ages.

the average particle size of mineral powder is 12.34 μm, the median diameter is 9.89 μm, and the specific surface area is 360 square meters per kilogram. At the same time, the nanocomposite building material silica was used as the experimental material, and the fumed nanosilica hydrophilic-300 (hydrophilic type) produced by Shanghai Aladdin Biochemical Technology Company was selected. The purity is about 99%. The specific surface area is 300 square meters per gram, and the particle size is in the range of 7-40 nm. Nano-silicon dioxide (English name nano-silicon dioxide) is an inorganic chemical material, commonly known as silica. Because it is ultrafine and nanoscale, with a size range of 1~100 nm, it has many unique properties, such as optical properties against ultraviolet rays, which can improve the aging resistance, strength, and chemical resistance of other materials. Finally, in order to ensure a scientific experimental environment, the admixtures that are often used in the preparation of cement-based materials, including water-reducing agents and expansion agents, are also added. The water-reducing agent used in this test is Wanshan brand naphthalene water-reducing agent, which has a relatively stable chemical structure, with a solid content of 92% or more and a water-reducing rate of 18%-28%. The expansion agent used in this test is UEA-type expansion agent produced by Shandong Yantai Hongxiang Building Materials, with an alkali content of 0.3%, and the recommended dosage is 0.3%-0.5%.

3.2. Experimental Process. First, the density test and the specific surface area test are carried out. The density of mineral blends is measured by liquid displacement method. After high-temperature drying, it is cooled in a dry environment and then wiped clean with filter paper, and 80 g sample is taken out. Put it in a pycnometer, use ultrasonic vibration to completely eliminate air bubbles, and use formula to calculate density. After calculating the mass of the material in the same way, put it into the FBT-9 full-automatic specific surface area tester for repeated calculations.

$$\rho = \frac{p}{v_2 - v_1}, \quad W = \rho V(1 - \varepsilon). \tag{1}$$

Subsequently, add nanocomposite materials and concrete for mixing; first, add water and disperse in ultrasonic for 6 minutes; then, add cement, mineral admixtures, and additives; stir for 2 minutes at different mixing speeds; and place them in the curing room for curing after vibrating. You can get the bulk density and porosity of the sand. As we all know, the comprehensive performance of concrete can be reflected by slump, so the test of concrete slump is also essential. According to the "Standard for Test Methods of Mechanical Properties of Ordinary Concrete" (GB/T50081-2002), the pressure resistance test is carried out. The sample is placed directly under the testing machine until the sample structure is broken, and the average value is obtained after repeated testing. In the process of testing the chemical shrinkage test of cement, test pieces are made with the help of molds. After the test pieces are formed, they are cured in a standard curing room and then, the molds are removed. The shrinkage test pieces are placed in a constant temperature and humidity room for curing, and then put the test piece into it. Read the dial indicator value after the specimen rack.

Finally, the results can be obtained by analyzing various data. The added nanocomposite silica itself also has stronger pozzolanic properties. During the production process, it speeds up the setting time of concrete and increases the toughness of the surface. The induction period of cement hydration exotherm can also be shortened by using nanosilica. In contrast, other mineral blends have not achieved this effect. Although the shrinkage time is accelerated to a certain extent, the compactness and uniformity need to be improved.

3.3. Experimental Significance. Through the above experiments, it can be known that the use of nanocomposite building materials can promote the process of cement hydration, increase the shrinkage of cement-based materials, and promote the hydration reaction of cement at the same time. Cement-based composite materials refer to Portland cement as the matrix and alkali-resistant glass fibers, general-purpose synthetic fibers, various ceramic fibers, high-performance fibers such as carbon and aramid, metal wires, and natural plant fibers and mineral fibers as reinforcements, a composite material formed by adding fillers, chemical additives, and water through a composite process [23, 24]. This shows that the current concrete-based architectural design ideas can be improved, and environmentally friendly, novel solutions can be added to match the nanocomposite materials that meet the quality requirements. As a basic issue of architecture, materials have always been the core of architectural design research. The selection of building materials is not only the use of different construction requirements and material characteristics but also the embodiment of architectural design and cultural skills. The architectural design displayed by different building materials is also very different. Therefore, in modern architectural design, the natural properties of the material and the emotional cognition of the material itself are equally important. Only in this way can we be comfortable in architectural design. Only when the professional skill attributes of architectural design and emotional belonging are integrated it is possible to make progress in the inheritance of traditional culture, science and technology, and concepts in architectural manufacturing. Therefore, the use of new materials, including nanocomposite building materials, is an innovation in life concepts and design concepts, which is particularly important for designers to grasp the relationship between architecture, space, and materials. At the cultural level, the continuous adjustment of architectural design is the development of design ideas and the enrichment of the practical process. The perfect combination of material materials and structural construction, as well as the natural environment, achieves practical, cognitive, and aesthetic social functions.

4. Data Analysis

As shown in Figure 1, the degree of shrinkage of cement is different according to different degrees of nanocomposite materials. With the increase of time, the change gradually increases. The chemical shrinkage without addition is a normal change, and the degrees of shrinkage are, respectively, 0 ml/g, 1.5 ml/g, 2 ml/g, 2.3 ml/g, 2.5 ml/g, and 2.6 ml/g. When the blending amount is 0.3%, the degree of shrinkage is 0.1 ml/g, 1.75 ml/g, 2.2 ml/g, 2.5 ml/g, 2.7 ml/g, and 3.2 ml/g, respectively. It can be seen that with the increase of time, the small amount of addition does not change much at the beginning, but after 50 hours, the gap begins to widen. When the blending amount is 0.6%, the degree of shrinkage is 0.15 ml/g, 1.9 ml/g, 2.5 ml/g, 2.8 ml/g, 3.5 ml/g, and 4.0 ml/g, respectively. When the blending amount is 0.9%, the degree of shrinkage is 0.3 ml/g, 2 ml/g, 2.6 ml/g, 3.2 ml/g, 3.9 ml/g, and 4.2 ml/g, respectively. These two compare at 40 hours. There have been different changes in growth rate. When the blending amount is 1.2%, the degree of shrinkage is 0.45 ml/g, 3 ml/g, 3.8 ml/g, 4.3 ml/g, 4.6 ml/g, and 5.1 ml/g, respectively.

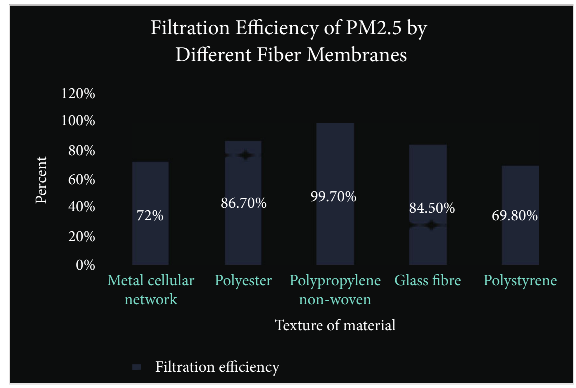

Figure 2: Filtration efficiency of different material fiber membranes for PM2.5.

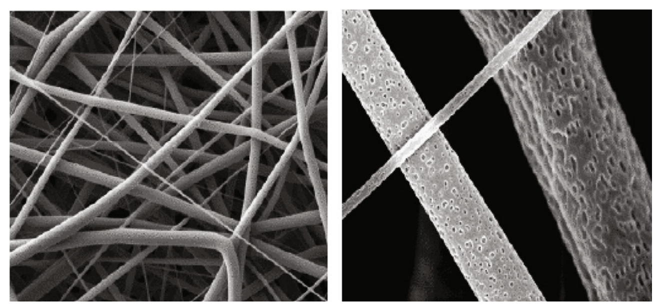

Figure 3: Nanocomposite fiber membrane under an electron microscope.

The use of nanocomposite building materials can prepare excellent fiber membranes, which can effectively purify indoor air while adsorbing harmful components. As shown in Figure 2, the fiber membrane made of metal honeycomb mesh has a filtration efficiency of only 72% for PM2.5. The polypropylene nonwoven fabric made of nanoparticles can intercept 99.7% of particulate matter when filtering PM2.5 and more embodies the environmental protection characteristics of architectural design. The fiber membrane made of polyester fiber material can achieve 86.7% of filtration effect, which is far inferior to nanomaterials. In addition, the use of glass fiber materials can intercept 84.5% of particulate matter, while polystyrene can achieve a filtering effect of 69.8%. The comparison shows that in the future, under the

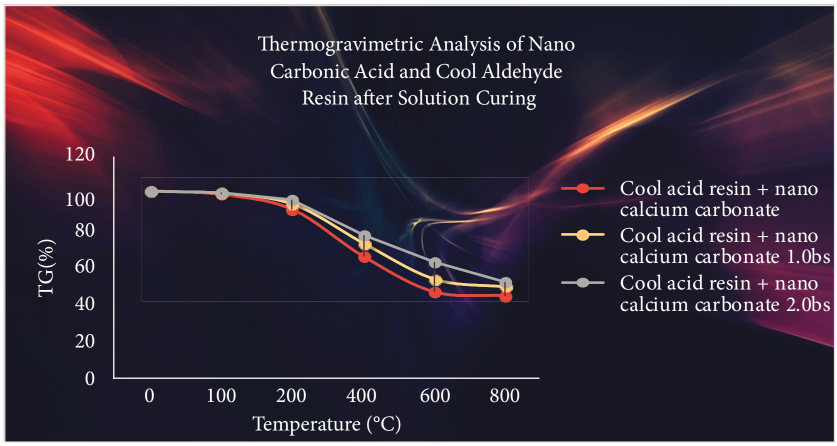

FIGURE 4: Thermogravimetric analysis diagram of nano-carbonic acid and phenolic resin after fusion and curing.

environmental protection and green architectural design concept, nanocomposite building materials will definitely access to a broad market.

As shown in Figure 3, the observation and research using an electron microscope can find that when the sampling speed is controlled to 1.0 ml/h, the particulate filtering polylactic acid material has extremely strong stability. Due to the low boiling point of chloroform, it is volatile and therefore, it will cause holes on the fiber surface. This creates a resultant force with balance properties during use. Under the same conditions of temperature, humidity, and spinning speed, the increase in voltage has a small effect on the diameter, but it will affect the depth of the hole. With the increase in voltage, the more obvious the hole formation, the deeper the hole depth and the hole and the clearer the interface. Under the same temperature, humidity, and voltage conditions, the injection speed has a small effect on the hole size and depth but has a greater effect on the fiber diameter. The fiber diameter increases as the injection speed increases. The high-quality properties of nanocomposite materials can resolve external influences and ensure the stability of the overall structure.

As shown in Figure 4 (figure from http://www.baidu.com/), by exploring the thermogravimetric analysis after the fusion and curing of nano-carbonic acid and phenolic resin, it can be seen that the thermal stability of nanocomposite materials is enhanced when making building materials, and the heat loss is low. On the whole, in the experimental environment, the three curves are in a state of weight loss as the temperature increases. At the starting temperature, the initial weight loss temperature is not much different, all of which are 100%. The first curve changes. It is 98%, 90%, 65%, 46%, and 44%. The second curve has a heat loss mass percentage of 49% at 800 degrees, and the third curve has a heat loss mass percentage of 44% at 800 degrees. In comparison, the slope of the first curve is small, indicating that the thermal reaction rate of the modified sol system becomes smaller, so that it is sufficient to obtain the thermal stability of the nanocarbonate and acid resin system after the modifier is added. There is increased performance and less heat loss.

5. Conclusion

With the continuous growth of the economic level and the improvement of the construction level, people's requirements for buildings are also constantly updated, which affects the development of architectural concepts, architectural design, building materials, and construction. Infrastructure construction is also an important industry for the development of a country's national economy, so the demand is very broad. In the current construction industry in most countries, the consumption of building materials accounts for more than half of the total consumption. 52% of the huge demand and consumption is concentrated in steel and cement. Therefore, the improvement of building materials will not only change the style of building design; it will promote the safety, applicability, and durability of engineering buildings. As an important branch of ecological environmental materials, according to its meaning, ecological building materials should refer to the coordination with the ecological environment in the process of material production, use, disposal, and recycling, to meet the minimum resource and energy consumption, minimum or no environmental pollution, and the best use performance; the highest recycling rate requires the design and production of building materials [25, 26].

Inferred from the current development speed, the problem of building energy consumption has gradually become an urgent problem that needs to be solved. It will not only cause a certain degree of waste but also cause considerable pollution to the environment. Therefore, under the influence of various conditions, new building materials occupy an increasingly important position. Many countries in the world have listed nanotechnology as an important national basic project. Although nanotechnology has not yet been widely applied to the market, a large amount of basic research has been completed at the technical and theoretical level, and some cutting-edge technologies have gradually been applied to cutting-edge fields. However, there are still some technical problems that have not been well perfected, such as how to control the structure and performance of nanomaterials. The cost of nanocomposite building materials in modified concrete and architectural coatings is very high, and it will take time to fully apply. As a new discipline, nanotechnology will inevitably affect all areas of society, and it will inevitably have an inestimable effect on the performance improvement and use of traditional building materials. Nanocomposite building materials conform to the development trend of economy, environmental protection, green, and energy saving and have become the top priority of current architectural design considerations in the future and represent the future development prospects of the construction industry. At present, the nanocomposite building material system that has been timed is complete and diverse, and its share in the market continues to expand. With the promotion of China's sustainable development strategy and the development of the construction field, new building materials will surely have their unique advantages in the construction industry, shine brilliantly, and promote human development and progress.

Architecture, as a special expression of culture and history, integrates the national and ethnic styles and the customs of various regions in the early design stage. In the architectural design process, we must fully consider the cultural connotation and the future direction of architectural manufacturing. The performance of architecture should reflect the humanistic spirit of different times. Material is the material carrier of the building and through it reflects the spiritual temperament that the building should have. With the development and development of new technologies, architectural design has made great breakthroughs in the way of expression, giving designers more imagination. On this basis, the current materials should be used optimally, their shortcomings should be reasonably compensated, strengths should be used to avoid weaknesses, and the synchronization of the times should be emphasized.

Data Availability

No data were used to support this study.

Conflicts of Interest

There is no potential conflict of interest in this study.

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