

Study on the Application and Properties of Plastic Materials in Modern Architecture

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Abstract. The properties and applications of plastics and related technologies are developing at a high speed at home and abroad. Its properties have a wide range of functions, including but not limited to high strength, high toughness, high durability, flame retardant, airtight, chemical inertness, etc., and the development of plastics still occupies an important position in scientific research and application. The purpose of this paper is to analyze the application of plastic materials in the field of construction in recent years and the properties of plastic itself or mixed with other materials. It is concluded that some plastic materials, such as Expanded polystyrene (EPS), have excellent performance in building fire insulation sandwiches. Some plastics have excellent performance when applied to the waterproof part of the building, such as polyvinyl chloride(PVC), thermoplastic polyolefin(TPO), and so on. Compared with traditional building materials, some properties of plastic materials are superior, and they often have the advantages of low cost, low energy consumption, low pollution and easy recycling. Not only that, plastic materials have a very large development potential and are expected to occupy a more important part of future construction and other fields.

Keywords: Plastic material, mixed plastic material, market of plastic doors and windows.

1. Introduction

Plastic, due to its shape and appearance, as physical and chemical properties have high development potential and excellent plasticity, has become one of the mainstream materials in modern materials. In addition, plastics are firmly occupying an important position in the field of construction and are widely used [1], becoming one of the largest production and consumption of artificial creations. Among them, the production of PVC plastic alone will reach 21.97 million tons in 2023 [2]. Compared with traditional building materials such as concrete and metal, wood, plastics tend to have lower density, more diverse chemical properties, greater compatibility with other materials, and better plasticity, while having good strength.

Plastics are currently the most widely used in architectural interiors and partitions as well as surface packaging. Due to the superior performance of a variety of high-performance plastic materials made of a variety of materials in mechanics, thermal, acoustic and chemical properties, these high-performance plastics also play an important role in building, common fire, waterproof, heat preservation, heat insulation, sound insulation, erosion prevention and other functions [3,4]. In addition, in the industrial production process, plastic materials compared with traditional building materials, the production process is simpler, the production energy consumption is lower, and it is easier to recycle, and has a better ecological advantage. Since the middle of the last century, domestic buildings have begun to use plastic materials, this phenomenon has become more and more common with the passage of time, and the plastic materials used in construction are constantly derived from more and more different colors, forms, and appear in various corners of the building, but also gradually assume more and more functions. Until today, plastic molecular materials in buildings are not only functional and decorative material, but even some plastic materials have become part of the main body of the building infrastructure.

This paper mainly studies the application of plastic materials in buildings in recent years through the form of data analysis, and through the performance analysis of EPS, phenolic foam and PVC, respectively, the performance of fire insulation and water resistance and erosion resistance of plastics

are studied. Finally, according to the performance advantages of plastics, suggestions and prospects for the future development of plastic applications are put forward.

2. Analysis of common use of plastic materials in recent years.

Table1. Market data of plastic doors and windows in recent 25 years

age	2000	2005	2010	2015	2020	2024
percentage	≤3%	<30%	≤45%	≤50%	25%	35%~45%

Plastic materials often have the properties of lightweight, high strength, corrosion resistance, strong plasticity and high durability, so since the development of plastic materials, they are often used as exposed non-load-bearing parts in buildings, such as doors and Windows, pipes, walls and so on. Germany, as the first country to use plastic doors and Windows, so far its use rate has exceeded the sum of metal doors and Windows and wood doors and Windows, occupying more than half of the door and window market, Britain, France and other countries have also reached more than 30% of the use rate.

Table 1 shows the proportion of plastic doors and Windows in the Chinese doors and Windows market in the past 25 years. Since 2000, due to the low cost and superior performance of plastic, China has implemented policies to encourage the application of plastic doors and Windows instead of traditional paper-wood doors and Windows. In 2005, plastic exceeded the standard to meet the requirement that the share of plastic doors and Windows in the country should reach 25%, and the development of plastic doors and Windows is still in a rapid development trend [5].

However, due to the problems of technology and quality as well as market competition, and due to the appearance of aluminum alloy doors and Windows and the erosion of time, the utilization rate of plastic doors and Windows in China has shown a cliff-like decline. However, with the continuous progress of technology, plastic doors and Windows have further developed and made breakthroughs in air tightness, durability, style, etc. Nowadays, plastic doors and Windows also occupy about 40% of the market in China, and the data still has the potential to rise [6]. Pipes made of plastic materials are often resistant to rust, have a long life, lightweight, high strength and smooth inner walls, and are easy to transport and disassemble. At present, many high poly plastic materials such as crosslinked polyethylene, random polypropylene and so on are made into plastic pipes into the market, as of 2024, most of the domestic construction pipeline use areas (such as building drainage pipes, urban drainage pipes, construction wire protection sleeve, etc.) in the plastic use has accounted for more than 80%. At the same time, raw materials such as PVC and PE also account for more than 80% of the cost of plastic pipes, which still has the potential for technological breakthroughs in materials.

Due to the good thermal insulation properties, electrical properties, corrosion resistance and specific strength of plastic materials, the large proportion of plastic materials used in construction also includes wall veneer, ceiling, non-load-bearing partitions and other large plates, and the building wall veneer and roofing material plate made of plastic have the characteristics of beautiful and easy to disassemble and assemble. However, due to the main tone of concrete buildings, the use of surface-covered plastic panels at home and abroad is not prominent, mostly used in office buildings, shopping malls and other public places as decorative panels instead of the wallpaper and floor use, and due to the development of plastic materials in its properties, as well as the development of ecology and the needs of all parties to use, the use of plastic materials still has great potential for development.

3. Fireproof and heat-insulating composite plastic material

Table 2. Heat-resistant and short-term temperatures of common and flame-retardant EPS materials [7]

material	EPS	Flame retardant EPS
Melting temperature	100°C	100°C
Ignition temperature	350°C	370°C
Autoignition temperature	450°C	500°C

Fireproof and insulating materials have been the focus of human research since ancient times. The early fireproof and heat-insulating materials include tung oil, brick chips, asbestos, etc., and in recent years, until modern times, plastic polymer materials such as phenolic resin, polystyrene foam, and polyurethane foam are used as fireproof and heat-insulating materials. Human beings all over the world are constantly exploring, developing and innovating in fireproof and thermal insulation materials, and various materials have been updated and evolved from generation to generation, until today, fireproof and thermal insulation materials have been dominated by a variety of composite plastic materials. EPS sheet has good thermal insulation properties and good thermal insulation. After adding 1% flame retardant to ordinary polystyrene board, the temperature range of its normal use is slightly expanded, and it has a high melting point and a short upper limit temperature of non-ignition and non-spontaneous combustion after a large amount of heat accumulation. The flame retardant ingredient is not easy to dissolve in water after being added to the EPS board, and the service life is long, and the effective time of the flame retardant can reach 20 years under normal circumstances. When the flame retardant fails, the heat protection of the EPS board decreases slightly.

It can be seen from Table 2 that in the normal indoor use of electrical appliances, the heat source is far away from the wall when the gas stove is used, and the temperature of the wall is small, generally not higher than 100 °C, only the ordinary EPS board can meet the daily requirements, and the temperature caused by electric sparks and cigarette butts is not enough to ignite the EPS board. When a fire occurs in the room, the indoor temperature quickly reaches above 500°C, causing the EPS board to burn, producing carbon dioxide and water vapor, and consuming a large amount of oxygen. According to studies, when the temperature of the heat source near the EPS plate is reduced to a certain temperature, the EPS plate can quickly stop burning [7]. At the same time, the density of the EPS board itself is very low, even if its combustion heat reaches twice that of ordinary wood, its combustion load is extremely low, and other insulating materials are basically the same, which also leads to the toxic flue gas produced when the EPS board is burned in the air. The proportion is very low, mainly carbon monoxide, carbon dioxide, and water vapor, and does not produce chlorine and cyanide and other substances, which is relatively safe.

The same is true of phenolic foam, which has relatively high heat resistance and can still be used normally at 140°C while being non-flammable when exposed to open flames. In contrast, the EPS board will shrink inward after being exposed to high temperatures, away from the heat source, reducing heat absorption, while phenolic foam will not shrink after being heated, and has relatively better structural and morphological properties, and phenolic foam also does not produce toxic gases when burned, compared with EPS boards, phenolic foam has a lower smoke output when burning, and when 5% CR-741 is added as a flame retardant, its smoke production is only 4 grams per second, and the average smoke release rate is 24.58 liters per second [8]. In daily thermal insulation, phenolic foam also has a lower thermal conductivity than EPS board and has better thermal insulation performance.

4. Waterproof and anti-erosion plastic material

In addition to the fireproof and thermal insulation performance, because the plastic material often has a tight structure and good sealing, it has a certain elasticity and flexibility, so that the plastic has

good tension, and it is not easy to break or change its microporous structure to a large extent. Therefore, from a physical point of view, plastic materials have excellent waterproof properties. Moreover, plastic materials are often chemically inert, do not easily react with other substances in the water environment or air, and have good anti-erosion ability. At present, there are many common waterproof and anti-erosion plastic materials on the market, including polyethylene (PE), polyvinyl chloride (PVC), thermoplastic polyolefin (TPO), high-density polyethylene (HDPE), etc. Depending on the characteristics of different plastics, they are often made into waterproof plastic films, plastic splints, accessories, membranes, and coatings [9,10].

PVC material is the most common in life, and China is also a major producer and user of PVC. As a polymer, PVC has the characteristics of high density and low porosity structure, its molecular structure is compact, the surface is smooth, and it will hardly be infiltrated by water in and out under low pressure, effectively blocking the stay and penetration of water. At the same time, PVC has strong toughness and plasticity and is easy to press and draw into components such as film plates, which is easy to transport and place, which greatly reduces the difficulty of disassembly, assembly and use in the building structure, and reduces the cost of construction technology and labor. PVC plastic materials do not easily react with water and other common substances in water, and when the concentration is in the low range, PVC almost does not react with sulfuric acid, and the weathering rate is relatively slow, the weather resistance is strong, and the ultraviolet blocking ability is strong, which is basically competent for rainwater corrosion, weathering corrosion, frosting, and sunlight in actual use [11,12]. However, when the amount of residual acid in PVC evaporation accumulates and exists for a long time, the degradation rate of PVC molecular chain will be accelerated, resulting in brittleness of the material, cracks and other problems, and the loss of superior waterproof performance, so it needs to be replaced, and the PVC after redox reaction under the influence of acid is difficult to be restored or recycled due to the irreversibility of the chemical reaction.

PVC materials are non-volatile, the process is relatively simple and clean, and the energy consumption reaches 7000 kWh per ton, which is relatively low compared with traditional building materials (concrete, steel, etc.) in terms of energy demand, and although the by-products are toxic, because PVC is stable enough and the general rate of by-product generation itself is not large, and the by-product HCl is easy to handle, the by-product removal process is simple and mature [13]. However, as PVC materials are difficult to degrade naturally, measures such as recycling are needed to reduce the long-term impact on the environment.

5. Prospects and suggestions

Due to its high ability to cooperate with other material additives, plastic materials have been well developed and applied in many fields. The addition of reinforcing agents and tougheners to plastics has greatly increased strength, and although it cannot be compared with steel at present, its extremely light weight advantage makes it far more advantageous than steel and alloys when used with lower counterweights and higher flexibility requirements. Plastic materials are highly plastic, simple to process, low cost, wide range of applications, civilian can be made into floors, wall skin, film, plastic floors, ceilings, etc., the military can be made into various coatings, polymer materials, firearms, etc. Due to the stability of the microstructure of plastic materials, and the current 3D printing technology is mature, the module production is flexible, and the structural design is convenient so that its construction cost is low and the pollution index is low.

6. Conclusion

This paper mainly studies the application of plastic materials in the construction field in recent years and the properties of plastics themselves or when mixed with other materials, and makes suggestions and predictions on their possible future development directions based on the performance potential of plastics. Since the last century, it has gradually begun to be used in all aspects of

construction at home and abroad and in various fields outside the building, and with the continuous development of molecular materials science, the performance and application of plastic materials for construction have been continuously upgraded and updated. According to analysis and speculation, plastic materials will not only make further breakthroughs in the shape design and basic properties such as fire and waterproofing in the future, but also plastic buildings will also get a good development.

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