FRP Application and Structural Engineering Innovation of High Performance Materials Based on Mechanical Analysis

Zhouxiaofan
Jinan University, Guangzhou, Guangdong, China, 510000

Abstract. FRP (Fiber Reinforced Composite) has been widely used in the reinforcement of concrete structures in recent years. FRP composites, as high strength, lightweight and high performance reinforcement materials, have been widely used not only in China, but also in foreign countries and in water and soil engineering. China has made a series of achievements in the development of high-performance FRP materials and their products suitable for civil engineering applications, and in the application of FRP key technologies in civil engineering. In the development of concrete structures in the new century, new requirements and challenges have been put forward for materials. Because FRP is a frontal composite material composed of many kinds of materials, its common advantages are light weight, high strength and elastic modulus, fatigue resistance, long service time, good corrosion resistance and low thermal expansion coefficient, etc. FRP is a new type of high performance material, which is of great significance to the sustainable development of civil engineering industry in our country. This paper introduces the properties and forms of FRP materials commonly used in structural engineering, puts forward the rational application of FRP and its structure, and analyses its advantages and disadvantages in order to promote the application and research of this new type of high performance material in civil engineering in China.

1. Introduction
High performance fiber reinforced composites (FRP) have been widely used in many fields due to their light weight, high strength, corrosion resistance and designability [1]. Because of its superior mechanical and physical properties, it has been widely used in strengthening components and structures, especially in post-earthquake structural repair, although the cost is relatively high in the early stage, but in the later stage of maintenance, the cost is low, so the economic benefits are obvious[2]. FRP composite materials have good corrosion resistance and durability, so when they are used in the structural reinforcement of concrete, the service life of concrete structures can be improved, especially in the corrosive environment, which can better reflect its advantages[3]. In the future, on the one hand, we will continue to study the performance of FRP in depth, accelerate the localization process of FRP materials, strive to develop the application potential of FRP, expand its application scope, and promote engineering innovation [4].

Composite materials are composed of reinforcing materials and matrix. According to the shape of reinforcing materials in composite materials, they can be divided into granular composite materials, laminated composite materials and fiber reinforced composite materials [5]. FRP is only one of the composite materials. In the past, concrete structure and steel structure were common in engineering structures, followed by masonry structure and glass structure, especially urban and rural construction. The existing research and engineering application at home and abroad show that FRP products are a new excellent material and way to strengthen and improve concrete structure, masonry structure and steel
and wood structure [6]. Its most remarkable characteristics are: strong corrosion resistance, that is, good durability; high tensile strength of materials, and low self-weight; strong elastic deformation and fatigue resistance [7].

2. Properties of Fiber Reinforced Composites

2.1 Basic Characteristics of Fiber Reinforced Composites

Fiber composites have the characteristics of designability, high specific strength and stiffness, anti-fatigue, anti-chemical reaction and good anti-corrosion and anti-seismic [8]. The performance of FRP material is quite different from that of traditional structural material. Only by understanding and mastering the advantages and disadvantages of FRP material, can we give full play to its advantages and avoid its shortcomings in the application of Engineering structure. In aseismic structures, the application of FRP materials can reduce the self-weight of structures and reduce the seismic action. FRP composite material has the advantages of high strength, high elastic modulus, light weight, thin thickness and corrosion resistance. Its material can adapt to arbitrary surface and shape structure, and its length and cross-section are not constrained. In addition, the application of FRP materials can also improve the structure's fatigue resistance and fatigue performance. The research and application of FRP is very hot in our country, and it is developing vigorously everywhere. Therefore, we should realize clearly that FRP, as a non-metallic material mainly under tension, can not replace steel, but is a very important supplement [9]. FRP structure refers to the structure formed by various basic force-bearing components made of FRP, while FRP composite structure refers to the structural form that FRP and traditional structural materials, mainly concrete and steel, work together to bear load through the combination of force-bearing forms.

Compared with concrete, ordinary FRP materials have poor fire resistance, but flame retardant can be added into FRP resin materials to improve its fire resistance. At present, the surface of CFRP compounded with epoxy resin mixed with flame retardant is treated with fire prevention, and its effect is comparable to that of concrete structure. Initial defects and working environment have significant effects on the fatigue resistance of FRP materials. In terms of material price, FRP structure and FRP composite structure are not competitive compared with reinforced concrete structure. However, due to the light weight and the low maintenance cost caused by corrosion resistance of FRP materials, the comprehensive economic benefits of FRP materials are worthy of attention. FRP includes glass fiber (GFRP), aramid fiber (AFRP) and carbon fiber (CFRP). Different fiber materials are compounded with specific resin materials through a certain manufacturing process to form corresponding fiber reinforced composite materials [10]. It has good durability. High ratio of quality to strength; Strong fatigue ability; High resistance and low magnetic induction. However, they also have disadvantages, that is, high cost and small fracture strain. The mechanical properties of these high-performance fiber materials and their comparison with steel are shown in Table 1.

| Material types                  | A steel bar | Steel Strand | GFRP Tendon | GFRP Cable | CFRP Cable | AFRP Cable |
|--------------------------------|-------------|--------------|-------------|------------|------------|------------|
| tensile strength               | 500-700     | 1400-1900    | 530-1150    | 1400-1800  | 1720-2520  | 1210-2090  |
| Yield strength                 | 280-430     | 1000-1400    | -           | -          | -          | -          |
| Tensile modulus of elasticity  | 210         | 180-210      | 40-55       | 40-55      | 153-170    | 50-152     |
| Ultimate elongation            | >0.1000     | >0.040       | 0.030-0.050 | 0.025-0.040| 0.010-0.015| 0.020-0.025|
| Coefficient of thermal expansion| 11.6        | 11.6         | 9.9         | 9.9        | 0.0        | -          |
| density                        | 7.85        | 7.85         | 1.30-1.90   | 2.50       | 1.50-1.60  | 1.30       |
2.2 Selection of FRP Composites

According to different natural environments, FRP composites are also selected differently. With the popularization and development of this technology in various parts of the world, the superior properties of FRP materials, such as light weight, high strength, corrosion resistance and good construction performance, have been gradually recognized by the engineering community, and have begun to be applied in various forms in various civil and building structural projects. A large number of test results show that the mechanical properties, durability and usability of hybrid fibers are better than those of single fiber composite materials. The performance meets the requirements of civil engineering, and the cost is greatly reduced. In order to make full use of the properties of F, suspension bridges, full F bridges, FRP industrial platforms and other new structures can be designed and manufactured, and buildings can be quickly constructed by FRP assembly structural components. Adding thick resin adhesive layer outside FRP composite material can provide better elastic protective layer, and coating a layer of high strength cement mortar on the outside of FRP composite material can also protect FRP composite material.

The material properties of FRP are quite different from those of traditional structural materials such as steel and concrete, and the products of FRP are also various. The mechanical properties of FRP depend strongly on the preparation process, so the preparation process must be considered in the design of FRP structure. The product forms obtained by different preparation processes are also quite different. The mechanical properties of FRP depend strongly on the preparation process, so the preparation process must be considered in the design of FRP structure. The product forms obtained by different preparation processes are also quite different. Concrete structure has many advantages. However, with the passage of time, its corrosion and deterioration problems continue to occur, of which steel corrosion is the most common. Great progress has also been made in the research of replacing traditional building materials with fiber reinforced composites in structures under special environmental conditions. In the construction of social security system, the application of fiber-reinforced composite materials in the improvement and progress of geological disaster prevention technology is worthy of attention and concern. At present, reinforcement technology has been greatly developed in China. FRP reinforcement has been widely used in strengthening components and structures due to its superior mechanical and physical properties. Especially when the reinforced structures are subjected to large earthquakes, the existing finite element method based on stiffness method can not accurately obtain the structural response under strong non-linear action. At the same time, there is a problem of excessive computational load when the finite element method is used to simulate large-scale structures. Although FRP materials have long been used to reinforce reinforced concrete structures in practical projects, the theoretical analysis of FRP reinforcement has only begun to develop to the structural level in recent years.

3. FRP Material in Structural Engineering

3.1 Modification of FRP Material

In recent years, with the continuous development of FRP research and application, more and more domestic enterprises can produce GFRP and CFRP bars. The application of FRP materials has promoted the development, production and application of FRP composites for infrastructure engineering in China. As a result, the number of applications of fiber reinforced composites in engineering has increased rapidly, and a new economic growth point has been formed. Fiber reinforced composites used in structural engineering mainly include concrete, intelligent, fiber polymer reinforcement and so on. The application of concrete fiber composite materials, through the improvement of its waterproof performance, mechanical performance, corrosion resistance, etc., makes it suitable for application in physical construction engineering. At the same time, it also has the capability of absorbing vibration waves, has good shock resistance, and is more suitable for application in various construction projects. In order to make full use of the performance of F, it is possible to design and manufacture new structures such as suspension structures, suspension bridges, all-F, FRP industrial platforms, etc. It is also possible to quickly build buildings through FRP assembly structural members. Fiber polymer reinforcement, due
to its unique properties, can be used as a proxy for reinforcement and applied to new and prestressed concrete structures. Intelligent use of its more performance, so that it can be put into the detection of building temperature and the detection of power conditions, and eventually provide electricity to the building.

FRP materials have long been used in aviation industry and national defense construction, and also in sports. Because of its high quality-strength ratio and chemical stability. Among them, CFRP has more application prospects than other materials in engineering structures because of its good and stable performance, and its raw materials can be obtained almost unlimited. And its random short fibers added to concrete can greatly improve the crack resistance, ductility and bearing capacity of concrete. The fabricated cloth or sheet can not only greatly improve the flexural, shear or torsional and compressive bearing capacity, but also reduce the crack width, and even improve the ductility and seismic performance of the outer column. First of all, it should be recognized that any material, not omnipotent, has its appropriate application range and occasion, which is different from traditional structural materials. FRP products are usually anisotropic. The strength and elastic modulus along the fiber direction are higher, while the strength and elastic modulus along the vertical fiber direction are very low. CFRP cloth or CFRP cable are suitable for engineering applications in common FRP materials. At present, CFRP sheets are the most suitable way to reinforce concrete structures. With the development of society, more and more materials have been applied in civil engineering construction, which can effectively improve the performance of buildings in all aspects, better resist the influence of external factors, and make buildings more solid and reliable. Therefore, further research is needed.

3.2 Application and Research of FRP

At present, the main application field of FRP material in our country is engineering structure reinforcement. With the deepening of research, various application technology level has been improved, key equipment and key technology development has made continuous progress. In the future, on the one hand, we should continue to study the performance of FRP deeply, accelerate the localization process of FRP material, and strive to develop FRP products application potential, expanding its application scope, promoting structural engineering innovation. On the other hand, with the development of FRP application in civil engineering, it will also promote the innovation and progress of structural engineering science and technology. Applying the developed FRP products and key technologies to engineering to form productivity and create economic benefits is the main purpose and development direction of applying FRP materials and products to structural engineering construction. FRP-aluminium alloy composite structure is another new type of structure worthy of attention. It has two characteristics of lightweight materials. At the same time, FRP greatly enhances the stiffness and load-bearing capacity of aluminium alloy components. FRP materials used in civil engineering have developed from the earliest single type of glass fiber to carbon fiber, aramid fiber, basalt fiber, and further to hybrid fiber. With the increase of fiber types, the performance is gradually improved, which provides a material basis for the application of FRP materials in civil engineering. In the construction of social security system, the application of fiber-reinforced composite materials in the improvement and progress of geological disaster prevention technology is worthy of attention and concern. With the deepening and development of FRP application research in structural engineering, it will also strongly promote the innovation and progress of structural engineering science and technology. In the next few
years, China will have a rapid development in the research and application of FRP materials, thus improving the innovation level of structural engineering in China.

In the middle of last century, in order to solve the problem of salt corrosion damage to reinforced concrete structures in offshore areas and cold climate areas, an American company produced a CFRP reinforcement for concrete structures. This is the beginning of the research and application of CFRP. The research and application of FRP in the United States and Japan is the earliest in the world. The research and preparation of CFRP materials used in civil engineering in China started earlier but developed slowly due to various reasons. However, in the past ten years, the research and application of FRP in China have developed rapidly. In recent years, with the continuous development of FRP research and application, more and more domestic enterprises can produce GFRP and CFRP tendons. At present, the research and application of FRP in China is still in the leading position. For the application of FRP, in order to make full use of the properties of FRP materials, new structures such as suspension structures, suspension bridges, full-F bridges and FRP industrial platforms can be designed and manufactured, and buildings can be quickly constructed by FRP assembly structural components. From the point of view of F as material, the composite structure of composite material and concrete can be made by replacing steel bar with F as reinforcing bar, so as to improve the durability of the structure. Of course, in order to use FRP materials and products more reasonably, there is still a lot of work to be done.

4. Conclusion
This paper introduces the characteristics of FRP, a new high-performance structural material, and its innovative research in structural engineering. It is hoped that through this article, engineers will have more knowledge of FRP materials, and in the next few years our country will have rapid development in the research and application of FRP materials, thus improving the level of civil and building structures in our country. FRP materials have a very broad application prospect in structural engineering, but there is still a lot of research work to be done on the basic theory and design methods of FRP structures and FRP composite structures. Through the performance of FRP composites and its application in strengthening concrete structures, it can be seen that FEP composites have obvious advantages and good economic benefits, and will have a broader space in the future development. FRP material is a new material. FRP structure and FRP composite structure are bound to be more widely used in structural engineering in the future.

References
[1] Ferrier E, Agbossou A, Michel L. Mechanical behaviour of ultra-high-performance fibrous-concrete wood panels reinforced by FRP bars[J]. Composites Part B: Engineering, 2014, 60:663-672.
[2] Zhao Y, Kun W. Experimental Analysis of Tensile Mechanical Properties of Sprayed FRP[J]. Advances in Materials Science and Engineering, 2016, 2016:1-12.
[3] Borgmeier E. Fibre reinforced plastic (FRP) an innovative approach to further development of rock bolt technology and the development of new outlets in tunnel and structural engineering[J]. Mining Report, 2015, 150(4):200-207.
[4] Gu C P, Ye G, Sun W. Ultrahigh performance concrete-properties, applications and perspectives[J]. Science China Technological Sciences, 2015, 58(4):587-599.
[5] Competitive manufacturing of 3D thermoplastic composite panels based on multi-layered woven structures for lightweight engineering[J]. Composite Structures, 2015, 133:415-424.
[6] Rodriguez, A, Campos P L, Garabito J, et al. Manufacture of High-Performance Concrete Made with Powdered Polyester Resin Waste and Carboxylic-Ester Based Superplasticizer[J]. Advanced Materials Research, 2015, 1129:523-529.
[7] Wang X, Wang Z, Wu Z, et al. Shear behavior of basalt fiber reinforced polymer (FRP) and hybrid FRP rods as shear resistance members[J]. Construction and Building Materials, 2014, 73:781-789.
[8] Müller, Harald S, Haist M, Vogel M. Assessment of the sustainability potential of concrete and concrete structures considering their environmental impact, performance and lifetime[J]. Construction and Building Materials, 2014, 67:321-337

[9] Cladera A, Weber B, Leinenbach C, et al. Iron-based shape memory alloys for civil engineering structures: An overview[J]. Construction and Building Materials, 2014, 63:281-293.

[10] Liu, Yi S. The Design and Application of the Mechanical Parts Based on the TRIZ Theory[J]. Applied Mechanics and Materials, 2014, 556-562:1241-1244.