*Proceedings of the 2022 International Conference on Smart Manufacturing and Material Processing (SMMP2022), A. Nayyar (Ed.)*


*doi:10.3233/ATDE220820*

# Long-Fiber Reinforce Thermoplastic Building Template

Bo WANG[1], Yanyang LI and Baojun CAO
*Beijing Municipal Road and Bridge Co., Ltd. Beijing, China*

**Abstract.** With the improvement of social and economic level, green construction and sustainable development have become the main development directions of the construction industry, and the disadvantages and limitations of traditional wooden template and steel template have gradually been exposed, which cannot meet the development of the construction industry in the new era. The development of new materials and new structural forms of formwork has become a problem that has attracted much attention in the template industry. EANTE's new composite material template adopts the self-developed LFT-D long fiber reinforced thermoplastic composite material molding technology, which stirs and mixes continuous glass fiber and modified PP (polypropylene). The combination of matrix plastic and glass fiber is well realized. Just like the relationship between concrete and steel bars, all aspects of the plastic matrix are enhanced by long fibers. In this paper, through the analysis of the mechanical properties of the EANTE template, it is proved that the template can be used in practical engineering.

**Keywords.** Construction Industry, Template, EANTE, Glass fiber, Plastic.

## 1. Introduction

As an important construction procedure of cast-in-place reinforced concrete, template engineering plays a decisive role in ensuring the construction progress and controlling the construction quality of reinforced concrete structures, and is also one of the important considerations for project cost control [1]. Therefore, the increase in the strength of the formwork and its recyclability are particularly important [2]. Effective measures must be taken to control the project cost and coordinate the relationship between good benefit and quality [3]. The demand for wood is expanding with the development of the construction industry, forest resources are decreasing day by day, and people's awareness of environmental protection is gradually improving, replacing wood with plastic has become a trend in the development of the construction industry [4-6]. This material is environmentally friendly, economical, waterproof and anti-corrosion. It is favored by people. It is worth mentioning that it can effectively replace the existing wood formwork, saving more wood for the country, so as to achieve energy saving and environmental

[1] Corresponding Author: Bo Wang, 2551082197@qq.com.

protection. The purpose of beautifying the environment and reducing carbon emissions is in line with my country's energy conservation and emission reduction policies. It can be said that the emergence of plastic formwork is a new innovation in construction projects [7].

Plastic formwork is an emerging building material, the main materials are polyvinyl chloride (PVC), polycarbonate (PC) and polypropylene (PP) [8]. Among them, PC formwork has good bending performance and high temperature resistance, but due to its high production cost, it limits the extensive use of PC formwork, and the overall cost performance is low; Although the price of PVC formwork raw materials is relatively low compared to PC formwork, the bending Poor performance and temperature resistance, narrow operating temperature range, not suitable for large building construction sites; PP, as a high-performance general-purpose plastic, occupies a large proportion in waste plastic recycling [9]. Therefore, it has a high recycling value, and has the advantages of light weight, easy to demould, low cost of raw materials, recyclability, smooth surface, and uniform thickness [10, 11]. It can save energy consumption, reduce costs and reduce environmental pollution in construction projects. However, the traditional PP formwork is limited in construction engineering due to its low toughness and large coefficient of thermal expansion and contraction [12].

Long glass fiber reinforced thermoplastics-direct (LFT-D) is a process technology for on-line direct production of long glass fiber reinforced thermoplastic composite materials. It is a recyclable and environmentally friendly lightweight composite material in the field of fiber reinforced polymers [13-15]. EANTE's new composite material template adopts LFT-D composite material molding technology, using continuous glass fiber and modified PP as raw materials, and stirring and mixing through a special process. The length of glass fiber in the mixture is ≥15mm, which can better realize the matrix. Combination of plastic and glass fiber. It is a kind of plastic building formwork with excellent properties such as high strength, low cost and easy recycling.

## 2. Experimental Method

The resin is dosed according to the template weight from the vacuum feeding system to the vector weighing system, heated and melted in the first twin-screw extruder, and then mixed with glass fibers for mixing and plasticizing. The roving glass fiber passes through the creel and is cut into filaments by the glass fiber cutting device, and then the glass fiber with a length of 24-25mm is added to the resin melt, and the secondary length change is carried out by the shearing action of the resin melt; After the two twin-screw extruders are uniformly plasticized, the raw materials are cut by the cutter according to the weight of the template, and then transferred to the displacement position of the reclaiming material under heat preservation. The raw material is taken out and put into a press mold for upper molding. The process flow chart is shown in Fig. 1 and the model is shown in Fig. 2.

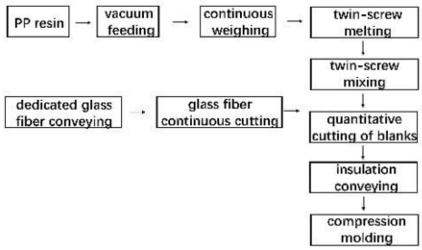


**Fig. 1.** Process flow diagram.

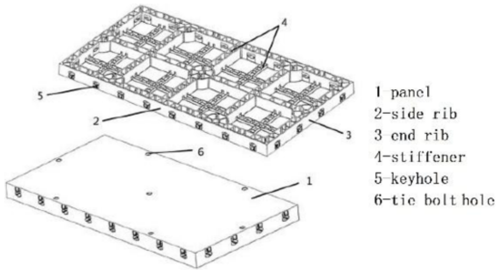


**Fig. 2.** Building template.

The template has been applied in a construction project in Nanjing and achieved good results.

## 3. Mechanical Properties of Templates

### *3.1. Stiffness Test*

A total of three sets of templates bending stiffness tests were carried out. The specific dimensions of the template are shown in Table 1.

**Table 1.** Size of the template

| Specimen number | A | B |
|---|---|---|
| Length(mm) | 1200 | 1200 |
| Width(mm) | 600 | 600 |
| Main Rib - Lateral(mm) | 3 | 3.5 |
| Main Rib (mm) Longitudinal(mm) | 3 | 4 |
| Side rib - Inner frame(mm) | 2.5 | 4.5 |
| Side Rib - Outer Frame(mm) | 4 | 4 |
| panel(mm) | 7 | 7 |
| node(mm) | 117 | 117 |
| secondary rib(mm) | 2 | 2 |
| weight(kg) | 10.5 | 11.5 |

As the load increases, the bending moment and maximum deflection of A and B are shown in Fig. 3.

It can be seen that as the load increases, both the bending moment and the maximum deflection increase. The curvature φ of each position is obtained according to the fitted curve, and the overall stiffness I of the plastic template is obtained according to the curvature φ.

But considering the actual situation of the template, when the strain is about 2000με, the bending moments of specimens 1, 2, and 3 are 0.786kN•m, 0.34kN•m, 0.63kN•m, respectively, and the corresponding moments of inertia I are 3.24E+ 06 mm2, 3.46E+06 mm2, 2.89E+06 mm2. The moment of inertia of the 600*1200 series specimen is taken as 3.19E+06 mm2.

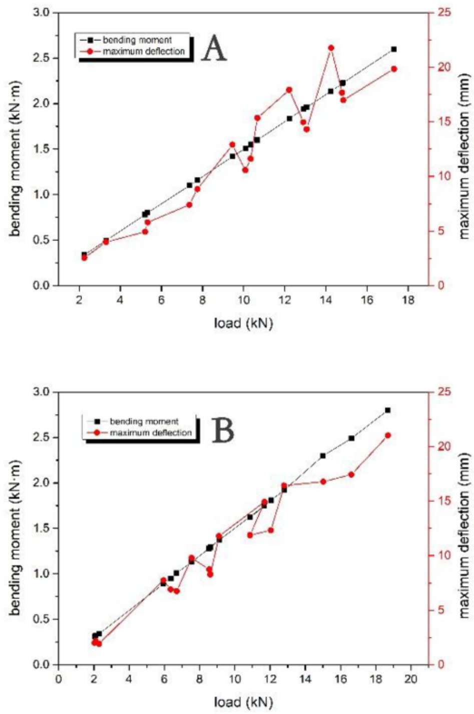


**Fig. 3.** Flexural strength diagram of template.

### *3.2. Shear Test of Handle*

**Pure Shear Test.** In construction, the pins mainly bear the combined action of shear force, tension force and bending shear. The pure shear or tensile strength of a single pin can be directly determined by the strength of the material and the geometric dimensions of the pin, so the test is mainly to determine the combined effect of shear and tension on the handle and the template as a whole, the bearing capacity of the pin and the deformation capacity of the corresponding handle. The test device shown in Fig. 4 is proposed to be used, and the shear force can be obtained through the jack loading, and the tensile force can be obtained through the bending moment. In addition, a strain gauge is attached to the panel to reflect the deformation between the beam and the panel through the strain.

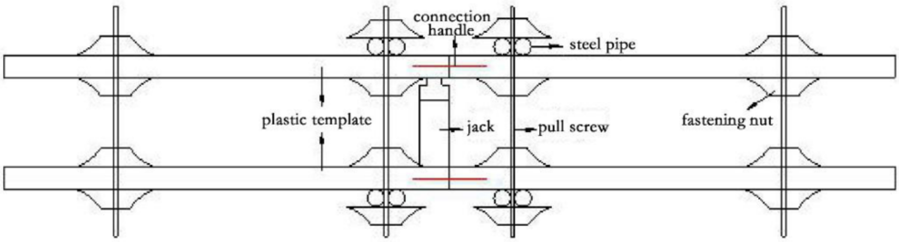


**Fig. 4.** Loading diagram of single handle pure shear experiment.

In order to measure the shear strength of the handle, steel pipes are arranged on the formwork on both sides of the handle as supports. When the distance between the supports is small enough, a jack is used to load, and the handle is mainly subjected to shear force. From the experimental results, it can be concluded that with the increase of pressure, the hole of the template handle is cracked and damaged, but the handle has no obvious damage. The static strain test system collects sensor data, and obtains the load value through the conversion factor. The maximum load that the plastic formwork can bear under the action of a single connection handle is 9.665kN, 7.74kN and 7.68kN, respectively. The average value of the three specimens is 8.36kN.

The shear test method for two handles is similar to that for a single handle, except that throughout the device, two handles are used to connect the panels. The purpose is to measure the force performance when the two handles are connected to the panel. In the pure shear test, the maximum loads that the plastic formwork can bear under the action of the two connecting handles are 11.98kN, 11.54kN and 9.15kN respectively, and the average value of the test results of the three specimens is 10.89kN.

**Bending Shear Test.** In order to determine the bending shear performance of a handle and formwork as a whole, the test device shown in Fig. 5 is proposed, which can be loaded by a jack to obtain the shear force and bending moment borne by the formwork handle. In addition, strain gauges are arranged on the template, and the deformation between the beam panels is reflected by the strain gauges.

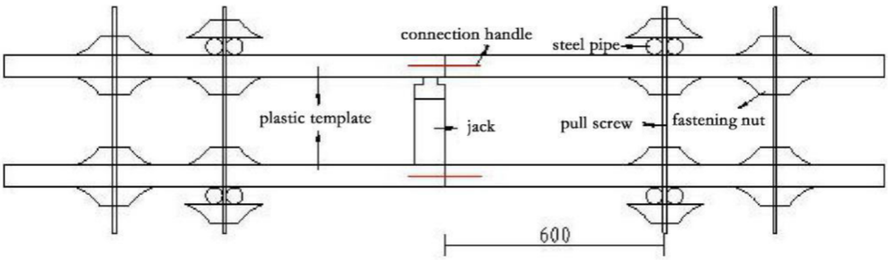


**Fig. 5.** Diagram of loading device for handle bending shear experiment.

Fig. 6 (a) shows the overall deformation of the formwork. It can be clearly seen from Fig. 6 (b) that during the test, the main hole in the formwork handle was cracked and damaged, while the handle showed no obvious damage. In (c), it can be seen that there are also obvious cracks in the template disc.

(a) Bending shear overall failure.

(b) Cracked template next to handle.

(c) Cracked template next to handle.

**Fig. 6.** Handle bending shear test failure state

The bending moment values of the two specimens when they fail are 2.72kN•m and 2.71kN•m, and the corresponding shear force values are 4.54kN and 4.52kN. The average shear force of the specimens is 4.53kN. (Shear force = concentrated force × 1/2, bending moment = shear force × 0.3m)

The bending shear test method for two handles is similar to the bending shear test method for a single handle, except that in the whole device, two handles are used to connect the panels. The purpose is to measure the force performance when the two handles are connected to the panel. It can be seen from the experiments that the bending moment values of the three specimens are 2.18kN•m, 2.49kN•m, 2.37kN•m, and the corresponding shear force values are 3.63kN, 4.08kN, and 3.96kN. The force average is 3.89kN.

**Flexural Test.** Considering the test loading conditions, it is proposed to adopt the form of concentrated loading. As shown in Fig. 7, the same rigid beam as in the bending test is used above the template, and a concentrated force is applied in the middle of the rigid beam. Record the value of the load when the handle is broken.

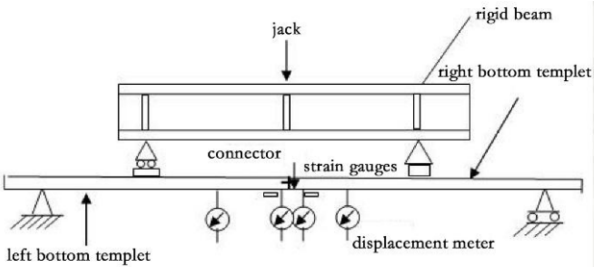


**Fig. 7.** Flexural test method for handles

Fig. 8 (a) shows the tendency of the two templates to bend downward when the template is loaded to a certain load. Fig. 8 (b) shows that there are irregular fractures in the arc-shaped area where the stress of the formwork is relatively concentrated. The bending moments of the two specimens at fracture are 0.61kN•m and 0.58kN•m, respectively. The average value is 0.595kN•m.

(a) Template down bend. (b) Cracked template next to handle.

**Fig. 8.** Handle flexural test failure state

**Tensile Test of Tension Bolts.** The tension screw is the key part of the force of the entire wall formwork system, so the bearing capacity of a single handle is the main basis for calculation and the basis for the number of handles. The upper and lower plastic panels are assembled by the counter-tension screw, and then set jacks on both sides of the counter-tension screw for loading. The tensile strength of the counter-pull handle can be calculated according to the loaded load, and the upper and lower panels are attached with strain. The size of the handle force through the wall is further verified by the size of the strain.

It can be seen from the test results that the damage is mainly due to the cracking of the template near the pull screw. When the template is cracked, the maximum tensile forces that the three groups of pull screws can bear are 54.15kN, 49.18kN, and 45.86kN, respectively. Therefore, the maximum tensile force that the pull screw can bear is 49.73kN.

## 4. Conclusion

A construction project in Nanjing has applied EANTE template. Engineering practice has proved that the template has the advantages of light material, many cycles, green and recyclable, etc. At the same time, the mechanical properties of the template are analyzed:

(1) According to the bending test experiment of the panel, when the bending check or deflection check is performed on the whole panel, the overall bending stiffness (I) of the 600*1200 template can be calculated as 3.55×106mm4.

(2) The connecting handle can withstand a pure shear bearing capacity of 8.36kN. However, the stress state of the connecting handle during construction is the most unfavorable in the case of bending shear. In this bending shear test, the connecting handle reaches a failure state when the bending moment is 2.5kN•m and the shear force is about 4kN.

(3) The ultimate tensile bearing capacity of the tension screw is 49.73kN.

## References

[1] Wen Fenghzi. Brief Analysis of Construction Technology of Formwork Engineering in Construction Engineering. Technology and Market, 26(8): 2 (2019).
[2] Li Sanqing, Zhang Mingliang. The Development Situation of Building Formwork in my country. Sichuan Building Materials, 42(3): 2 (2016).
[3] Suo Hao, Cui Shen, Zhao Yuanjian, et al. Research progress on re-preparation of waste polypropylene for new building formwork. Plastic Technology, 45(9): 7 (2017).
[4] Li Qinghong, Feng Yongmin. On the Constructive Significance of Timber in Architectural Design. Shanxi Architecture, 42(15): 2 (2016).
[5] Lian Li. Application of Glass Fiber Reinforced Composites in Building Materials. Plastic Technology, 43(12): 3 (2015).
[6] Hao Meiping. Application prospect of glass fiber products and composite materials in the field of construction. Glass Fiber, (4): 8 (2015).
[7] Chen Shunqi. Research on the application of new plastic building formwork in construction engineering. Smart City, 4(4): 2 (2018).
[8] Wang Guiman. Application of PVC plastic formwork in building construction. Plastic Industry, 46(4): 4 (2018).
[9] Yan Luke, Liu Rong, Zhou Jian, et al. Development and Application of Green Ecological Hollow Plastic Building Template. Engineering Plastics Application, 48(8): 5 (2020).
[10] Mei Hua, Li Zhangmiao, Li Ruihong. Present Situation and Development Prospect of Composite Plastic Building Formwork. Synthetic Resins and Plastics, (6): 4 (2015).
[11] He Fan, Wu Jiangyu. Research on the Application of Polypropylene Recycled Materials in Building Formwork. Value Engineering, 30(12): 2 (2011).
[12] Wu Houzeng. Research on the Application of Polypropylene Plastic Formwork in Construction Engineering. Lanzhou University.
[13] Wang Zaifu, Ouyang Jie, Zhu Qingpeng, et al. LFT-D production process and mechanical properties analysis of composite materials. Machinery Manufacturing and Automation, 45(2): 4 (2016).
[14] Mei Tingli. LFT-D production process and mechanical properties of composite materials. Residence, (26): 1 (2018).
[15] Li Yongge, Dai Shixi, Wang Yigao, et al. The key technology of material unloading in LFT-D molding production line. Forging technology, 42(8): 5 (2017).