# Research on application of steel-plastic composite template

Mocheng Yi, Jingkun Li, Zhenhai Tian, Lin Wang and Bin Luo*

The Fourth Engineering Company of CCCC First Harbor Engineering Co.,Ltd., Tianjin 300000, China

*Corresponding author's e-mail: 183301028873@163.com

**Abstract.** As an energy-saving high-tech green and environmental-friendly product, the steel-plastic combined template is in line with the industrial policy guidance of "replacing wood with plastic and steel with plastic". It is another new generation product after the wooden template, the combined steel template, the bamboo-wood glued template and the all-steel large template. The template is made of polypropylene (PP) resin as raw material, adding long glass fiber and other auxiliary materials, and is molded by a single molding process. All the physical and mechanical properties of the template are more than the plastic template industry standard. This study can provide referential experience for its subsequent large-scale promotion.

**Keywords:** steel-plastic combined template; assembling and transportation; mechanical performance

## 1 Introduction

In the past 20 years, bamboo (wood) plywood as a template material has been widely used in the building template market with the characteristics of low quality, easy consumption and low cost[1-3]. Although bamboo resources have the characteristics of strong reproduction and regeneration ability and short growth cycle, the domestic production of bamboo (wood) plywood is mostly low -value consumable plain panel, and some also use inferior glue or urine aldehyde glue as a binder, the product has been uneven thickness, surface inequality more difficult to solve the problem. Due to the poor quality of bamboo (wood) plywood, and the turnover time of wood plywood is similar, if the plywood is used 4 to 6 times, it will be scrapped, but also greatly caused environmental pollution. Although the steel template meets the advantages of more times of turnover, easy demoulding, easy maintenance, etc., the one-time investment of the steel template is large, and the weight is large, which is not conducive to the turnover use[4-5].

Compared with steel template and wood plywood, the use of steel-plastic composite template takes into account the advantages of wood template and steel template at the


D. Li et al. (eds.), *Proceedings of the 2023 9th International Conference on Architectural, Civil and Hydraulic Engineering (ICACHE 2023)*, Advances in Engineering Research 228,
https://doi.org/10.2991/978-94-6463-336-8_84

same time, it has the advantages of simple assembly and transportation, low template cost, improve construction efficiency, and reduce material and labor costs[6-9].

This paper mainly discusses the advantages and methods of steel-plastic composite template used in engineering and the comparison with other template.

## 2 Technical highlights and construction methods of steel-plastic composite template

### 2.1 Technical highlights

The technical highlights of the steel-plastic composite template are as follows:

(1) Low one-time input cost, on-site processing, strong adaptability;

(2) The template has high strength and can be turned around more times;

(3) High wear-resisting, anti-corrosion and installation accuracy;

(4) Easy assembly and transfer installation, saving labor and auxiliary materials[10];

(5) After the product is formed, the appearance quality is good;

(6) Various specifications and shapes of the template style is rich, through flexible assembly, can meet the assembly needs of various structures; According to different structures, the matching rate of the secondary mold reaches more than 90%;

(7) The template is light in weight and high in strength. It is connected by rotating 90° handle and easy to disassemble and assemble. No need to use nails, iron wire, electric drill, saw and other auxiliary equipment materials;

(8) The surface of the plate is non-stick concrete, the appearance quality can achieve the effect of water template, and the flatness can be controlled within 3 mm;

(9) After the template is abandoned, it can be all recycled and reused to completely avoid environmental pollution.

### 2.2 Construction method

**Installation method.**

After brushing the steel-plastic combination template with water-based release agent, assemble the side wall template according to the mold drawing provided by the steel-plastic combination template manufacturer. When assembling the template, use the L80 connection handle to rotate 90° to connect it into a whole. During the mold setting process, the template is temporarily fixed through the diagonal brace. After completing the assembly of the template on one side of the side wall, poke off the butt screw plug reserved in the template, set the butt screw through, install the other side template of the side wall, and complete the assembly of the side wall template. The connection of the handle and the template is shown in Figure 1.

**Fig. 1.** Schematic diagram of connection handle and template connection.

**Precautions for template removal.**

The template can be removed only after the concrete strength meets the design requirements. After the template is removed, it should be cleaned and maintained in time, and the numbers should be placed neatly for the next turnover[11]. Precautions when removing the template are as follows;

(1) When removing the template, attention should be paid to the template falling, violent construction is prohibited, and the service life of the template is extended;

(2) It is strictly prohibited to throw the template from the height to the ground, and can be manually lifted with ropes

(3) after removing the mold, the template should be cleaned in time and stacked neatly;

(4) the maintenance of finished concrete should be strengthened after the template is removed.

**Mold removal tools.**

Common mold removal tools and template removal are shown in Figure 2 and Figure 3 respectively. The common mold removal tool can replace the spot crowbar and is mainly suitable for removing the side wall and top plate. In the process of removing the mold, first remove the connecting handle of the template, hook the handle of the mold removal tool into the handle hole of the template, and then apply force to the removing rod to achieve the effect of removing the mold. The use of professional mold removal tools instead of crowbars can avoid the occurrence of damage to the template panel. The cleaning rod on the mold removal tool is used to clean the handle hole blocked by concrete. Align the cleaning rod with the handle hole of the template and hit down with the hammer until the concrete falls out of the hole to complete the cleaning. This process is simple and efficient, which can improve the working efficiency.

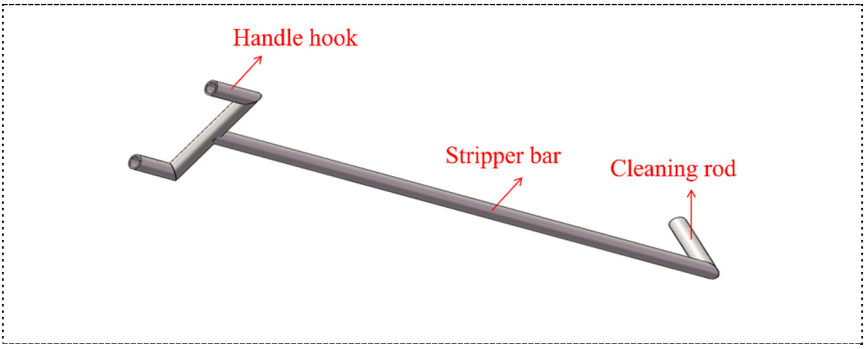


**Fig. 2.** Common mold removal tool.

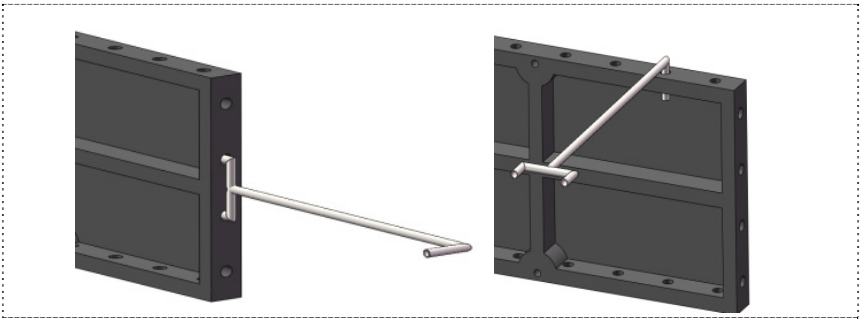

**Fig. 3.** Template removal diagram.

The side wall mold removal tool and mold removal diagram are shown in Figure 4 and Figure 5 respectively. The side wall mold removal tool is used for the more difficult to remove side wall template. When removing the mold, first remove the template connection handle, insert the hand hook of the side wall mold removal tool into the hand handle hole of the template, and then place the support rod on the high rib back bar of the adjacent template, apply force to the mold removal rod, and use the lever principle to achieve the mold removal effect. The use of the side wall mold removal tool can effectively reduce the damage to the template in the process of mold removal.

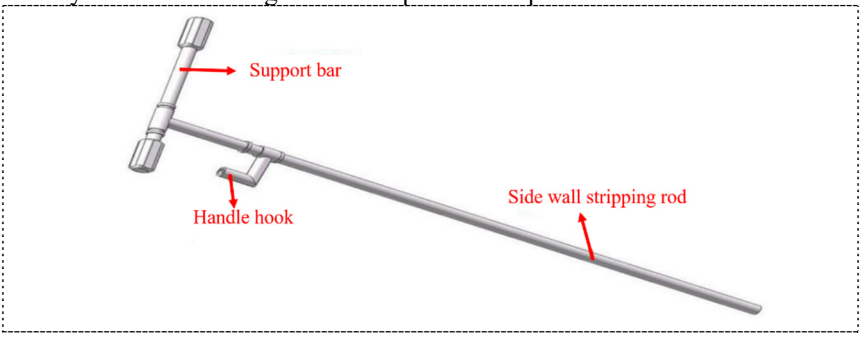


**Fig. 4.** Side wall mold removal tool.

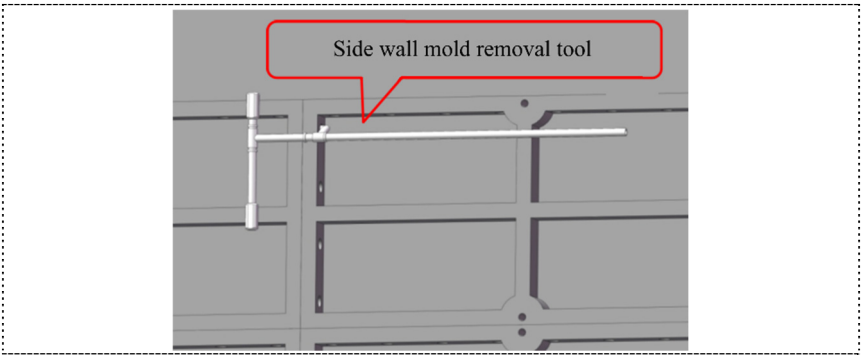


**Fig. 5.** Side wall mold removal diagram.

**Template inversion.**

The template reversing tool is mainly composed of a template support platform and a moving wheel. The upper end of the template translation pulley is provided with a template brake rod. The connecting hole on the side of the template is used to prevent the template from sliding relative to the translation pulley in the process of moving. The overall template of each large unit of the side wall is placed on the template translation pulley and moved to the next construction section along the construction direction. Two template translation pulleys are used for each template unit [12]. The template inversion diagram and template translation pulley are shown in FIG. 6 and FIG. 7 respectively.

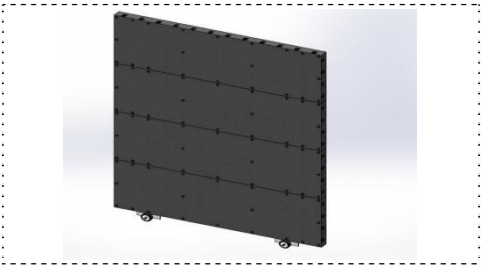

**Fig. 6.** template translation pulley.

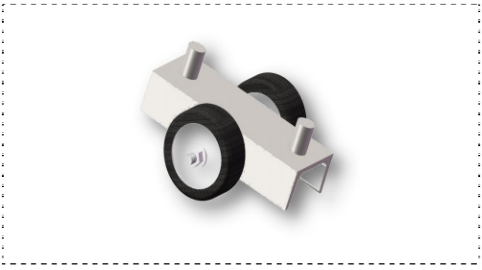

**Fig. 7.** Template translation pulley.

# 3 Template force calculation

## 3.1 Basic parameters

Taking a certain project track beam as an example, the standard section of the track beam is 25 m long, the side wall has a net height of 1.6 m, a net width of 2.6 m, a wall thickness of 900 mm, and a total area of 142 $m^2$ [13]. The template panel adopts steel-plastic composite template. The inner keel spacing is 400 mm, the inner keel is 100×100 mm wooden square, and the outer keel is 48 mm×3.0 mm double steel pipe. The cross-tension bolts are arranged in 3 ways, the horizontal spacing in the section is 250+500+450 mm, the span direction spacing of the section is 600 mm, and the diameter is 16 mm. The thickness of the panel is 5.6 mm, the shear strength is 44.4N /$mm^2$, the bending strength is 140.0N /$mm^2$, and the elastic modulus is 5530.0N /$mm^2$. The shear strength is 1.7N /$mm^2$, the bending strength is 17.0N /$mm^2$, and the elastic modulus is 10000.0N /$mm^2$.

## 3.2 Load standard value calculation

The strength checking calculation should consider the side pressure of the newly poured concrete and the design value of the load generated when the concrete is dumped; The deflection checking calculation only considers the standard value of load generated by the side pressure of the newly poured concrete.

When the pouring speed is greater than 10 m/h or slump is greater than 180 mm, the side pressure of newly poured concrete is calculated according to formula (1); In other cases, according to formula (1) and (2), take the smaller value of the two:

$$F = 0.28\gamma_c t_0 \beta \sqrt{V} \tag{1}$$

$$F = \gamma_c H \tag{2}$$

Where: γc is the gravity density of concrete, taking 25 kN/$m^3$; t0 is the initial setting time of newly poured concrete, which is 5 h; T is the molding temperature of concrete, which is 20 ℃; V is the pouring speed of concrete, take 3 m/h; H is the total height from the calculated position of the side pressure of concrete to the top of the newly poured concrete, which is 1.35m; β is the correction factor for the influence of concrete slump: when the slump is greater than 50 mm and less than 90 mm, β is 0.85; when the slump is greater than 90 mm and less than 130 mm, β is 0.9; when the slump is greater than 130 mm and less than 180 mm, 1.0; This example takes 1.0.

The standard value of side pressure calculated by the formula is 33.750kN/$m^2$. Considering the importance coefficient of the structure 0.90, the standard value of side pressure F1 = 0.90×33.750 = 30.375kN /$m^2$ is adopted in the actual calculation. Considering the importance coefficient of the structure 0.90, the standard value of load generated during concrete pouring F2 = 0.90×4.000 = 3.600 kN/$m^2$.

### 3.3 Template panel alculation

The template panel is a flexural structure, and its flexural strength and stiffness need to be calculated. The template panel is calculated as a continuous beam, and the calculated width of the panel is 0.5m. Calculated load value q = 1.2×30.375×0.5+1.40×4.000×0.5 = 21.03 kN/m.

The section moment of inertia I and section resistance moment W of the panel under different template widths are respectively shown in Table 1, and the calculation diagram of the template panel is shown in Figure 8.

**Table 1.** Numerical table of moment of inertia and moment of resistance under different template widths

| Serial number | Template width/ mm | X-axis section moment of inertia I/ $cm^4$ | Minimum resistance moment of section*W*/ $cm^3$ |
|---|---|---|---|
| 1 | 200 | 157.25 | 28.20 |
| 2 | 250 | 168.61 | 29.14 |
| 3 | 300 | 177.96 | 29.86 |
| 4 | 350 | 185.80 | 30.43 |
| 5 | 400 | 245.78 | 41.48 |
| 6 | 450 | 254.12 | 42.11 |
| 7 | 500 | 261.51 | 42.66 |
| 8 | 550 | 268.11 | 43.13 |
| 9 | 600 | 275.69 | 43.62 |
| 10 | 1200 | 581.08 | 91.94 |

In this example, the section resistance moment W = 42.66cm, the section inertia moment I = 261.51cm.

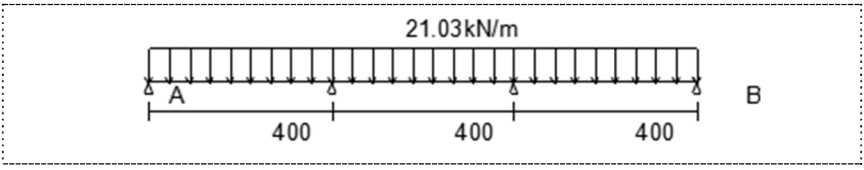


**Fig. 8.** Schematic of template panel calculation.

(1) Calculation of bending strength:

$$f = \frac{M}{W} < [f] \tag{3}$$

Where: f is the calculated bending strength of the panel; M is the maximum bending distance of the panel; W is the net section resistance moment of the panel; [f] is the design value of the bending strength of the panel, which is 140.00 N/$mm^2$.

$$M = 0.1ql^2 \tag{4}$$

Where: q is the design value of load.

According to formula (4), M = 0.336 kN·m is obtained, and according to formula (3), the calculated bending strength f of the template panel is 7.876N /mm2. In this

example, the design bending strength [f] of the panel is 140.00 N/mm$^2$. Therefore, the flexural strength of the panel is calculated. [f], meet the verification requirements.

Deflection calculation:

$$v = \frac{0.677ql^4}{100EI} < [v] = 1/400 \tag{5}$$

In this example, the maximum deflection of the panel is calculated v = 0.182mm, and the maximum deflection is less than 400/400= 1.0mm, which meets the requirements of the checking calculation.

### 3.4 The tensile bolt is calculated

The bearing capacity of tension bolt is calculated as follows:

$$N < [N] = fA \tag{6}$$

Where: N is the pulling force on the bolt; A is the effective area of the tension bolt; f is the design value of the tensile strength of the bolt, which is 170 N/mm$^2$.

In this calculation example, the diameter of the tension bolt is 16 mm, the effective diameter is 14 mm, the effective area A = 144 mm$^2$, the maximum allowable tension value [N] = 24.480kN, the maximum tension N = 14.515kN, and the checking calculation of the tension bolt strength meets the requirements.

## 4 Precautions for the use of number templat

(1) When using the steel-plastic combination template, do not contact the open flame, such as the steel bar needs to be welded, you should take protective measures;

(2) Temporary steel pipe support is used to prevent the template from overturning;

(3) Before the template construction, special water-based release agent should be evenly applied. It is prohibited to use waste oil and other release agents that produce chemical reactions with the template;

(4) The handle needs to be fully locked from the top down, otherwise it is easy to leak out, and prevent the inflow of cement slurry that makes the handle difficult to remove;

(5) After locking the handle, check whether the joint position of the template is slightly wrong. If there is a wrong table, use a rubber mallet to smooth the joint of the template;

(6) Use a small plug to block the holes that are not in use;

(7) The inner stay should be placed properly and close to the pull screw (within 10 cm) to prevent deformation during reinforcement;

(8) The pull screw and PVC sleeve are required to have a certain length, the length of the pull screw is appropriate to the wall thickness plus 60 cm, and the wall thickness of the PVC sleeve is appropriate to the wall thickness plus 16 cm;

(9) The construction process is strictly in accordance with the construction mold drawings to ensure that the handle and casing are fully installed and the nut is tightly locked;

(10) When concrete is poured, if the back of the template is seriously stained with ash, wash it immediately with a spray pipe;

(11) When concrete is poured, there must be a special person to look at the mold. If any abnormality is found, effective measures should be taken in time to strengthen and prevent the expansion and explosion of the mold;

(12) When the wall template can be dismantled as a whole, it will not be dismantled, and when there is mechanical equipment, it will be used as a whole;

(13) Avoid brutal construction in the construction process to ensure the turnover of the template;

(14) Familiar with the mold drawing, understand the mold intention, in strict accordance with the mold drawing and reinforcement plan construction.

## 5 Comparative analysis of all kinds of templates

(1) The comparative results of wood template, composite steel template and steel-plastic composite template are shown in Table 2.

**Table 2.** Comparison of advantages and disadvantages of wood template, composite steel template and steel-plastic composite template

| Comparison of advantages and disadvantages | Wood template | Composite steel template | Steel-plastic composite template |
|---|---|---|---|
| advantage | Low one-time input cost;<br>Field processing, strong adaptability. | High strength of template;<br>A lot of turnover. | Light weight, convenient construction;<br>Flexible combination, high turnover;<br>Molding appearance quality is good;<br>Moisture resistance,corrosion resistanc-e,high precision. |
| disadvantage | Poor molding quality, wrong table, bulging, etc.;<br>Material waste is serious;<br>Easy to wear, not environmentally friendly. | Maintenance cumbersome, easy to rust;<br>The operation is not good, the construction is difficult, depends on machinery, low efficiency;<br>Heavy weight, construction handling is not convenient. | Shape the size, special nodes need to connect with the wooden template;<br>The flame retardant performance is general, and fire prevention should be paid attention to in construction. |

(2) The comprehensive comparison results of wood template, composite steel template and steel-plastic composite template are shown in Table 3.

**Table 3.** omprehensive comparison of wood template, composite steel template and steel -plastic composite template

| item | Wood template | Composite steel template | Iante template |
|---|---|---|---|
| Panel material | 15 mm thick laminated plywood | 3 mm thick steel plate | 5.4 mm thick panel |
| Form thickness | 15 mm | 55 mm | 80 mm |
| Form weight | 12 kg/m$^2$ | 50 kg/m$^2$ | 15 kg/m$^2$ |
| Carrying capacity | 30 N/mm² | 90 N/mm² | 60 N/mm² |
| Environmental protection and energy saving | Not environmental protection, not energy saving | Furnace and welding required | Green, low carbon and energy saving |
| Recycling and regeneration | nonrenewable | Recyclable but costly | Low cost of recycling |
| Number of turns | 2-3times | 100times | 40-60times |
| Construction difficulty | easy | harder | easy |
| Maintenance cost | low | higher | low |
| Labor resources | There is no need for mechanical coordination, on-site cutting processing, and the technical level of workers is high | Requires a small amount of mechanical cooperation, the template is heavy, difficult to handle, difficult to operate | No mechanical coordination, simple assembly, a small amount of manual can be easily operated |
| Construction efficiency | medium | Low | high |
| Molding effect | The surface is rough, easy to leak pulp, wrong table, bulging and so on | The surface is rough, the precision is poor and easy to leak | Smooth and smooth, can meet the cleaning requirements of finishes and decorations |
| Product characteristics | Non-conductive, water absorption rise, peeling, high temperature deformation, material waste is serious | It is easy to conduct electricity and rust, and it must be polished before each construction, and it is difficult to check the mold after deformation | Safe insulation, acid resistance, alkali resistance, high temperature resistance, moisture resistance, light weight and high strength, accurate size, easy to deform, easy to release, simple maintenance |

# 6 Application effect of steel-plastic combination template

(1) Personnel input and efficacy comparison

Taking the track beam as an example, the standard section is 25 m long, the side wall has a net height of 1.6 m, a net width of 2.6 m, a wall thickness of 900 mm, and a total area of 142 m2[13]. The comparison of personnel input and efficacy between steel template and steel-plastic composite template is shown in Table 4.

**Table 4.** Comparison table of personnel input and efficacy

| process | Man-hours required for steel-plastic composite template | | | Man hours required for steel template | | |
|---|---|---|---|---|---|---|
| | Master engineer | Skilled technician | Unskilled labourer | Master engineer | Skilled technician | Unskilled labourer |
| 1, the side wall model | | 3 | | 1 | 3 | |
| 2, through the pull screw | | | 2 | | | 2 |
| 3. Side wall reinforcement | | 3 | | | 3 | |
| 4, side wall chamfer template assembly | | 1 | | | 2 | |
| 5. Casting the mold | 0.5 | | | 0.5 | | |
| 6. Side wall reinforcement and demolition | | 3 | | | 3 | |
| 7. The side wall template is removed | | 1 | 2 | | 4 | 4 |
| 8. Template cleaning and correction | | | 2 | | 4 | 2 |
| Total | 0.5 | 11 | 6 | 0.5 | 17 | 8 |
| Total cost | | 3675 | | | 5355 | |
| Construction efficiency | | Per job 17.1 $m^2$/d | | | Per job 13.7 $m^2$/d | |

[a] The fee is 350 yuan/workday for large workers, 220 yuan/workday for medium workers and 180 yuan/workday for small workers.

(2) The overall cost input of steel template and steel-plastic template is shown in Table 5 and Table 6 respectively.

**Table 5.** Overall cost input of steel template

| Type specification | Quantity of work | Unit | Unit price/Yuan | Amount/Yuan |
|---|---|---|---|---|
| φ48*3.0mm Steel tube | 10.579 | t | 5200 | 55009.47 |
| φ48*3.5mm Steel tube | 14.617 | t | 5200 | 76006.20 |
| 50*100mm Square timber | 3.150 | $m^3$ | 1700 | 5355.00 |
| 5# Steel channel | 1.689 | t | 5000 | 8445.60 |
| M14 Water stop screw(1 m) | 544 | Number | 6 | 3264.00 |
| M14 Water stop screw(0.9 m) | 408 | Number | 6 | 2448.00 |

| | | | | |
|---|---|---|---|---|
| Mountain fastener | 1904 | Number | 1 | 1904.00 |
| Nut | 1904 | Number | 1 | 1904.00 |
| Jacking | 408 | Number | 15 | 6120.00 |
| Template | 1206 | $m^2$ | 350 | 422100 |
| | Total | | | 582556.26 |

**Table 6.** Overall cost input of steel-plastic composite template

| Type specification | Quantity of work | Unit | Unit price/Yuan | Amount/Yuan |
|---|---|---|---|---|
| φ48*3.0mm Steel tube | 3.229 | t | 5200 | 16789.59 |
| φ48*3.5mm Steel tube | 14.617 | t | 5200 | 76006.20 |
| 50*100mm Square timber | 3.150 | $m^3$ | 1700 | 5355.00 |
| 5# Steel channel | 1.689 | t | 5000 | 8445.60 |
| M14 Water stop screw (1 m) | 906 | Number | 6 | 5436.00 |
| M14 Water stop screw (0.9 m) | 704 | Number | 6 | 4224.00 |
| Flat gasket | 3220 | Number | 1 | 3220.00 |
| Nut | 3220 | Number | 1 | 3220.00 |
| Jacking | 408 | Number | 15 | 6120.00 |
| New reinforcement | 1606 | m | 49.8 | 79978.80 |
| Composite template | 1206 | $m^2$ | 170 | 205020 |
| | Total | | | 413815.19 |

(3) Promotion prospects

Since 2019, steel-plastic composite template has been gradually promoted and applied in the southern construction market, and has achieved good results in many construction fields, such as municipal and housing construction projects. At present, in the construction of relevant buildings in Xiongan New Area, steel-plastic composite template is also being widely promoted and used [14]. The assembling effect of steel-plastic composite template is shown in Figure 9, and the appearance of concrete after mold removal is shown in Figure 10.

**Fig. 9.** Steel-plastic composite template assembly effect.

**Fig. 10.** Appearance of concrete after mold removal.

## 7 Conclusion

With the continuous development of infrastructure construction, the application of steel-plastic composite templates is becoming increasingly widespread. Compared to traditional methods, they offer significant improvements in project efficiency and quality, while also reducing economic costs. Furthermore, they embrace the concept of green and low-carbon construction, enhancing environmental protection. The utilization of steel-plastic composite templates plays a crucial role in elevating China's infrastructure construction capabilities and improving overall project quality.

## References

1. Zhao, Z.X., Wang H.J, (2023) Application of Plastic Steel Formwork in Water Conservancy Construction Projects[J]. Yunnan Water Power.39(08):251-253.
2. Hu, E.Y., Yang, W., Sun, K.M (2023) The application of plastic steel formwork in concrete construction for subway station structures. [J]. Technology Innovation and Application, 13 (12): 170-172+176.
3. Ni, D.Y., Yang, D.S., Shi, J. (2023) On Design and Construction of All Steel Large Formwork for Special-shaped and Changeable Super High-rise buildings[J]. Shanxi Architecture, 49(17): 121-123+126.
4. Han, G.G., Yang, D.S., Yu, J.Q., (2022) Application of Novel Plastic Formwork in Construction of Comprehensive Utility Tunnel[J]. Building Construction, 44(07): 1469-1471+1475.
5. W. B. Kareem, R. O. Okwori, H. O. Abubakar, etc. (2019) Evaluation of Wood and Plastic Formworks in Building Construction Industry for Sustainable Development [J]. Journal of Physics, DOI: 10.1088/1742-6596/1378/3/032007.
6. Wang, L. (2023) Application of Combined Steel Formwork in T-beam Construction of Water Conservancy and Hydropower [J]. Building Technology Development, 50(09): 113-116.
7. Hao, D.J (2020) Construction Engineering Steel Mold Construction Process[J]. Building Technology Development, 47(05): 35-36.
8. Hu, P. (2020) pplication of plastic steel template in construction of urban integrated pipe corridor [J]. Engineering and Construction, 34(5): 961-963.

9. P L A, Luthan. N, Sitanggang. P, Betaubun. (2020) Implementation of Green Construction on the Use of Formwork at St. Thomas Building Construction Project [J]. Earth and Environmental Science, DOI 10.1088/1755-1315/473/1/012084.
10. Yu, H.G., D, H. T,. Zha, L (2023) Research on The Improvement of Construction Speed and Economic Benefits by Using Plastic Steel Formwork in Tibet. [J]. Scientific and Technological Innovation, (17): 118-120.
11. Chen, Y. (2023) Construction Techniques and Quality Assurance for High-rise Building Formwork [J]. Low Carbon World, 13(09): 73-75.
12. Zhang X., Wang, H.Y. (2023) Optimization Design and Application of Annular Ribbed Steel Formwork with Different Construction Heignts[J]. Construction Technology, 52(12): 94-100.
13. Li, W. (2022) Comparative Analysis of Formwork Application in Urban Integrated Pipe Corridor Construction [J]. Technology Innovation and Application, 12(07): 194-196(In Chinese).
14. Liu, X.W. (2023) Optimization Measures for the Management of Construction Technology in Building Projects [J]. Theoretical Research in Urban Construction, (23): 85-87(In Chinese).