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Research on Construction Technology of Integrated Construction of Planted Roof and Self-Insulated Exterior Wall Panel Based on Building Information Modeling

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Abstract This paper analyzes the design structure of the planted roof and the construction process of each construction level to find the steps that can be integrated with the self-insulated exterior wall panels. Based on the building information model, the development program of assembled composite self-insulated exterior wall panel is developed to complete the information coding of related structural components. Combine the dual code network planning (DCNP) and particle swarm algorithm to construct the construction progress-cost target optimization mathematical model and determine the optimal integrated construction scheme. The results show that the total heat transfer heat flow of the planted roof is 136.51W/m^2, which is at a good level and is suitable for integrated construction with self-insulated exterior wall panels. The heat transfer coefficients of 4 combinations are 0.545, 0.376, 0.452, 0.317, which are in line with the actuality through the exterior wall panel model designed by the development program. In the wall panel width area of 0-0.25m, the degree of temperature influence of each type of components in order of magnitude is as follows: tie member>connector>steel reinforcing mesh, and it is necessary to take into account the amount of purchase of components and the time for purchasing, and to reduce the cost of construction losses.

Index Terms building information modeling, information coding, two-code network planning, particle swarm algorithm, integrated construction

I. Introduction

In the foreseeable future, the increase in the number of buildings will make the already serious problem of energy consumption appear increasingly prominent. Relevant data show that at present, building energy consumption accounts for about 30-40% of total energy consumption [1]. Due to the influence of global warming, it is expected that the global heating energy consumption in 2100 will be reduced by about 50%, while the cooling energy consumption will increase by nearly 248% [2], [3]. Energy efficiency in buildings has become one of the important topics of current research. Secondly, the large amount of hard paving brought by urbanization will also further aggravate the urban environmental problems, triggering environmental problems such as heat island effect, urban flooding, and deterioration of air quality, which will directly threaten human health [4], [5]. Taking the heat island effect as an example, the temperature difference between the developed city center and the surrounding environment can reach up to 4.4℃, and the temperature difference is still increasing, in order to effectively alleviate this series of problems, one of the important research directions is to reduce the area of hard pavement, and restore the green area as much as possible in order to restore the self-healing function of the ecological environment [6]-[8].

Planted roofs, also known as green roofs and ecological roofs, originated in Germany in the 1960s. A large number of experimental studies have proved that planted roofs can effectively mitigate the urban heat island effect [9]. It has good heat preservation and insulation properties and reduces building energy consumption [10]. Reduce the carbon dioxide content in the atmosphere, play a role in purifying the air [11]. Reduce urban noise pollution [12]. It can also store rainwater, delay the peak time of roof runoff, and purify rainwater quality [13]. The building energy-saving effect played by the planted roof is affected by its own thermal insulation performance, and its thermal insulation principle is equivalent to attaching a layer of thermal insulation heat resistance to the roof, isolating the roof from the direct contact pathway of the outdoor environment [14], [15]. However, the traditional planted roof and exterior wall insulation panels are constructed separately, which increases the cross-layer leakage probability, material loss, and thermal bridge effect, and does not conform to the realization route of energy-saving buildings

[16]. The construction of integrated planted roof and self-insulated exterior wall panel construction has become a key research direction.

Building information modeling is to take all the relevant information data of the construction project as the basis of the model, to carry out the establishment of the building model, and to simulate the real information that the building has through digital information simulation. It has the five characteristics of visualization, coordination, simulation, optimization and chartability, which provides technical support for the construction of an integrated construction plan, and provides assistance for energy-saving buildings by building the planted roof and self-insulated exterior wall panels with building information modeling [17], [18].

The level of integrated construction is improved to promote cost reduction and efficiency in construction projects. This paper determines the construction process and integrated construction steps in combination with the planted roof structural levels and construction steps. The assembly composite self-insulated exterior wall panel row plate design program is developed on the building information modeling (BIM) platform. From the four modules of model identification, automatic panel scheduling, optimization, and flat steel design, the structural component information coding and modeling of self-insulated exterior wall panels are realized to improve the information processing efficiency of the construction project. Aiming at various types of schedule objectives, a schedule-cost optimization mathematical model is designed using dual code-network planning (DCNP) and particle swarm algorithm. Comprehensive schedule-cost objective functions and constraints are integrated to calculate the optimal construction plan for the integration of planted roofs and self-insulated exterior wall panels.

II. Analysis of the process of realizing integrated construction based on building information modeling

II. A. Planted roof waterproofing site control

II. A. 1) Structural levels of planted roofs

The structural level of planting roof generally includes roof structure layer, heat insulation layer, leveling layer, ordinary waterproof layer, root-puncture resistant waterproof layer, isolation layer, water drainage (storage) layer, filtration layer, planting medium layer and vegetation layer. Among them, the isolation layer can be determined according to the actual situation to determine whether the need to set.

II. A. 2) Construction of structural layers of planted roofs

1) Roof structure layer construction

The structural layer bears all the load on the upper part, and at the same time, as the last barrier of waterproofing, so in the choice of concrete, priority is given to the same strength of impermeable concrete, from the original material ratio to the construction and maintenance should be focused on control.

Thoroughly moisten the template before pouring to reduce the accumulation of dust on the surface of the template. Clean up the construction joints, and if necessary, set up water-stopping steel plate and grouting pipe at the position of construction joints to strengthen the waterproof performance of the joint surface. Pouring should be continuous, and the interval between each truck of concrete should not be too long. Vibration should be “fast insertion and slow extraction”. The curing time with mold is controlled between 6-12d to reduce the production of shrinkage cracks.

2) Construction of heat insulation layer

Thermal insulation layer generally choose lightweight materials, mainly polyurethane materials. Before the construction of the heat insulation layer needs to be processed on several surfaces, to ensure that the two fit closely, the upper and lower layers of staggered seams 25cm, the joints with similar materials fill punch.

3) Slope layer (leveling layer) construction

Leveling layer is located at the bottom of the waterproofing layer, as a paving membrane waterproofing layer of the grass-roots level, should have a flat, solid characteristics, at the same time to meet the requirements of the drainage slope, generally using waterproof mortar or aerated concrete. Cement mortar leveling layer before construction, clean the roof and sprinkle water wet. Priority is given to special locations such as pipe openings, yin and yang corners. The mortar is a rigid material, so it is necessary to set up expansion joints to avoid cracking, the width of the joints should not be greater than 2.5cm, and it is best to control the joints between the joints at about 6.0cm. The surface of the mortar needs to be smoothed, in order to fit perfectly with the upper layer of waterproofing membrane.

4) Waterproof layer construction

Planting roof waterproofing key to root puncture waterproof layer. The first waterproofing using non-curing rubber asphalt waterproofing coating, before construction need to clean up the base surface, and fill the low-lying areas leveling. Spraying needs to be on the pipe mouth, yin and Yang corner, construction joints and other weak positions to strengthen the treatment. When encountering windy days need to stop construction, to prevent dust mixing and affect the effect of water discharge. Protect the finished product in time after construction.

The second waterproofing root puncture resistant waterproofing roll-roofing, construction needs to be baked in place, the flame size is moderate. Coil paving should first pave the details of the location of the pipe mouth and then large surface construction, paving height control in the soil layer above 165mm. large surface paving to minimize the number of laps, the construction can be used to squeeze the roller to discharge the internal air, to ensure that the fit is tight.

5) Protection isolation layer construction

Protect the isolation layer is mainly to prevent subsequent construction of waterproofing layer damage or sunlight for a long time to accelerate the aging and set up, generally using cement mortar can be. Set a layer of asphalt linoleum isolation layer above the waterproof layer to prevent mortar aggregate damage to the waterproofing membrane. After the pouring is completed in a timely manner to complete the cut seam, maintenance work, to reduce the cracks.

6) Drainage layer, filter layer construction

Drainage layer is located below the filtration layer, to a certain extent, instead of protecting the isolation layer, the material is generally used in polyvinyl chloride press molding of lightweight plastic plates, both water storage and drainage characteristics. Before construction, complete the base surface cleanup work, adjacent drainage boards are fastened to prevent soil and water from flowing into the gap, affecting the drainage effect.

The filter layer should be constructed as soon as possible after the drainage layer is constructed. The filter layer should be paved from low to high, and the whole layer should be smooth and close. When encountering corners and other locations need to be completed first detail treatment before paving a large area. Lap width should not be less than 165mm, the joints need to be firmly sewn, continuous alignment. The paved area should be pressed by water tanks to keep it in close condition. The end position is firmly pasted with adhesive. Before paving the planting layer need to comprehensively check whether there is damage to the filter layer, and if there is, then repair.

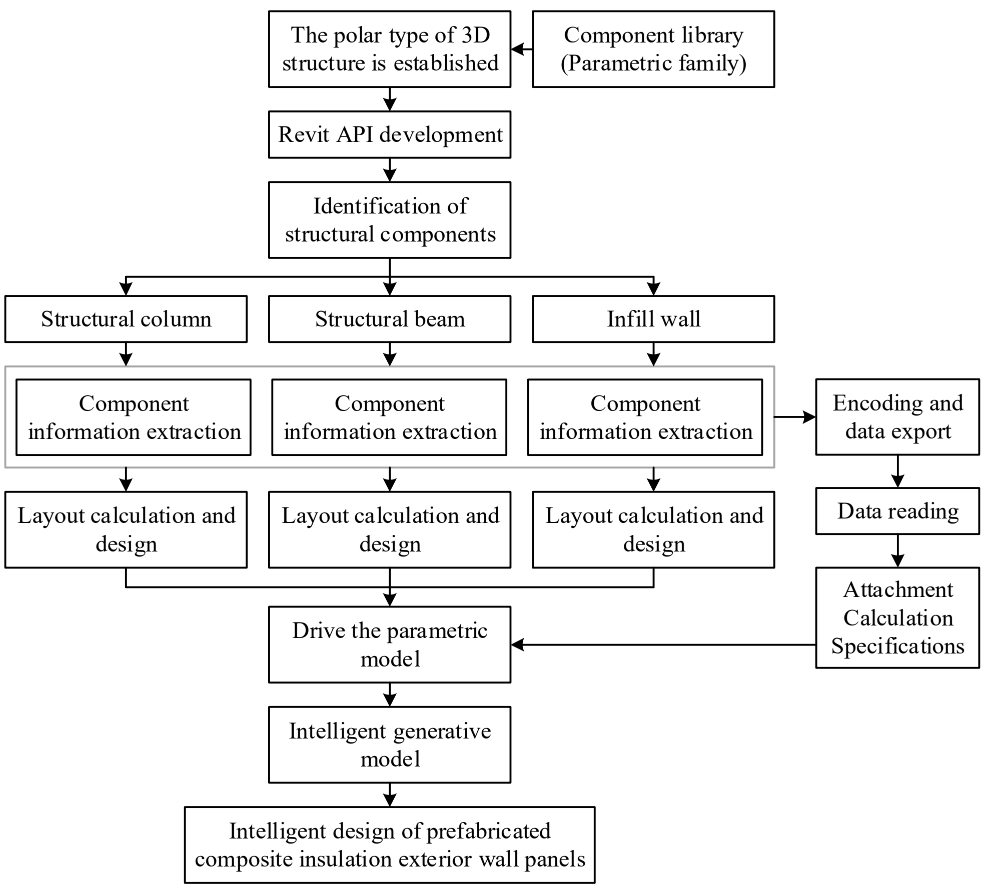

Figure 1: Development process

II. B. Overview of the development program for assembled composite self-insulating exterior panels

II. B. 1) Introduction to the development process

The development platform of the assembly composite self-insulated exterior wall panel design program is based on the building information model (BIM) platform, with the help of Visua Studio software, using C# language, to complete the assembly composite self-insulated exterior wall panel intelligent identification and panel design. The model recognition module realizes the function of recognizing the classification code of structural components and data export; the automatic plate module realizes the function of reading structural data and intelligently arranging plates according to the data; the optimization module realizes the function of optimizing the plate joints to reduce the rate of non-standard plates; the flat steel design module realizes the function of calculating the load of flat steel, generating models by selecting the type, and generating the calculation book automatically. Based on BIM technology and Revit secondary development technology, with the goal of digital, intelligent and automated layout, the above functions are realized, and the .dll files of all kinds of function codes are integrated into the Ribbon panel plug-in. Figure 1 shows the overall development process.

II. B. 2) Rules for encoding structural model components

Information coding is a unified view of a certain thing, unified understanding and information exchange of a technical means to minimize the naming of information, description of the misunderstanding caused by inconsistency and loss of information coding is directly related to the automation of information processing, transmission and retrieval of the efficiency and level of information coding can improve the ability of computers to carry out information processing and speed, to promote the exchange of information between the system and the sharing of data and the The degree of automation of information system. The consistency of transmission and exchange of information between information systems is the prerequisite and foundation for realizing information sharing and interoperability between systems, and this consistency is based on the common agreement of the information systems on the name, description, classification and code of information. The consistency, universality, operability, extensibility and connectivity with computer systems of component codes are used as coding design principles.

Structural components of many types and large quantities, need to be classified and coded, so this paper based on the above basic design principles of coding to structural columns, structural beams and infill walls as an example of their coding and classification statistics.

Structural model components are coded with their component names, dimensions, serial numbers and other data, using a three-layer code, with a 2-digit uppercase English letter code for the first layer, a 4-digit numeric code for the second layer, and a 4-digit numeric code for the third layer, and the codes are connected to each other with “-”. Figure 2 shows the specific coding structure. Description: the first layer of code on behalf of the structural component name code, structural column code for GZ, structural beam code for GL, infill wall code for TQ; the second layer of code on behalf of the structural columns, structural beams component cross-section size, infill wall wall thickness and the number of window and door openings; the third layer of code on behalf of the structural component drawing order serial number.

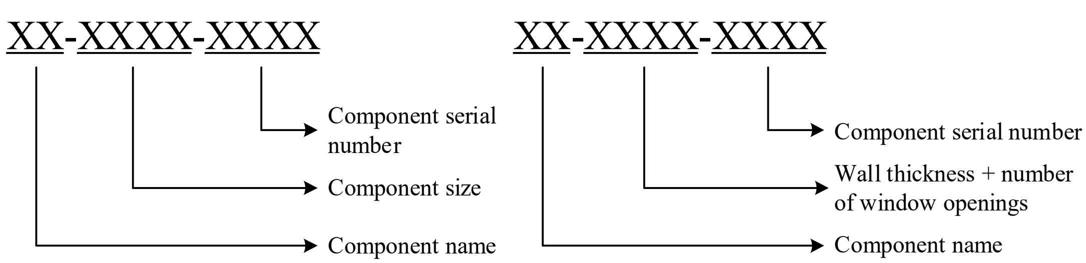

Figure 2: Coding structure diagram

II. C. Construction schedule-cost objective optimization model design

II. C. 1) Analysis of progress targets

The duration of a project is the span of time required for a construction project from commencement to completion, which directly affects the investment, efficiency and quality of the project. There are various types of calculations for duration, including:

Theoretical Duration: The minimum time required for the fastest and most efficient construction method during the construction of a project, regardless of any external constraints (e.g., resource shortages, weather impacts, supply chain issues, etc.), when resources are adequate and fully coordinated. The theoretical duration assumes that all conditions in construction are optimal, and therefore it represents an ideal duration rather than a realistic achievable duration.

Actual duration: The actual duration is the time required to adopt the optimal construction method during the construction of the project under realistic conditions (e.g., limited resources, weather changes, policies and regulations, holidays and other uncontrollable factors). The actual duration is calculated according to the actual progress of the project and external conditions, so it is more in line with reality. Actual duration is usually the duration faced during the project, which is affected by various real-life factors and may be longer than the theoretical duration. It is also usually the real time record of the project after completion.

Stipulated Duration: A stipulated duration is a period of time specified in a contract or agreement for a project by the owner or a related party. It is a legally binding time requirement for the constructor to complete the project within the stipulated period, or face possible penalties for contractual breach or compensation for delay. Unlike theoretical and actual periods, stipulated periods are usually based on contract negotiations or the specific needs of the project owner and may differ from reality. The length of the stipulated duration may affect the organization of the project and the arrangement of resources.

Feasible duration: Feasible duration refers to the time required to adopt a feasible construction program, taking into account the project's resource constraints, technical difficulties, staffing arrangements and other factors. Feasible duration is a reasonable prediction between theoretical duration and actual duration, reflecting the most likely duration of the project under the existing conditions. Feasible duration not only takes into account the actual configuration of project resources, but also reflects the technical ability of the project team and the ability of organization and coordination. Therefore, it is a more realistic duration plan for schedule management and construction organization arrangement.

Emergency Duration: Emergency duration is a project schedule that must be compressed under special circumstances, such as emergencies, disaster relief projects, government requests, or other emergencies. Emergency work periods usually require the use of overtime, deployment of more resources to complete the task, may be completed in a shorter period of time to complete the project construction. Emergency schedules usually require more resources and manpower, which may result in higher construction costs and, in some cases, greater challenges in quality management and safety control. Therefore, such duration management requires a careful balance between schedule and quality.

As a network planning method based on arrows to represent tasks, Double Code Network Plan (DCNP) is widely used in project schedule management.In DCNP, the logical relationship, sequence and duration of tasks can be visualized to calculate the critical path of the project duration and rationally arrange the construction schedule. The following is the calculation principle of DCNP working time parameters:

$$ES_{i-j} = ET_i \tag{1}$$

$$EF_{i-j} = ES_{i-j} + D_{i-j} \tag{2}$$

$$LF_{i-j} = LT_j \tag{3}$$

$$LS_{i-j} = LF_{i-j} - D_{i-j} \tag{4}$$

where ES is the earliest start time of the activity, EF is the earliest completion time of the activity, LF is the latest completion time of the activity and LS is the latest start time of the activity. The paper uses two-code network diagram to represent the construction sequence and as a constraint basis for the optimization of particle swarm algorithm.

II. C. 2) Establishment of a mathematical model for progress-cost optimization

Each project process can be executed in a number of ways that depend on the amount of technology, equipment and resource utilization used. Each execution choice is related to the specific process duration and cost. Here, an optimization model is first developed using PRET network and then particle swarm algorithm is used to solve the optimization problem.

P is all the routes in the two-code network diagram plan, P_i is the longest of all the routes, then the sum of the durations of all the processes on the route P_i is the total duration of the project T.

$$T = MAXp_i\left[\sum_{i=1}^{l} t_i^{(k)} x_i^{(k)}\right], p_i \in p \tag{5}$$

where $t_i^{(k)}$ denotes the duration of activity i at the execution of the k nd option and $x_i^{(k)}$ denotes the execution of activity i at the k th option.

1) Determination of the objective function

The objective function of progress is:

$$f_1(x) = MinT = \sum_{i=1}^{n} T_i \tag{6}$$

The objective function of the cost is:

$$f_2(x) = MinC = \sum_{i=1}^{n} C_i \tag{7}$$

2) Setting of constraints

In order to ensure the correctness of the results of the schedule-cost optimization mathematical model, the following constraints are set: the time of each construction activity is between the maximum duration and the normal duration; the cost incurred by each construction activity is between the maximum cost and the normal cost; the cost incurred by each construction process is a nonlinear function of time; and the calculation of the time parameters of each process is in accordance with the network plan diagram.

$$C_i = \frac{C_i^{\max} - C_i^{\min}}{(T_i^{\max} - T_i^{\min})^2}(T_i - T_i^{\max}) + C_i^{\min} \tag{8}$$

$$T_i^{\min} \le T_i \le T_i^{\max} \tag{9}$$

In the optimization model, the two objectives of schedule and cost affect and constrain each other. In order to find a relatively balanced Pareto optimal solution, the model must comprehensively consider the following key points:

Duration Optimization: Shorten the duration and complete the project as early as possible by making reasonable arrangements for the construction plan and work processes. It is necessary to weigh the allocation of time and resources in the construction process, and determine which processes have the greatest impact on the overall duration, so as to determine the critical path. In this process, the model will introduce time requirements and importance weights for each process to ensure that critical processes are prioritized to optimize the total duration.

Cost optimization: the main objective is to reduce project costs and increase the economic efficiency of the project. The model needs to consider direct costs (e.g., materials, labor, machinery and equipment) and indirect costs (e.g., management costs, site rental costs). In the optimization process, the relationship between cost and duration is weighed. For example, shortening the duration by increasing the input of labor and equipment may increase the direct cost, so the model needs to dynamically adjust the resource allocation to find the most economically efficient solution.

Constraints: In multi-objective modeling, the importance weights of the processes are key factors in determining the critical path and schedule. In addition, the time, cost, and quality requirements of each process serve as constraints that must meet the technical standards and customer needs of the project. The sustainability and economic benefits of the project also constitute constraints that require the model to achieve duration and cost optimization without compromising the overall quality and sustainability of the project.

In summary, the core of the duration-cost optimization model is to find the balance point between duration, cost and quality by dynamically adjusting the process arrangement, resource allocation and quality control. Particle swarm algorithm plays a key role in this process, searching and updating continuously to find the optimal solution by simulating different construction scenarios. Using BIM-4D technology for construction simulation, each parameter in the model can be monitored and adjusted in real time to ensure that the model is always pointing to the Pareto optimal solution during the construction process to meet the requirements of the project.

III. Integrated construction practices based on building information modeling

In this chapter, the application of the designed model is verified through integrated construction experiments. The following is the specific validation process.

III. A. Experimental study of planted roofs

III. A. 1) Comparative bottom temperature analysis

This experiment is set up on the roof of a large building in Guangzhou, which belongs to the subtropical monsoon climate in the hot summer and warm winter regions, and continuous experimental testing is carried out in the summer in Guangzhou. Composite planting ventilated roof from top to bottom structure is set as 125mm leek, 150mm planting layer, 25mm ceramic granule layer, 15mm root puncture-resistant layer, 25mm grille support layer, 250mm overhead layer and 15mm waterproof layer. The planted roof was set up with 150mm planting layer, 25mm ceramic granule layer, 15mm root-puncture resistant layer and 15mm waterproof layer. The exposed roof was also set up as a comparative experiment.

Outdoor air temperature has a positive correlation with solar radiation intensity. Three experimental roof bottom temperature data were analyzed over the course of a day. Figure 3 shows the variation of the bottom temperature of the test roofs during one day. The temperature of the bare roof is the highest, which can reach about 52.6°C at noon; the temperature at the bottom of the composite planted and ventilated roof is the lowest, with a maximum temperature of about 28.8°C only. According to the experimental data, it can be concluded that the average temperature of the bottom temperature of the exposed roof is 41.2℃, and the temperature fluctuation is 23.1℃. The average temperature at the bottom of composite planted ventilated roof is 27.3℃, and the average temperature at the bottom of planted roof is 32.4℃.

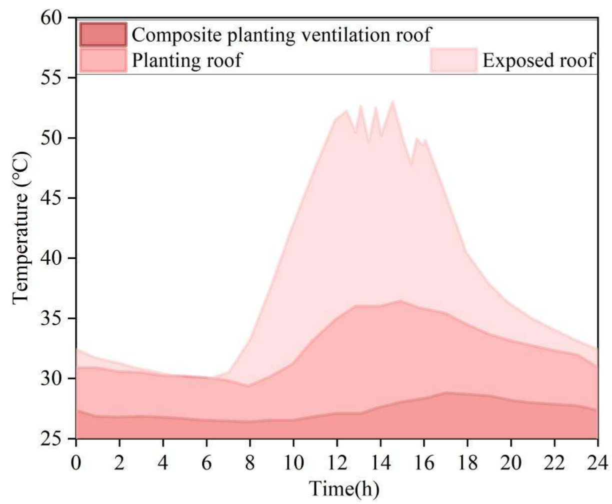

Figure 3: Test the temperature change at the bottom of the roof

III. A. 2) Comparative Analysis of Thermal Insulation Performance

Figure 4 shows the time-by-time variation of heat transfer heat flow of the three roofs. The total heat transfer heat flow of the composite planted ventilated roof is 58.28 W/m^2, the total heat transfer heat flow of the planted roof is 136.51 W/m^2, and the total heat transfer heat flow of the bare roof is 225.45 W/m^2.It can be judged that the integration of the self-insulated exterior wall panels with the planted roof can effectively utilize the heat of the planted roof and reduce the construction, without considering the bare roof. Cost.

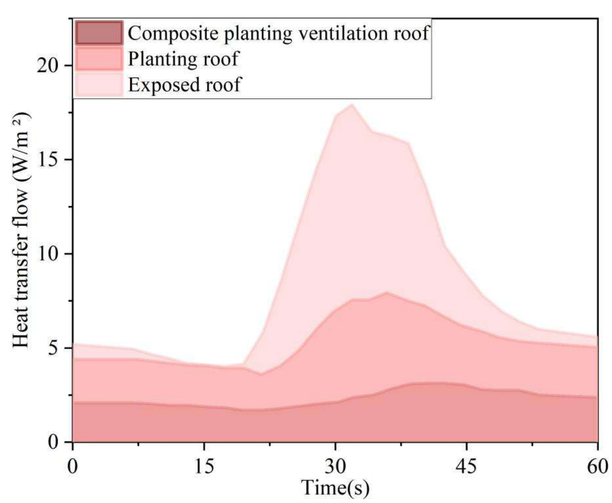

Figure 4: The hourly variation of heat transfer flow in the roof

III. B. Intelligent Development Program Application

Using the building information modeling-based assembly composite thermal insulation exterior wall panel development program, input the relevant structural components required for the construction of thermal insulation exterior wall to complete the build code. After that, combined with the schedule-cost optimization mathematical model constructed in this paper, click on the intelligent coding, statistical quantities and construction drawings functional area to initially generate the wall panel material order, flat steel material order and construction drawings. Table 1 is the wall panel material order (part). Table 2 is the flat steel bill of materials (part). In this paper, the planting roof and self-insulated exterior wall panel integration construction project partially uses 1525 pieces of composite thermal insulation exterior wall panels, using flat steel 8550.25 kg. From the point of view of the specific material size of the bill of materials, the need for a variety of materials, and the existence of the theoretical length and the actual length of the production of the length of the error, need to be combined with the particle swarm algorithm and progress - cost optimization model to achieve further adjustment and optimization.

Table 1: Wall panel cutting list (Partial)

Serial number	Wall panel specifications	Total	Wall panel width (mm)	Production wall panel height (mm)	Theoretical height of wall panels (mm)	Total volume of wall panels (m^3)	Volume of gas filling plate (m^3)
1	Standard plate: A1-1450*350	10	350	1390	1450	1.98	0.67
2	Standard plate: B1-2250*450	15	450	2195	2250	3.55	2.05
3	Standard plate: B2-2250*650	23	650	2195	2250	3.63	3.81
4	Standard plate: B3-3000*500	40	500	2945	3000	2.49	1.02
5	Standard plate: C1-3500*450	55	450	3440	3500	1.34	28.16
6	Standard plate: C2-3500*650	17	650	3445	3500	31.06	16.97
7	Standard plate: D1-4000*250	170	250	3945	4000	25.17	0.81
8	Standard plate: D2-4250*450	123	450	4180	4250	2.40	65.27
9	Standard board: D3-4500*600	15	600	4445	4500	3.24	3.92
10	Standard plate: D4-4500*800	37	800	4440	4500	105.45	2.22

Table 2: Flat steel cutting sheet (Partial)

Hole opening specification	Crossbar length /mm	Crossbar width /mm	Crossbar thickness /mm	Longitudinal length /mm	Longitudinal material width /mm	Longitudinal material thickness /mm	Flat steel weight /kg
200*200	2000	55	10	3250	75	10	30.15
200*200	2000	55	10	3250	75	10	30.15
200*200	2000	55	10	3250	75	10	30.15
200*200	2000	55	10	3250	75	10	30.15
200*200	2000	55	10	3250	75	10	30.15
250*250	2500	65	15	3500	80	15	35.60
250*250	2500	65	15	3500	80	15	35.60
250*250	2500	65	15	3500	80	15	35.60
250*250	2500	65	15	3500	80	15	35.60
250*250	2500	65	15	3500	80	15	35.60

III. C. Thermal performance analysis and optimization of self-insulated exterior wall panels

III. C. 1) Modeling

Modeling of self-insulated exterior wall panels for an integrated construction project. The length of the board H=3575mm, Table 3 shows the thickness of each layer of material and the correction coefficient of thermal conductivity of the external wall board. The thickness of the inner leaf of the self-insulated exterior wall panel is taken as 125mm, 165mm and 185mm, and the diameter of the steel bar is taken as 5.5mm and 6.5mm, with double-layer reinforcement; the thickness of the outer leaf of the aerated concrete wall panel is 65mm, with single-layer reinforcement, and the inner and outer leaf panels are connected by the metal tie members.

Table 3: Thickness and parameters of exterior wall panel materials

Structural layer	Layering thickness	Thermal conductivity coefficient	Correction coefficient
Outer leaf aerated concrete	65	0.25	1.30
Inorganic cotton insulation core layer	45	0.55	1.55
	55		
	65		
	75		
	85		
	95		
	105		
	115		
Inner leaf aerated concrete	125	0.25	1.30
	165		
	185		

III. C. 2) Model validation

In order to verify the reliability of the self-insulated exterior wall panel model designed by the development program based on building information modeling, and to ensure that the construction cost and time, etc. are optimized, the heat transfer coefficients of the multi-layer homogeneous panels were compared using the heat transfer coefficients calculated by the multi-layer homogeneous panels and the programmed calculation method, respectively.

Self-insulated exterior wall panels of span 3525*650 without considering the effect of reinforcement, ties and connections are used. Table 4 shows the heat transfer coefficients obtained for different combinations of different thicknesses. It can be seen that the values obtained by the specification algorithm and the program calculation method are exactly the same, and the heat transfer coefficients for the four different combinations are 0.545, 0.376, 0.452, and 0.317, respectively, which indicates that the thermal performance of self-insulated exterior wall panels can be accurately calculated by using the program modeling and analysis strategy of this paper.

Table 4: Calculation result of heat transfer coefficient

Number	D/mm/λ ($W \cdot m^{-1} \cdot K^{-1}$)			K/ ($W \cdot m^{-2} \cdot K^{-1}$)	
	Outer blade plate	Inorganic insulation board	Inner blade plate	Formula calculation	Model calculation
1	65/0.175	55/0.055	110/0.175	0.545	0.545
2	65/0.175	65/0.055	110/0.175	0.376	0.376
3	65/0.175	95/0.055	110/0.175	0.452	0.452
4	65/0.175	115/0.055	110/0.175	0.317	0.317
5	65/0.175	55/0.055	185/0.175	0.545	0.545
6	65/0.175	65/0.055	185/0.175	0.376	0.376
7	65/0.175	95/0.055	185/0.175	0.452	0.452
8	65/0.175	115/0.055	185/0.175	0.317	0.317
9	65/0.175	55/0.055	185/0.175	0.545	0.545
10	65/0.175	65/0.055	185/0.175	0.376	0.376

III. C. 3) Optimization of single-layer reinforcing mesh for outer-leaf aerated concrete slabs

In order to study the model optimization of single-layer reinforcing mesh on aerated concrete thermal conductivity correction coefficient of the outer leaf plate of self-insulated exterior wall panels simulation, designed for simulation and analysis of group A specimens.Group A specimens a total of five specimens, specimen A1 only to consider the specification of the correction coefficient of the impact on the aerated concrete, does not take into account the impact of reinforcing steel and tie members on the aerated concrete. Specimen A2-A5 reinforcement configuration of single-layer reinforcing mesh, not configured with tie members. The initial correction coefficient takes the value of 1. Specimen A2-A3 is configured with 3 longitudinal reinforcement bars in a single layer, and specimen A4-A5 is configured with 5 longitudinal reinforcement bars in a single layer, and the diameters of longitudinal reinforcement bars and transverse reinforcement bars.

Table 5 shows the effect of optimizing the single-layer reinforcing mesh of the outer leaf on the correction factor of the wall panels. Compared with specimen A1 without reinforcement, the heat transfer of the outer-leaf aerated concrete wall panels configured with single-layer reinforcing mesh increased, and compared with specimen group A1 where only the code correction factor was considered, the increase in the equivalent thermal conductivity versus the correction factor was 0.13%-0.21% when the outer-leaf aerated concrete panels were configured with 3 longitudinal reinforcement bars, at which time the correction factors for the thermal conductivity coefficients were 1.23 and 1.24. When the outer-leaf aerated concrete panel is configured with 5 longitudinal reinforcement bars, the increase in the equivalent thermal conductivity of the wall panel with the correction factor is 0.36%-0.42%, at which time the correction factor of the thermal conductivity is 1.25 and 1.26. It shows that the optimization of the relevant components of the external wall panel using the model can improve the thermal conductivity of the panel, i.e., the self-insulation capacity.

Table 5: Influence of single-layer steel mesh on the correction coefficient

Specimen Number	A1	A2	A3	A4	A5
Specimen thickness /mm	65	65	65	65	65
Longitudinal reinforcing bars	-	Single layer 3*3	Single layer 3*4	Single layer 5*3	Single layer 5*4
Transverse reinforcing bars	-	3	4	5	4
Correction coefficient given by the specification	1	1	1	1	1
Heat transfer capacity /W	86.12	86.43	86.68	86.51	86.87
Equivalent thermal conductivity/ (W/m·K)	0.1423	0.1424	0.1425	0.1426	0.1427
Model correction coefficient	1.20	1.23	1.24	1.25	1.26
Increase in equivalent thermal conductivity /%	-	0.13	0.21	0.36	0.42

III. C. 4) Temperature distribution of internal components of self-insulated exterior wall panels

After optimizing the thermal conductivity of the material components, the temperature variation of the self-insulated exterior wall panel design model was analyzed again. Figure 5 shows the temperature distribution of the internal components of the self-insulated exterior wall panel. As can be seen from Figure 5, in the temperature distribution diagrams of the reinforcing mesh, tie members and connectors, the reinforcing mesh has the smallest impact on the temperature distribution, and the temperature of the reinforcing mesh only decreases from 16.7°C to 5.8°C during the process of the wall panel width area from 0m to 0.25m in depth. The tie members had the greatest impact on the overall temperature distribution, with the temperature of the tie members decreasing from 16.6°C to 0.63°C for the same area change. The connectors, on the other hand, because they were set halfway inside the wall panels, had only half of the area affected by the thermal bridge, with the temperature decreasing from 14.3°C to 3.5°C. Based on the various types of internal components affected by temperature, the schedule-cost optimization model can be used to calculate the optimal construction route to ensure that the purchase time and quantity of the various types of components are in line with the construction plan, so that the various types of components can perform their roles and reduce the cost of construction consumption.

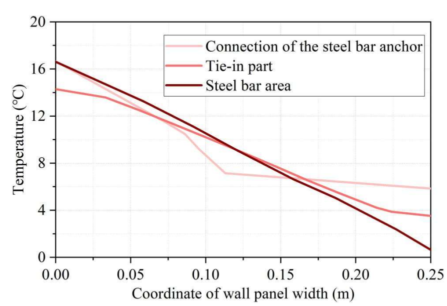

Figure 5: Temperature distribution inside the wall panel

IV. Conclusion

This paper integrates the development procedure of assembled composite self-insulated exterior wall panel and the construction progress-cost optimization model to realize the cost reduction and efficiency of the integrated construction of planted roof and self-insulated exterior wall panel. The average temperature of the bottom of planted roof is 32.4℃ in 24 hours, and the total heat transfer heat flow is 136.51W/m^2 in 1 hour, which can provide convenient conditions for the construction of self-insulated exterior wall panels. The heat transfer coefficients of the exterior wall panel models of 4 groups with different combinations are 0.545, 0.376, 0.452, and 0.317, which are consistent with the actual ones, indicating that the program modeling is effective. The width region of the wall panel varies in the range of 0m-0.25m, and the temperature of the reinforcing mesh decreases from 16.7°C to 5.8°C, the temperature of the tie member decreases from 16.6°C to 0.63°C, and the temperature of the connection member decreases from 14.3°C to 3.5°C. When calculating the optimal construction program, the temperature-affected conditions of different structural members need to be considered comprehensively to avoid unnecessary waste. In the future, the information of larger construction projects can be used to train the designed program and model to improve its application.

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