Calculation and seasonal difference analysis of energy consumption and carbon emission of industrial buildings

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Abstract. This article focuses on the production stage of industrialized building components. Through the analysis of the measured data, it is concluded that the unilateral carbon emissions generated by the consumption of natural gas in the steam curing stage of the northern factory account for more than 80% of the production process. The difference in natural gas consumption is the energy consumption and carbon emissions in the component production stage. The energy consumption and carbon emissions of the Nanfang (Longxin) plant in summer are higher than the transition season and winter; the power consumption and carbon emissions of auxiliary equipment in summer are close to 20% of the total carbon emissions during the production process, which is the season for energy consumption and carbon emissions in the component production stage. The main reason for sexual differences.

1. Introduction
Greenhouse gases are one of the main causes of global climate change. With the continuous improvement of global urbanization and the increasing construction activities, the carbon emissions generated by the construction industry have become the main source[1]. The construction industry consumes about 40% of the world's energy consumption and produces about 33% of the greenhouse gases every year[2]. Research shows that buildings can easily achieve 50%-60% energy saving effect through reasonable design [3]. Therefore, the research on energy consumption and carbon emission in the construction industry and the work on energy conservation and emission reduction are of far-reaching significance for the development of low-carbon economy and the control of global warming. In the process of the gradual reform of architectural type, industrial architecture as a new form of construction and carrier also came into being. Compared with traditional buildings, industrial buildings are characterized by high construction efficiency, short construction period, long building life, simple maintenance in the later period, resource saving and little impact on the environment [4]. At present, my country is vigorously promoting the development of industrialized buildings. The increase in the number of buildings will inevitably lead to an increase in energy consumption and carbon emissions. To reduce energy consumption and carbon emissions generated by buildings, the first thing to do is to accurately quantify these two items. Obtaining actual energy consumption and carbon emissions data at each stage of the building is the basis for scientifically and effectively promoting building energy conservation. Although the use and maintenance stage of buildings is the subject to calculate the energy consumption and carbon emission in the whole life cycle of buildings, the production stage of components, which is unique to industrialized buildings, is also the key point.
to study how to reduce energy consumption of industrialized buildings. In the component production stage, the energy consumption and carbon emissions of the same component in different seasons and different temperatures are different. Therefore, the reason for the seasonal difference in energy consumption and carbon emissions of assembled components is studied, which is proposed for the actual production of the factory. A more economical, environmentally friendly, energy-saving and emission-reduction direction is necessary to reduce energy consumption and carbon emissions in the construction industry.

2. Energy consumption and carbon emission calculation scheme of fabricated composite plate

2.1. The test object
This study mainly analyzes and studies the seasonal differences of energy consumption and carbon emissions. The biggest difference between different seasons is the difference in temperature, so the emphasis of seasonal difference analysis is the impact of temperature on energy consumption and carbon emissions in the production process of fabricated composite plate. In this study, a representative factory was selected as the test object in each constituency of China's north and south, namely Beijing Yantong Construction Component Factory located in Beijing and Longxin Factory located in Jiangsu Province. Yantong Construction component Factory belongs to the cold region, and the gas-fired steam boiler is used for steam maintenance of the components all year round. Longxin factory belongs to the area with hot summer and cold winter. Most of the time in a year, the natural maintenance work is carried out on the components. Only in winter, the gas steam boiler is selectively opened to carry out steam maintenance on the components such as the assembled composite plate.

2.2. Measuring and testing methods of assembled laminated plates
According to the results of field investigation, the production area of prefabricated composite plate is divided into six parts, namely concrete mixing station, prefabricated composite plate production line, steel bar production and processing, in-plant transportation, steam curing and auxiliary equipment. In this study, electric quantity recorder and current transformer are mainly used to test the current and voltage of each equipment in the process of assembling composite plate production in the factory, the daily output cubic meter of composite plate, the time and cubic meter of transportation in the factory and other contents.

3. Test results and analysis
The measured electricity consumption and natural gas amount are evenly distributed according to the total volume of the assembled composite plate produced, and the electricity consumed by the production unit cubic meter composite plate is the single power consumption, and the natural gas consumption is the single gas consumption. Then, according to the average carbon dioxide emission factor of unit power supply of China regional power grid and the value of natural gas carbon emission factor selected from IPCC carbon emission factor library [5], the single-side power-consumption carbon emission and the single-side gas-consumption carbon emission were calculated respectively, and the calculation results were compared and analyzed. In this study, the carbon emission factor of natural gas was 2.36kg/m³, the carbon emission factor of electric power of Beijing Yantong Plant was 0.8843kg/kWh, and the carbon emission factor of electric power of Jiangsu Longxin plant was 0.7035kg/kWh.

3.1. Data analysis of Beijing Yantong component Factory

| Date | concrete mixing plant | Automatic production line | Steam curing |
|------|-----------------------|---------------------------|-------------|

Table 1. Energy consumption of single-side fabricated composite plate produced during the test week
Table 1 shows the power consumption and carbon emissions of the assembled composite plate produced in the test week. The single-side carbon emissions from the mixing station and the automatic production line are about 6 kWh/m³, and the single-side carbon emissions from the steam curing stage can reach up to 143.98 kg/m³.

As can be seen from Figure 1 and Figure 2, the carbon emissions from natural gas consumption in both the test week and the whole year account for more than 80% of the total carbon emissions from the factory's production of prefabricated composite plates, while the electric carbon emissions from the concrete mixing station and the automatic production line account for a very small proportion of the total carbon emissions. It can be seen that carbon emissions from natural gas consumption in the steam maintenance stage play a dominant role in the production of prefabricated composite plates in Yantong Plant, which is also the biggest reason for the seasonal differences in energy consumption and carbon emissions in Yantong plant.

![Figure 1 Proportion of unilateral carbon emission in Yantong test Week](image)
Figure 2. Seasonal differences of carbon emissions in Yantong plant

Table 2. Seasonal differences of Carbon emissions in Yantong plant

| Time               | Single power consumption carbon emission (kg/m³) | Steam curing single consumption of carbon emissions (kg/m³) | Average one-way carbon emission (kg/m³) |
|--------------------|--------------------------------------------------|----------------------------------------------------------|----------------------------------------|
| Winter             | 11.86                                            | 94.10                                                    | 105.96                                 |
| Summer             | 13.84                                            | 60.43                                                    | 74.27                                  |
| Transition season  | 11.36                                            | 73.53                                                    | 84.89                                  |

As can be seen from Table 2, there is a small difference between the single power consumption of the three time periods, so it can be considered that the electricity consumption of the concrete mixing station and the assembled composite plate automatic production line in the production process has nothing to do with seasonality. However, there is an obvious seasonal difference in the unilateral gas consumption, which also proves that the main influencing factor of the gas consumption for steam maintenance mentioned above is the temperature at the location of the plant.

3.2. Longxin data processing and analysis

Table 3. Single power consumption and single power consumption carbon emission in winter working conditions of Longxin Plant

|                           | Concrete mixing plant | Automatic production line | Factory transportation | Steel bar production line | Total |
|---------------------------|-----------------------|----------------------------|------------------------|---------------------------|-------|
| Power consumption of single square concrete (kWh/m³) | 2.01                  | 3.65                       | 1.14                   | 1.74                       | 8.54  |
| Single power consumption carbon emissions (kg/m³)     | 1.42                  | 2.57                       | 0.75                   | 1.23                       | 5.97  |

Table 4. Single power consumption and single power consumption carbon emission in summer
working conditions of Longxin Plant

|                              | Concrete mixing plant | Automatic production line | Factory transportation | Steel bar production line | Axial flow fan | Total  |
|------------------------------|-----------------------|---------------------------|------------------------|---------------------------|----------------|--------|
| Single power consumption     | 2.01                  | 3.65                      | 1.14                   | 1.74                      | 1.89           | 10.43  |
| (kWh/m³)                     |                       |                           |                        |                           |                |        |
| Single power consumption     | 1.42                  | 2.00                      | 0.75                   | 1.23                      | 1.33           | 6.73   |
| carbon emissions (kg/m³)     |                       |                           |                        |                           |                |        |

Table 3 illustrates the tables 3 and 4, respectively is winter and summer conditions, dragon letter factory in the production of prefabricated composite plate unilateral power consumption and single carbon emissions, winter conditions, production of unilateral cubic meters of power consumption is 8.54 kWh/m³ after, the unilateral power consumption carbon emissions of 5.97 kg/m³ after, summer conditions, production of unilateral cubic meters of power consumption is 10.43 kWh/m³ after, the unilateral power consumption carbon emissions of 6.73 kg/m³ after.

![Figure 3. Ratio of carbon emission in winter in Longxin Plant](image)

![Figure 4. Proportion of single carbon emission in summer of Longxin Plant](image)

As can be seen from FIG. 3, the part of the automatic production line that accounts for the largest proportion between the power consumption and carbon emission in winter is more than 40%. The second is the concrete mixing plant, the least is the in-plant transport part.
It can be seen from Figure 4 that in summer, except for the automatic production line and concrete mixing plant, the electricity consumption of axial flow fan, which is unique to working conditions in summer, takes up the third part, accounting for nearly 20%. Thus, it can be seen that although the production process of assembled laminated plates in summer working conditions is the same as that of other time periods, the addition of axial flow wind opportunity has an impact on the energy consumption and carbon emission in the production stage of assembled laminated plates in summer working conditions.

4. Conclusions and Suggestions for energy conservation and emission reduction

The seasonal difference of energy consumption and carbon emission in northern factories is caused by the different temperature, which leads to the different amount of natural gas used for steam maintenance. In winter, the temperature is the lowest, and the energy consumption and carbon emission are much higher than other seasons. Under the premise of the longxin plant located in the south without steam maintenance in winter, the seasonal difference of energy consumption and carbon emission in the south plant is mainly caused by the use of axial flow fans.

Based on the above analysis, it is suggested that the factory should reasonably arrange the production plan:

1. Reduce unnecessary steam leakage
   In each season, the carbon emissions from the natural gas consumed by the Yantong plant in Northern China account for more than 80%. Therefore, the sealing of the steaming cellar is increased.

2. Increase flue gas waste heat recovery device
   The gas exhaust smoke temperature is up to 150℃, which contains a lot of sensible heat and latent heat. If the waste heat in the flue gas can be recovered, not only the waste of energy can be reduced, but also the economic cost of the project can be reduced.

3. Make full use of solar energy resources
   Add a solar steam maintenance device. The steam maintenance stage is the stage that produces the most energy consumption and carbon emission in the production process of assembled composite panels. If the solar energy device can be used as the heat source of the steam needed in the maintenance stage, the consumption of natural gas can be greatly reduced, so as to reduce energy consumption and greenhouse gas emission. Add a solar photovoltaic power generation unit at an appropriate location in the plant to provide electricity for the office and production areas of the plant.

References

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