Discussion on the Effectiveness of JGJ 26-2018 "Energy Efficiency Design Standard for Residential Buildings in Severe Cold and Cold Areas"

Hanyi Xu[1,a,*]

[1]*Aulin College, Northeast Forestry University, Harbin, China, 150006*
a. xu_susanna@163.com
**corresponding author*

Abstract: Building energy consumption is a substantial part of total energy consumption and is rising in the context of energy crises and environmental issues. To maximize energy savings and limit carbon emissions, the government recommends updating construction requirements. The Ministry of Housing and Urban-Rural Development of China proposed JGJ 26-2018 "Energy Saving Design Standard for Residential Structures in Extreme Cold and Cold Regions" in accordance to national policy. Several reports noted that some Chinese design requirements just stack energy-saving materials and technology without actually reducing energy consumption. This study proves the JGJ 26-2018's legitimacy. This essay first selects three major variables that have the largest impact on the energy consumption of buildings in extreme cold and cold areas—exterior walls, roofs, doors, and windows—and then gathers four cases of housing restoration of these three essential components according to JGJ 26-2018. The partial success of the strategy is proven by comparing energy consumption before and after building renovations, which provides a reference for energy-saving residential building design in severe cold and cold regions.

Keywords: energy consumption, severe cold and cold areas, residential buildings JGJ 26—2018, exterior walls, roofs, doors and windows

1. Introduction

China is suffering a severe energy crisis and natural environmental pollution, and buildings consume 45% of society's energy and 50.6% of its carbon emissions [1]. Building energy consumption will rise as the building sector develops, making energy-saving in structures more difficult. Designing green and low-energy building codes is crucial. Hence, the state consistently develops energy-saving rules and regulations and various building energy-saving standards to reduce building energy consumption as much as possible. The state's latest standard, JGJ 26-2018 "Energy Saving Design Standard for Residential Buildings in Extreme Cold and Cold Regions," regulates residential building construction characteristics to reduce energy consumption [2]. Although JGJ 26-2018 standards have become more and more popular in recent years, there are still studies that question various domestic energy-saving standards. For example, a previous report said that China has insufficient understanding of green and low-carbon buildings, and is only stacking various energy-saving materials and technologies [3]. Jiang Yi, an academician of the Chinese Academy of Engineering and a professor at Tsinghua University, pointed out that in recent years, many green energy-saving demonstration buildings have actually operated higher energy consumption than ordinary buildings [4]. Therefore, this paper collects four studies comparing the energy consumption of residential buildings located in severe cold and cold areas before and after renovation, and analyzes them. It aims to verify the effectiveness of the revision of JGJ 26-2018, and provide a theoretical basis for future new construction, expansion and reconstruction in severe cold and cold areas according to this standard.

2. Key Factors Affecting Building Energy Consumption

Since JGJ 26-2018 "Energy Efficiency Design Standards for Residential Buildings in Severe Cold and Cold Areas" imposes certain restrictions on the internal and external envelopes, heating, ventilation, gas, water supply and other aspects of buildings, this paper only focuses on a few factors that have the greatest impact on residential energy consumption. Liu Zongjiang et al. used the uni-variate analysis method to evaluate the regional adaptability of energy-saving technologies, and finally found that exterior walls, roofs, doors and windows are the three most important factors affecting residential energy consumption [5]. When a single enclosure is modified, it is called a single modification, and when multiple enclosures are modified at the same time, it is called a comprehensive transformation. All the cases listed in this paper are comprehensive renovations around the three factors of exterior walls, roofs, doors and windows. The parameters of heat transfer coefficients of external walls, roofs and doors and Windows stipulated in JGJ 26 -- 2018 are shown in Table 1 below.

Table 1: The partial standards in JGJ 26 – 2018.

Region	Part of the enclosure structure		Heat transfer coefficient(w/(m2·K))
Severe cold zone B	Roofs		0.20
	Exterior walls		0.35
	Windows	area ratio of window to wall≤0.30	1.8
		0.30<area ratio of window to wall≤0.45	1.6
Severe cold zone C	Roofs		0.20
	Exterior walls		0.40
	Windows	area ratio of window to wall≤0.30	2.0
		0.30<area ratio of window to wall≤0.45	1.8
Cold zone B	Roofs		0.30
	Exterior walls		0.45
	Windows	area ratio of window to wall≤0.30	2.2
		0.30<area ratio of window to wall≤0.45	2.0

3. China's Civil Building Energy Conservation Standards

China's extreme cold and cold areas endure a protracted winter with an average coldest month temperature of -10°C and -10°C ~ 0°C, respectively. Building performance has changed due to energy-saving design regulations. The first step of China's building energy conservation development is to lower local general design energy usage by 30% since 1986 [6]. The revised criterion required

30% energy savings for the second stage if the first stage was met in 1999–2006 [7]. From 2010~2018, on the basis of meeting the requirements of the second stage, an additional 30% energy saving (65% of the total energy saving) is the third stage [8]. An additional 25% of energy savings (75% of total energy savings) based on meeting the third stage requirements from 2019 [2].

4. Cases of the Renovation of Residential Building in Severe Cold and Cold Areas

4.1. The Renovation of Residential Building in Zhengzhou

4.1.1. Residential Buildings Before Renovation

In 2022, Ma Mengru investigated the renovation of a residential area (Completed by 2006) in Zhengzhou City (Cold B District) [9]. One of the residential buildings has a total of seven floors, with a total construction area of 4636m2, a heating and air conditioning area of 3277m2. Table 2 shows the condition of the original main envelope of the building. Most of the external walls of the building are not insulated, and the windows are mainly plastic steel single-layer windows or hollow windows.

Table 2: The condition of the original main envelope of the building.

Building parts	The composition of each enclosure structure before renovation	Heat transfer coefficient(w/(m2·K))
exterior walls	Cement mortar(20 mm)+Clay porous brick(240 mm)+ Lime cement mortar(20 mm)	2.05
roofs	Petroleum asphalt roofing felt (6 mm)+Reinforced concrete(40 mm)+Expanded perlite (40 mm)+EPS(60 mm)+Reinforced concrete (120 mm)+Lime cement mortar(20 mm)	2.18
windows	Aluminium alloy single-layer window	5.70
doors	Wooden framed single level solid door	1.70

4.1.2. Reconstruction Plan

The building belongs to the civil building in the second phase period, and according to the national energy-saving design requirements, the energy consumption of the existing building based on the status quo should be reduced by 40%. Based on the objectives, the residential buildings were renovated in Table 3 below.

Table 3: The condition of the main envelope of the building after the reconstruction.

Building parts	The composition of each enclosure structure before renovation	heat transfer coefficient(w/(m2·K))
exterior walls	PF (60mm)	0.34
roofs	PF (50mm)	0.28
windows	Vacuum+Low e membrane glass	2.20
doors	Wooden framed single level solid door	1.70

4.1.3. Energy Consumption After Transformation

Ma Mengru revised the coefficient of the standard calculation method, and gave the calculation formula of the heat consumption index q suitable for the renovation scheme of building envelope

DOI: 10.54254/2754-1169/29/20231348

structure. Calculations show that only by renovating the envelope structure can the building's heat consumption be lowered to 45% of the original, meeting the 40% energy reduction goal.

4.2. The Renovation of Residential Building in Shenyang

4.2.1. Residential Buildings before Renovation

DEST — H simulation software was used to simulate the energy consumption of a residential building rehabilitation project in Shenyang (Severe Cold Zone B)[10]. The building has five stories and 3187.5 m2. Table 4 displays the building's original primary envelope condition.

Table 4: The condition of the original main envelope of the building.

Building parts	The composition of each enclosure structure before renovation	heat transfer coefficient(w/(m2·K))
exterior walls	Cement mortar (30mm)+Crushed brick concrete (200mm)+Cement mortar (30mm)	2.42
roofs	Cement mortar (40mm)+Crushed brick concrete (40mm)+Reinforced concrete(140 mm)+Cement mortar (40mm)	2.81
windows	Ordinary single glazed window	4.70
doors	Wooden framed single level solid door	2.30

4.2.2. Transformation Plan

The building belongs to the civil building in the first phase of the period, and according to the national energy-saving design requirements, the energy consumption of the existing building based on the status quo should be reduced by 60%. Based on the objectives, the residential buildings were renovated in Table 5 below.

Table 5: The condition of the main envelope of the building after the reconstruction.

Building parts	The composition of each enclosure structure before renovation	heat transfer coefficient(w/(m2·K))
exterior walls	XPX (70mm)	0.37
roofs	PF (70mm)	0.20
windows	High light transmittance low-E film glass + air + transparent	1.90
doors	Aluminum-clad wooden door	1.30

4.2.3. Energy Consumption after Retrofitting

Liu Xin et al. simulated building renovation energy consumption using DEST–H. The envelope structure's multi-element change lowered the building's annual cumulative heat load and enhanced its energy savings rate.

4.3. The Renovation of Residential Building in Urumqi

4.3.1. Residential Buildings before Renovation

In the study "Comparative Analysis of Energy-saving Renovation Schemes of Existing Residential Structures in Severe Cold Regions," a residential area in Urumqi (Severe Cold Zone B) was renovated

DOI: 10.54254/2754-1169/29/20231348

using three energy-saving schemes based on updated design standards [11]. The residential community was completed during 1985 to 1990. There are 8 buildings, each building has 6-7 floors, brick-concrete structure water wall, and the construction area of 21,700 m2. Table 6 shows the condition of the original main envelope parts of the building.

Table 6: The condition of the original main envelope parts of the building.

Building parts	The composition of each enclosure structure before renovation	heat transfer coefficient(w/(m2·K))
exterior walls	Light mortar clay brick masonry(370mm)+ Cement mortar(20mm)	1.02
roofs	waterproof layer (4mm)+Cement mortar(20mm)+clinker (200mm)+Lime cement mortar(20 mm)	0.97
windows	Double layer steel window (general 5mm glass)	3.12

4.3.2. Transformation Plan

The original building is renovated using three energy-saving strategies to verify the test: Energy-saving standards of 30% for modest renovations, 50% for medium-scale renovations, and 65% for overhauls. The first-phase residential building must lower its energy use by 65% to meet national energy-saving design standards. This article only cites the overhaul proposal. Table 7 shows the principal renovation plan.

Table 7: The condition of the main envelope of the building after the reconstruction.

Building parts	The composition of each enclosure structure before renovation	heat transfer coefficient(w/(m2·K))
exterior walls	EPS (140mm)	0.31
roofs	Polyurethane (80mm) spray for slag (200mm)+Cold bottom oil barrier+Two-layer SBS (3mm)	0.20
windows	65 series single frame three glass two air plastic steel window flat open	1.80

4.3.3. Energy Consumption after Transformation

After the actual measurement of indoor temperature and energy consumption, the data are obtained. The coal saving amount per unit area during the heating period is 25.5kg, and the coal saving rate is 69.85%, exceeding the energy saving target of 65%.

4.4. The Renovation of Residential Building in Harbin

4.4.1. Residential Buildings before Rrenovation

Hebai Community in Harbin is the first existing residential building in Heilongjiang Province to carry out energy saving renovation according to the 75% energy saving standard, and it is also the demonstration project of green renovation of existing residential building in cold area. The paper "Actual Measurement of Energy saving Effect of Green Renovation of Existing Residential Buildings Hebai Community in Harbin" introduces the general situation of the buildings before and after the renovation and the technical measures of the renovation [12]. Harbin Hebai Residential Community is located in Harbin, built in 1999. The total construction area is 290,000 m2, with a total of 28 houses. There are a total of 15 residential buildings in this renovation, all of which are brick-concrete structures, 11 with 7 floors and 4 with 9 floors. The total construction area of renovation is 168159m2. Table 4.7 shows the condition of the original main envelope structure of the building.

Table 8: The condition of the original main envelope structure of the building.

Building parts	The composition of each enclosure structure before renovation	heat transfer coefficient(w/(m2·K))
exterior walls	Exterior wall paint finish + Thick cement mortar (2.2mm) + Solid brick wall (clay porous brick KP1) (3.5mm) + Cement mortar (4.2mm) + Interior wall plaster finish	1.25
roofs	Asphalt waterproofing roll + Cement mortar screed layer (2.2mm) + Slag concrete finding layer (3.8mm) + Cement mortar screed layer (4.2mm) + Cement expanded perlite insulation layer (5.1mm) + Cement mortar screed layer (6.2mm) + original roofing plate	1.26
windows	Double glass plastic steel window	2.50

4.4.2. Transformation Plan

The envelope is strictly modified in accordance with the Energy Saving Design Standards for Residential Buildings in Severe Cold and Cold Areas (JGJ26-2018). After the renovation, the exterior wall insulation mainly adopts 100mm thick B1 grade fireproof insulation material EPS polystyrene board, which is pasted with adhesive and the base wall, supplemented by plastic expansion nails and iron core expansion nails. The protective layer is a polymer anti-cracking mortar and embedded with alkali-resistant glass fiber mesh to enhance its performance, and the protective layer is a thin plastered surface layer with a thickness of 5mm and a paint finish. Fireproof isolation belts are set up every two floors, arranged horizontally along the direction of the floor slab, and 300mm wide Class A fireproof insulation materials are adopted. For the roof, remove the original slag, perlite and other materials with poor weight and thermal insulation performance, re-make the insulation and waterproof layer, use sprayed rigid foam polyurethane as the insulation layer on top of the original air insulation layer, and add two layers of SBC120 waterproof membrane. For exterior windows, the original window sealing strip is replaced with EPDM strip, and the glass spacer adopts warm edge spacer. A single frame double glass plastic steel window is added to the original outside window to form a double frame four glass window with excellent thermal insulation and sound insulation performance.The renovation plan is shown in Table 9 below.

Table 9: The condition of the main envelope of the building after the reconstruction.

Building parts	The composition of each enclosure structure before renovation	heat transfer coefficient(w/(m2·K))
exterior walls	Exterior wall paint finish + flexible water resistant putty + polymer crack resistant mortar (embedded glass fiber mesh cloth) (3.5mm) +EPS (100mm) + original base wall	0.35

Table 9: (continued).

roofs	C20 fine stone concrete with @100 bidirectional steel mesh (40mm) + low grade mortar isolation layer (10mm) +SBC120 waterproof membrane + 1:3 cement mortar screing layer (20mm) + 1:10 slag concrete find 3% slope (thinnest 30mm) +rigid foam polyurethane insulation layer (80mm) + reinforced concrete floor (150mm) + original roof air barrier layer	
windows	Single frame double glass steel window + double glass steel window	1.40

4.4.3. Energy Consumption after Transformation

JGJT 357-2015 "Technical Rules for On-site Detection of the Heat Transfer Coefficient of the Enclosure Structure" [13] guides envelope structure heat transfer coefficient testing. After testing, envelope structural insulation improves building energy efficiency. The building's heat consumption index is 15W/m2, 47.2% lower than the original building's, resulting in significant energy savings. The remodeling effect is successful since the building only needs to consume 40% less energy than the original building to achieve the standard in the second phase. The average household temperature during heating season is above 22°C, ensuring thermal comfort.

5. Conclusions

This study collates the energy consumption of four cases that have undergone renovation or simulation since the implementation of JGJ 26-2018 "Energy Efficiency Design Standards for Residential Buildings in Severe Cold and Cold Areas", aiming to verify the effectiveness of the revised Energy Saving Design Standards for Residential Buildings in 2018. The results of this study confirm this conjecture. The results show that the revised building energy saving standard, the energy efficiency of cold and cold areas have achieved 75% energy saving standard, and the energy saving effect is remarkable. This means that China's building energy conservation still has a lot of room for progress, which provides a solid foundation for China to achieve carbon neutrality before 2060. This study can provide a theoretical basis for the widespread implementation of energy-saving renovation in the future. In addition, this study only focuses on the effectiveness of the new standard and does not perform an analysis of economic performance, which has limitations. Therefore, further research can include parameters such as the cost and benefit of reconstruction, study the economy of energy-saving renovation, and develop the optimal solution that takes into account the energy-saving effect and economic performance, so as to avoid the problem of "energy saving without saving money".

While actively developing and striving to protect the environment, the whole country should increase efforts to promote energy-saving renovation, starting with government pilot projects and starting from point to point. Allowing residents to get a comfortable living environment while improving the urban environment. The energy-saving renovation of existing residential buildings is beneficial to the country and the people, and it is an inevitable choice. Whether it is the government, residents, families or even individuals, it must be enough to pay attention to. We should correctly understand the significance of energy-saving renovation and contribute to carbon neutrality by 2060.

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