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EIFS in China - History, Codes and Standards, Features, and Problems

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Abstract

Exterior Insulated Finishing System (EIFS) was introduced into China in the early 1980's. Since then, it has gone through several stages of development and is now enjoying the largest market share among all energy-efficient wall systems. The history of EIFS gradually becoming the most common energy-efficient exterior wall system is briefly reviewed. China has a series of EIFS-related codes and standards that can be divided into two categories: (1) codes and standards on building energy efficiency in general, (2) codes and standards specifically addressing EIFS. This paper reviews these codes and standards with a focus on the important regulations that are different from those in North America and Europe. Chinese EIFS has some features and problems that may or may not exist in its foreign counterparts. These features and problems, along with the underlying reasons, are discussed.

Keywords-component; EIFS; energy; wall; code; standard

1. Introduction

Exterior Insulated Finishing System (EIFS) is a type of exterior wall system that usually consists of a base wall, an insulation layer, one or multiple layers of exterior finishes, and other necessary components such as bonding agents, strenthening mesh, etc. EIFS was first developed in Europe after the World War II. Germany was generally credited as the birthplace of EIFS (Thomas, 1998).

Since EIFS addressed two immediate needs after the War, namely lack of natural materials such as petroleum and the need to provide insulation to the building, it quickly gained momentum in Europe and has been popular since then.

Europeans introduced EIFS into North America in the late 1960's. The US and Canada simultaneously developed their own EIFS industry and invented new versions of EIFS that suit the North American building needs. The two oil crisises in 1973 and 1979 made EIFS one of the most popular exterior wall systems designed and specified by architects and engineers. In the 1980's, EIFS market in the US expanded from the east coast to the west coast. Buildings with EIFS wall could be seen throughout the

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country. Since then, EIFS has been competing against other types of exterior wall systems and held its ground very well. It should be pointed out that the US EIFS, although having an European origin, differs from its European counterpart in several ways. One of the differences is that the European EIFS is typically installed on a solid base wall such as a masonry block wall while in the US a lot of EIFS are installed on a light-framed wall system, i.e., wood-framed walls and light gauge steel-framed walls.

2. EIFS in China

EIFS first appeared in China in early 1980's, approximately 30 years after it was invented in Europe and 20 years after Europeans introduced it into North America. The first group of EIFS advocates in China were some foreign EIFS companies who realized that China has a potential to become a significant market for EIFS. The current status of EIFS in China certainly proves that those people had a vision and a good sense of market 30 years ago.

Although EIFS is currently one of the most popular energy-efficient wall systems in China, it encountered a great deal of difficulty when it first entered the Chinese Market. Several reasons causing this difficulty are as follows:

1) In the 1980's, building energy conservation started becoming a concern in China. However, it was far from being a top priority in the eyes of the government and the building industry. Therefore, there were not much incentives for the architect, engineer, and building owners to abandon the traditional Chinese wall system that they are familiar with and embrace the new EIFS imported from abroad.
2) When EIFS first appeared in the Chinese market, it was by far the most advanced wall system, especially for energy performance. It was also much more sophisticated than the traditional Chinese wall that dominated the market then. Quite often, this wall was just one layer of 240mm-thick solid red clay brick, the interior and exterior being finished with mortar and plaster. The EIFS promoters found that there was no codes or standards they could refer to, which is absolutely vital to ensure quality construction for such a sophisticated wall system. The designers were hesitant to design or specify EIFS because no codes or standards was available. They tended to stick with the traditional wall system because it was easy and much less prone to design errors. Although the EIFS manufacturers provided them with specifications and data sheets, these documents were not considered official or authorative. Hence, the market share of EIFS was low.
3) Similar to other countries, the Chinese building industry is an industry with a great deal of inertia, i.e., having a strong tendency to stick with the old and familiar products and being reluctant to accept the new and innovative ideas and products.

All these factors caused a relatively low market share of EIFS in China throughout the 1980's. The fate of EIFS took a sharp turn in the 1990's. Starting from the early 1990's, the Ministry of Construction (MOC, now the Ministry of Housing and Urban-Rural Development of China, abbr. MOHURD) and the provincial construction administrations, acting on a realization that EIFS is a superior energy-efficient wall system to the traditional Chinese wall, took a lead on developing new EIFS's that are suitable for the Chinese market. Many universities, research institutes, design companies, and manufacturers were active in importing the EIFS technology from abroad. In 1996, MOC organized the First National Meeting on Building Energy Conservation. This meeting turned out to be a monumental event in the development of EIFS in China. It discussed and summarized the practice of EIFS in China and reached a consensus that promoting EIFS should be a priority for the Chinese building industry to achieve energy efficiency.

After the 1996 meeting, EIFS started thriving and quickly became the most popular energy-efficient wall system in China. The Association of EIFS was founded and a series of books and technical manuals on EIFS were published, among which two of them are noteworthy: Technology of Exterior Insulated

Finishing System (Ma, 2007) and One Hundred Questions on EIFS Technology (Zhenli, 2007). These publications typically address two issues: (1) the theory and technology of EIFS that is already well established in Europe and North America, (2) the current status of EIFS and some EIFS's originally developed in China. Meanwhile, the fast growing Chinese EIFS market is attracting many foreign companies and organizations to China for collaboration, technology exchange, international meetings, and business opportunities. The most active countries include the US, Germany, Canada, the UK, Holland, Denmark, France, etc.

3. Codes and standards

There are many codes and standards in China that are relevant to EIFS. They can be categorized into two groups: (1) the codes and standards that address buildings and building energy efficiency in general, (2) the codes and standards that are issued specifically for EIFS.

4. Codes and Standards Concerning Building Energy Efficiency in General

All of the codes and standards related to EIFS start from the code on climate classification in that China is a vast country with various climate zones and each climate zone has different requirements for EIFS. The current Chinese national standard on climate classification can be found in "Thermal Design Code for Civil Building" (MOC, 1993). It was issued and adopted in 1993. Little has been changed since then. This code is referred to as GB50176-93 ("GB" stands for National Standard).

GB50176-93 is a comprehensive design code for thermal design of civil buildings. In Section 3.1.1, China is divided into five climate zones, namely Severe Cold (SC), Cold (C), Temperate (T), Hot Summer and Warm Winter (HSWW), and Hot Summer and Cold Winter (HSCW). Table 3.1.1 in GB50176-93 is shown below:

Table I. Climate zones of China for thermal design of civil buildings

Climate zone	Zoning criteria	
	Primary criterion	***Secondary criterion***
SC	$T_{avg,cold}\leq$-10℃	$D_5\geq145$
C	-10℃$\leq T_{avg,cold}\leq$0℃	$90\leq D_5\leq145$
HSCW	-10℃$\leq T_{avg,cold}\leq$0℃ 25℃$\leq T_{avg,hot}\leq$30℃	$90\leq D_5\leq145$ $40\leq D_{25}\leq100$
HSWW	$T_{avg,cold}\geq$10℃ 25℃$\leq T_{avg,hot}\leq$29℃	$100\leq D_{25}\leq200$
T	0℃$\leq T_{avg,cold}\leq$13℃ 18℃$\leq T_{avg,hot}\leq$25℃	$0\leq D_5\leq145$

In Table 1, $T_{avg,cold}$ denotes the average temperature of the coldest month; Tavg,hot denotes the average temperature of the hottest month; D_5 denotes the number of days with a daily average temperature lower than 5℃; D_{25} denotes the number of days with a daily average temperature higher than 25℃. A climate zoning map is included in GB50176-93 and the code does not state how this map was developed and no literature can be found on the development of the map.

The current climate classification for thermal design of civil buildings has been implemented in China for over 15 years. It has a profound influence on EIFS and the building energy efficiency in general. However, it has several drawbacks that can be improved:

- The climate zoning map is, in essence, a thermal map in that the primary parameter considered for classification is the average temperature of the coldest month and the hottest month. The secondary parameter is the number of days with a daily average temperature lower than 5℃ or higher than 25℃. Both these two parameters are essentially temperature related. Moisture effect is not taken into account at all in the climate classification.
- The boundary of each climate zone does not exactly match the boundary of the county, the basic political district in China. Therefore, the boundary of the climate zones divides some counties into two or even three parts. This makes the implementation of the code somewhat difficult in those counties because which climate zone applies is not clearly defined.
- As previously mentioned, there is no literature available on how this climate classification was developed more than 15 years ago. The idea, logic, principles, and other detailed information on the development of the map are unknown. Hence, it is difficult to assess the scientific rigor of the classification.

Despite the limitations aforementioned, the current climate classification addresses one of the most significant features of the Chinese climate, i.e. the HSCW (Hot-Summer-Cold-Winter) climate zone. The HSCW climate zone encompasses 16 provinces along the Yangtze River, in which more than 550 million people live. It is the most developed economic region with a very dense population. The construction activity in this region accounts for a large portion of the total construction activity in China.

The HSCW zone has, as its name suggests, a hot summer and a cold winter. The average temperature of the coldest month is between 0~10℃. Low temperature below freezing point occurs quite often in January and February. The average temperature of the hottest month is between 25~30℃. The temperature in July and August is often as high as 35℃. This kind of climate imposes a unique challenge on building enclosure and mechanical system design. Both cooling in summer and heating in winter need to be addressed. The optimal R-value (in China, K-value, the reciprocal of R-value, is more often used to describe the insulating capability of the enclosure) of the enclosure system, the selection and sizing of the mechanical system, the detailing of the building, etc. need to be calculated and designed carefully. Summer in the HSCW zone is both hot and humid. High temperature combined with high humidity makes the indoor environment almost unbearable without air-conditioning, which unfortunately is the case for most buildings built in and before the 1980's.

There are currently more than ten active codes addressing building energy efficiency in China. They are written based on different building types and climate zones. Two issues need to be noted:

- These codes divide buildings into two categories: residential and public. Here, "public building" is a large category that includes almost all of the non-residential buildings such as commercial, educational, medical, office, etc. This broad definition has caused some problems in the practice. Since the code tends to be too general, it is not able to precisely address some special requirements of particular building types.
- MOC has been working on developing one building energy efficiency code for each of the 5 climate zone. It is natural that the first climate zone that China started to develop such code for is the one with the largest population and the most developed economy. Therefore, the first building energy efficiency code is "JGJ134 - Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (MOC, 2001). The framework of JGJ134 was later adopted by the same codes for other climate zones. The active Chinese codes and standards concerning building energy efficiency are summarized in Table 2. In addition to these national codes, many provinces have their own codes and standards regulating building energy efficiency. Most of them are primarily based on the national code that is applicable to the climate zone that

the province is located in. Some more detailed regulations are usually added to these provincial codes and standards.

An interesting finding is that Table 2 lists six national codes on building energy efficiency and five of them are applicable to residential buildings. This should not be a surprise in that it is predicted that in the next 15 years China will build more than 15 billion square meters of residential buildings (THUBERC, 2007). As discussed previously, the term "public building" used in the Chinese codes and standards includes a variety of non-residential buildings. Hence, that only one national code on building energy efficiency is applicable to public buildings is a major drawback. All being public building, hotels, hospitals, educational facilities, and shopping malls clearly have drastically different design requirements concerning energy efficiency. The codes and standards development of energy efficiency for public buildings in China needs to be improved.

ASTM in North America and EOTA in Europe have a series of standards and specifications on EIFS, addressing the materials, the system, the quality control, the testing methods, etc. Similarly, China also has codes and standards specifically addressing EIFS. The most important ones include: Standard for Exterior Insulated Wall System (JGJ 144-2004), Exterior Insulated Wall System with Expanded Polystyrene Board (JG 149-2003), Exterior Insulated Wall System with Expanded Polystyrene Particles (ETIRS, JG 158-2004), Guide for Exterior Insulated Wall System.

5. Features and problems of chinese eifs

5.1 Features

Although Chinese EIFS was originally imported from abroad, it has been evolving to form some unique features that differentiate itself from its European and North American counterpart. Two of them are discussed in this section.

A large number of buildings in China are finished on the exterior with tiles, made of ceramic, clay, or other materials. During the 1980's and 1990's, tile-finished buildings dominated the market, especially on residential buildings. Therefore, Chinese EIFS has to accommodate different tiles as the exterior finishing. These tiles are directly attached or "glued" to the substrate by adhesive, usually mortar. Problems such as separation from the substrate and even falling of the tiles have been reported. Hence, some stake-holders proposed that tiles should not be allowed to be directly attached to EIFS as the exterior finish. This topic has been debated in the Chinese EIFS community. So far, the national codes on EIFS have been neutral on this issue.

In addition to the EIFS commonly seen in Europe and North America, ETIRS (Expanded Polystyrene Granule as Aggregate System) has some market share in China. ETIRS was invented by Zhenli High Technology Company, a large Chinese EIFS manufacturer in Beijing. ETIRS does not use pre-manufactured insulation board or spray-on foam insulation; rather, it makes the insulation layer on site by mixing expanded polystyrene granule aggregate with inorganic binding powder and water. Compared with the conventional EIFS, ETIRS is cheaper in cost and faster in construction. However, ETIRS is not able to provide an adequate R-value that satisfies the building energy code in the cold region. Therefore it has been gradually fading out of the market in northern China. Nevertheless, it is argued that ETIRS is still a suitable EIFS for southern China where winter is mild. Meanwhile, Zhenli has been actively promoting three principles of designing and constructing EIFS: (1) EIFS is superior to the interior insulated finishing system, i.e. attaching the insulation on the interior surface of the exterior wall. (2) Cracking-free EIFS can be achieved by designing a so-called "system with gradually changing and flexible components". It is believed that the reason why the conventional EIFS in China has serious cracking problems is that the system is designed and built with too much rigidity. Zhenli promotes to design an EIFS with each component's physical properties changing gradually and having enough flexibility. These properties include strain, elastic modulus, flexibility, and compressive strength. The detailed requirements for these properties can be found in (Zhenli, 2007). (3) There should be no cavity between the base wall and the insulation layer.

Table II. Chinese codes and standards on building energy efficiency

Code	Applicable building type	Applicable climate zone	Year issued
GB50176 - Thermal Design Code for Civil Building	Residential	All 5 climate zones	1993
GB50189 - Design standard for energy efficiency of public buildings	Public	All 5 climate zones	2005
JGJ134 - Design standard for energy efficiency of residential buildings in hot summer and cold winter zone	Residential	Hot summer and cold winter zone	2001
JGJ26 - Energy Conservation Design Standard for New Heating Residential Buildings	Residential	Severe cold and cold zones	1995
JGJ75 - Design standard for energy efficiency of residential buildings in hot summer and warm winter zone	Residential	Hot summer and warm winter zone	2003
JGJ129 - Technical Specification for Energy Conservation Rennovation of Existing Heating Residential Building	Residential	Severe cold and cold zones	2000

ETIRS was patented in China and quickly gained momentum. The standardization and codification process of ETIRS first started in Beijing where the manufacturer is located. In 2001, the construction guideline for ETIRS was approved by MOC as a national guideline. In 2004, MOC issued "External thermal insulating rendering systems made of mortar with bonding powder and using expanded polystyrene granule as aggregate" (MOC, 2004b). These industry standards have greatly helped the system to gain popularity in China. Lately, ETIRS has seen decreasing market share in northern China mainly because it is difficulty to achieve a high R-value required in a cold climate. On the other hand, it has moved south and found new market in southern China.

5.2 Problems

Since it first appeared more than 30 years ago, EIFS has steadily grown to become the dominant energy-efficient wall system in China. As more and more EIFS are being designed, specified, and constructed on various types of buildings, some problems arise. This section is not intended to provide an exhaustive list of EIFS problems; rather, several important ones that have attracted much attention and caused heated debate in China are discussed. Note that these problems are not unique for China in that they also exist in North America and Europe to a certain degree.

5.3 Fire safety

Due to the organic nature of thermal insulation, EIFS, compared with a concrete or brick wall, is more susceptible to fire. Fire in a high-rise building usually spreads faster and wider than that in a low-rise building and therefore, causes more serious damages. In China, EIFS applied on a high-rise building is more common that that in Europe and North America. Hence, fire safety of EIFS is a more critical issue for China. The code that is applicable to fire safety in high-rise buildings is "Code of Fire Safety for High-rise Civil Buildings" (MOC, 2001b). Unfortunately, it does not cover the fire safety issue for EIFS. As this paper is written, there is no national code that addresses the fire safety of EIFS. It is worth mentioning that some international EIFS companies, when marketing in China, intentionally or unintentionally ignore the fire safety issue. Disasters caused by EIFS catching fire have happened in Beijing, Jinan, Guangzhou, Shanghai, and several other Chinese cities. The fire safety of EIFS, especially on high-rise buildings, is an urgent issue and needs to be addressed immediately.

5.4 Quality assurance

When EIFS was first introduced into China by some foreign companies, Chinese developers, designers, and construction workers were not familiar with this new type of building wall construction. In addition, EIFS was more sophisticated than the Chinese traditional wall system and no codes or standards were available. Hence, the quality of EIFS built then was not satisfactory, to say the least. As EIFS gradually gained market share and codification moved forward, the situation was getting better. Quality assurance is critical to install a working and durable EIFS. The most common quality problems of EIFS in China include cracking, separation, bulging, etc. Construction deficiencies include inadequate detailing, low-quality materials, poor workmanship, application under hostile environment, etc. It is widely believed that good design and careful application are equally important and education is the key.

5.5 Durability

Compared with internally insulated system, EIFS is more exposed to the exterior environment. The thermal insulation is more vulnerable to degradation caused by environmental loading. Among the five climate zones in China, the HSCW zone poses the most serious challenge to the durability of EIFS. Under a large temperature cycle, a significant thermal stress may develop on the exterior finishing layer. For instance, in Shanghai, the surface temperature of the exterior finishing layer of EIFS can be as high as 75 °C under direct summer sun. In a thunderstorm, the sudden temperature drop can reach 50 °C, causing a high thermal stress. The deformation of the exterior finishing layer can cause crack and separation from the substrate.

Since China has not conducted enough research on the durability of EIFS, MOC referred to several foreign standards, mainly EOTA ETAG004 (EOTA, 2003), and issued a Chinese standard test for the durability of EIFS as part of JG149-2003 (MOC, 2003). It involves a large-scale mock-up test in which cyclic thermal loads and cold rain under high temperatures are applied. The standard test provides a means to check the durability of EIFS. However, it is not used in practice as often as it should be mainly because of the unwillingness to pay the testing fee. On the other hand, how suitable ETAG004 is for the Chinese climate and the Chinese EIFS practice is still questionable. More research work needs to be carried out on this topic.

5.6 Overhead hazard

EIFS with exteriorly attached tiles is a popular choice for a lot of developers and architects in China. Tiles are often attached using mortar to the substrate and mechanically fastened tiles are rare. It is vital to ensure a good bonding between the tile and the substrate to avoid falling of the tiles and overhead hazard. That this type of EIFS is commonly installed on high-rise buildings accecerbates the problem because wind suction to pull the tiles off, especially around corners, can be significant on high levels. There is currently an on-going debate in China on whether or not the EIFS with exteriorly attached tiles should be allowed on high-rise buildings.

6. Conclusions

EIFS, first imported from abroad, has become the most common energy-efficient wall system in China. It encountered difficulties when entering the China market in the early 1980's. The tide turned in the 1990's as the government realized that EIFS is a suitable energy-efficient wall system. MOC and the provincial bureaus of construction have issued a series of codes and standards regulating and guiding the design and construction of EIFS.

EIFS in China has some unique features differentiating itself from its North American and European counterparts. EIFS with exteriorly attached tiles is common in China. ETIRS was invented by Zhenli and became a viable system. Chinese EIFS industry faces some problems that need to be resolved. Several more important ones include fire safety, quality assurance, durability, and overhead hazard.

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