

黄 圻 主编

**ARCHITECTURAL CURTAIN**  
WALL AND STRUCTURE

# 建筑幕墙 与构造

中国建材工业出版社

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## 内 容 简 介

为了充分反映我国近几年幕墙业的发展成就,更好地促进建筑幕墙行业的发展,特编写此书。本书主要介绍文化建筑、办公建筑、酒店建筑、商业建筑、体育建筑和交通建筑六个方面32个工程,包括上海东方艺术中心、中央电视台新址、北京新保利大厦、国家游泳中心“水立方”、国家体育场“鸟巢”和北京首都国际机场等。这些工程都是我国独立开发具有自主知识产权的产品,在重大幕墙工程招标中显露出独特的设计思路,在施工组织方案设计中体现了中国特色的企业文化和管理。这些建筑幕墙和构造具有时代性、前瞻性,对国内建筑幕墙设计和施工具有一定的参考价值,是建筑设计师必备的工具书。

## 建筑幕墙与构造

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# 前言 Foreword

建 | 筑 | 幕 | 墙 | 与 | 构 | 造

中国建筑幕墙行业虽然起步较晚，但起点高，1983年北京长城饭店第一个玻璃幕墙的兴建，拉开了我国建筑幕墙应用技术的序幕。25年来，中国始终坚持技术创新的发展道路，通过引进国外先进技术，开发适合我国的新产品，开拓市场，优化产业结构，形成了具有中国特色的可持续发展的技术创新机制。

## 一、中国建筑幕墙行业20多年的发展

中国铝门窗、建筑幕墙行业经过25年的发展，已经成为由1.2万家生产企业和2500多个配套企业组成的生机勃勃的新兴建筑产业。2006年全行业工业总产值达1616.4亿元人民币，其中幕墙总产值为687.8亿元人民币，年消耗建筑铝型材520万t。目前，铝门窗幕墙行业拥有一级幕墙施工资质企业291家，二级资质企业845家。由国外特大型幕墙企业和门窗系统公司组成的建筑幕墙设计、施工专项技术队伍已成为该行业不可或缺的生力军。以150多家产值过亿元的技术创新骨干企业为代表，这批大型骨干企业完成的工业产值约占全行业工业总产值的60%以上。它们承担了国家重点工程、大中城市形象工程、城市标志性建筑等大型建筑幕墙工程，为全行业树立了良好的市场形象，成为全行业技术创新、品牌创优和市场开拓的主力军。在这些团队中不乏一些优秀企业，沈阳远大企业集团就是优秀的企业之一，该集团2007年总产值高达120亿元人民币，他们承接了奥运会的水立方、鸟巢、新保利大厦等幕墙工程，前不久还承接了具有欧洲第一高楼之称的俄罗斯联邦大厦的幕墙工程和德国法兰克福机场的扩建工程；深圳金粤幕墙装饰工程有限公司刚刚完成了广州电视塔的幕墙设计，该塔是比加拿大多伦多电视塔还要高的世界第一电视塔，幕墙设计施工难度可想而知；北京江河幕墙股份有限公司正在施工的北京中央电视台幕墙工程，技术要求高，幕墙不仅要求达到最佳的保温、节能和隔声性能指标，而且还要具有防爆炸、防火性能。防爆炸幕墙设计在我国幕墙工程中尚属首例，为此建设部、公安部的有关专家做了大量的研究工作。近些年的建筑幕墙工程还有国家大剧院、北京首都机场三期工程、2008奥运会场馆幕墙工程等。由此我们可以说：建筑幕墙早已不是建筑上“一件花哨的外衣”，而是具有节能、保温、隔声，甚至具有防火、防爆炸等作用的最为理想的建筑外维护结构体系。

近几年，中国建筑幕墙的产量始终维持在5000万m<sup>2</sup>/a以上的水平。我国的建筑幕墙建设，从北京的奥运会场馆到上海世博会，从东部沿海地区到西部，随处可见新型建筑幕墙装点着秀丽多姿的现代化建筑，建筑幕墙与周边环境和谐辉映，已成为美化城市不可或缺的人文景观。

## 二、建筑幕墙是现代新技术、新材料的集中体现

建筑幕墙之所以有生命力，是由于近些年世界各国都在致力于建筑新技术、新材料的应用。多年来，各国科学家不断研制具有节能、环保、防火等技术特性的材料，如Low-E玻璃、具有保温隔热性能的铝合金型材、真空玻璃、各种人造幕墙板材等，这些产品的应用大大促进了传统幕墙产业的发展。特别是在节能、环保、降噪等技术方面取得的重大突破，为实现我国建筑节能的总体目标“到2020年，我国住宅和公共建筑建造和使用的能源资源消耗水平要接近或达到现阶段中等发达国家的水平”奠定了良好的基础。

近几年，我国的幕墙企业通过产、学、研相结合的科技创新机制，不断地开发新产品，形成了优化产业结构和可持续发展的技术创新机制，取得了一系列重大技术成果。

近几年来，中国建筑业的蓬勃发展也为建筑幕墙行业提供了一个大显身手的场所。这些可以满足不同建筑结构的设计需求的幕墙产品，如单元式幕墙、点驳接幕墙、双通道幕墙、单索及网索幕墙、光电幕墙和智能幕墙等在工程实践中的成功应用说明：建筑幕墙是迄今为止最理想的大型公共建筑外维护结构。

《公共建筑节能设计标准》(GB 50189)的实施，为建筑幕墙行业提出了更高的要求，从而推动了我国建筑幕墙行业的技术进步，适时推广节能门窗幕墙产品，逐步改造旧有建筑墙体和既有建筑中达不到建筑节能标准的幕墙，其前景极其广阔。

## 三、建筑霓裳，构筑美妙绝伦的都市风采

未来五年，中国铝门窗及建筑幕墙行业还将继续保持稳步增长的态势，建筑幕墙仍将是公共建筑中外维护结构的主导，是美丽都市风采的缔造者。2008年的北京奥运会工程已经成为当今世界建筑幕墙行业的亮点，奥运会主体建筑幕墙工程既是世界顶级幕墙公司展示自己实力和最新技术的舞台，也是国内外幕墙公司拼实力的战场。这些建筑幕墙工程的技术以体现建筑主体风格、通透、节能环保和舒适为特点。在未来的发展过程中，建筑幕墙索结构设计、玻璃结构设计等关键的前沿技术将取得更大突破。2010年中国的建筑幕墙行业的主要技术领域将达到国际先进水平。

回顾近些年来我国建筑幕墙行业取得的重大成就，中国人民无不为之感到骄傲与自豪。国家大剧院——世界首座大型钛金属板幕墙工程，工程采用0.44mm的钛金属复合板，其金属光泽可维系百年不变，幕墙的保温、隔声性能极高，能保证大剧院内部常年恒温，即使在剧院外面降大雨的情况下，也能保证剧场内部的绝对安静。新保利大厦采用了全世界最奇特的索结构玻璃幕墙，不仅在设计上突破创新，挑战多项纪录，在施工技术上也开创了国内之先河。同时，项目采用了大量超高强度、超规范、超标准建筑材料，在世界范围内也是首次应用，施工难度极大，主拉索拉力最高达1828t，而非对称索结构设计使得每一块玻璃的安装都具有相当大的难度。中央电视台建筑幕墙工程全部使用铝合金隔热型材，四片中空夹胶玻璃，具有极高的保温隔热性能，其隔声性能在40dB以上，保证了室内声音、视频采集工作的特殊要求。北京奥运会国家游泳中心“水立方”位于北京奥林匹克公园内，幕墙工程宽度177m，采用ETFE膜结构设计，幕墙由3700多个气枕构成，最大气枕跨度10m，每一个充气枕为一个独立的单元，充气泵用计算机控制，保证了气膜体的均匀一致，是世界面积最大、技术难度最大、最复杂的膜结构工程。当初中国奥委会之所以选中了膜结构就是看中了它的通透、节能保温特性。北京南站的主站屋顶，使用了4186块太阳能光电板，整体面积6700m<sup>2</sup>，占了整个屋顶采光面积50%左右，总发电量约320kW。玻璃采光屋顶可以有效地增加白天的采光面积，节约大量的电费，太阳能光电板可以发电，是一个真正意义上的建筑节能产品。

中国还将继续成为全世界建筑幕墙行业的热点。目前，中国已经能够独立开发具有自主知识产权的产品，在重大幕墙工程招标中已显露出企业独特的设计思路，在施工组织方案设计中则更体现了中国特色的企业文化和企业文化。近几年，一大批令世界建筑行业瞩目的大型幕墙工程陆续开工。这个时期行业积蓄待发、蓬勃发展，中国建筑幕墙行业开始走向成熟发展阶段。

#### 四、建筑节能工作促进新型幕墙材料工业的发展

根据我国国情和实现经济与社会可持续发展的要求，节能是我国的一项长期方针，建筑节能是我国发展的基本国策之一。建设部发布的《关于发展节能省地型住宅和公共建筑的指导意见》，无疑是吹向建筑幕墙行业的春风，它不断催生出适合建筑幕墙行业发展的新技术和新产品，因而也促进了新型幕墙材料工业的发展。许多新型建筑材料的使用，提高了建筑幕墙的节能指标，扩大了建筑幕墙的使用范

围，如大理石材、铝单板、复合铝板、蜂窝铝板、微晶玻璃、瓷板、陶土板、树脂木纤维板、纤维增强水泥板、石材蜂窝板、纤维增强水泥板等的使用，大大增加了建筑幕墙的内涵和外延，使幕墙由原来的单一墙体演变成为结构新颖，饰面材料亮丽，既能满足建筑外观又能满足建筑节能要求，给人以耳目一新的视觉冲击感的新型多功能建筑结构，完全打破了千百年来普通混凝土墙体、砖墙、瓷砖的老面孔，这无疑是建筑行业的一场革命。

中国的建筑幕墙行业经历了25年的发展，培养了一大批具有实践经验的技术人员，设计研发能力居世界领先地位；我们积累了丰富的实践经验，施工能力位居世界前列。2007年我国的建筑幕墙出口总值约350亿元人民币，幕墙工程在英国、德国、俄罗斯、沙特阿拉伯、美国等50多个国家应用、建设。中国的幕墙行业正在进入持续稳定的蓬勃发展时期，中国的幕墙开始走向世界。

公共建筑节能标准的实施是我国推动行业技术进步、提高行业设计施工水平的大好时机，优胜劣汰，逐步淘汰前几年的陈旧、不节能的老产品，适时推广节能产品，逐步改造旧有建筑墙体和既有建筑不节能的幕墙。中国的幕墙行业已经进入持续稳定的辉煌发展时期。

为反映最近几年我国幕墙业的发展成就，我们特编写此书。本书由中国建筑金属结构协会副秘书长黄圻主编，参加编写的有沈阳远大铝业工程有限公司谢海状、高晓峰和陈立鹏、深圳金粤幕墙装饰工程有限公司王春和董米丘、深圳市三鑫特种玻璃技术股份有限公司张桂先、邱奕文和郭建国，北京江河幕墙股份有限公司魏东海，武汉凌云建筑装饰工程有限公司胡忠明。

由于作者水平有限，失误和不当之处在所难免，敬请读者指正。

黄圻

2008年10月18日于北京



# Foreword

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Despite a relatively late catch up, China's Curtain Wall Industry has started at a high level. The first glass curtain wall application on Beijing Great Wall Sheraton Hotel in 1983 has drawn up the curtain for the applications of curtain walls on buildings in China. Over the past 25 years, China has persistently taken the path of technology innovations for development. A sustainable technology innovations mechanism has been established with Chinese characteristics, by introducing advanced technologies from overseas countries, developing new products suitable for China, exploring markets, and optimizing the industrial structure.

## I. 20 Years of Development of China's Curtain Wall Industry

With 25 years of development for Aluminum windows, doors and curtain wall industry in China, it has turned into a vigorous emerging construction industry, composed of 12000 manufacturers, and over 2500 supporting enterprises. In 2006, the annual industrial output reached 161.64 billion RMB, among which the curtain wall output hit 68.78 billion RMB, at a consumption of 5.2 million tons of aluminum profiles. Up until now, there are 291 Grade A enterprises for curtain wall construction, and 845 Grade B enterprises in the industry of aluminum windows, doors and curtain walls. Teams with expertise and special technologies and teams of professional curtain walls design formed by overseas large sized curtain wall enterprises and fenestration corporations

are indispensable mainstreams in this industry. Represented by over 150 back bone enterprises with technology innovations and an output of more than 100 million RMB, this large batch of back bone enterprises accomplished an industrial output of over 60% out of the total for the whole industry. They have shouldered the responsibilities of large curtain wall constructions like National Key Projects, Large & Medium City Image Projects, Landmark Projects, ect., which has established a noble market image for the entire industry, and has become the main force of industrial technology innovations, brand stewardship and market explorations. Among these teams, prominent enterprises abound in Shenyang YuanDa Group and many others. Shenyang YuanDa Group realized a 12 billion RMB worth of output in 2007, when they were contracted with curtain wall constructions for Water Cube, Bird's Nest, New Poly Building, etc. Not long ago, the curtain wall installation on Russian Federal Building, the Tallest Building in Europe and an expansion project for Frankfurt airport in Germany have been contracted to them. Curtain wall design and construction for the tower taller than the World's Tallest TV Tower of Toronto TV Tower is extremely difficult as imagined. The curtain wall project for Beijing CCTV Tower under construction by Beijing JiangHe Curtain Wall Co.,Ltd, is highly required in technologies, which include not only optimized thermal insulation, energy conservations and sound proof performance

indexes, but also explosion proof, and fire proof performances. Explosion proof design for curtain walls is the first to be found in China, and therefore experts with Ministry of Construction and Ministry of Public Security have conducted a lot of research and study. Curtain wall projects for recent years also can be found in National Grand Theater, Beijing Capital Airport Phase Three, and 2008 Olympic Venues, etc.. Therefore, we can fairly say: "Curtain Wall Industry has long transformed from 'a fancy overcoat' to the most ideal envelope of the buildings with functions of energy conservation, thermal insulations, sound proof and even fire proof and explosion proof."

In recent years, the output of China's curtain walls has remained above 50 million m<sup>2</sup>/a. In China's curtain wall constructions, from Beijing Olympic venues, to Shanghai World Expo, from East coastal areas to the West, we can easily find new curtain walls decorating the modernized buildings harmoniously echoing with the surrounding environments, as indispensable cultural and humanistic views to beautify the cities.

## II. Concentrated Displays of Modern New Technologies and New Materials from Curtain Walls

The reason that curtain walls are so vigorous is the dedicated applications of new technologies and new materials all over the world in recent years. For many years, scientists from all countries never stopped developing and researching materials

with features of energy conservation, environmental protection, and fire proof, etc., such as Low-E glass, thermal insulated aluminum profiles, vacuum glass, and all types of man-made boards, etc., all the applications of which have greatly promoted the development of traditional curtain wall industry, especially the technological breakthroughs in energy conservation, environmental protection and noise reduction, etc., paving a way for the realization of the target in energy conservation for buildings, that is “by 2020, the energy consumption for residential and public buildings should get close to or reach the current level in medium developed countries”.

In recent years, through a scientific innovation mechanism combining production, study, and research in curtain wall enterprises, and a continuous development of new products, an optimized industrial structure, and a sustainable technological innovations mechanism have been formed, achieving a series of significant technological breakthroughs.

China's construction industry also has been given a playing field for prosperous development over recent years. Curtain wall products that will satisfy varied design requirements and needs for different building structures, such as unit curtain walls, overlap connection curtain walls, dual channel curtain walls, single layer cable and cable network curtain walls, PV curtain walls and intelligent curtain walls, etc., proven to be successful in engineering practices, have indicated that

curtain walls in buildings are the most ideal building envelopes for large public buildings until now.

The implementation of Design standard for energy efficiency of public buildings (GB 50189-2005, [s]) has set higher bars for construction industry in curtain walls, which has put forward the technological advances in curtain walls in China, and the timely promising curtain wall products with energy efficiency have gradually upgraded the old walls or the exiting walls that fail to meet the standards of energy efficiency.

### III. Urban Glamour with Building Fashion

In the next five years, China's aluminum windows, doors and curtain wall industry will keep a steady momentum of growth, and the curtain wall will still remain the dominance in public building envelopes at home and abroad, thus hailing it as a fashion maker for the beautiful urban glamour. The 2008 Beijing Olympic Projects have already become the highlights in the world curtain wall industry, and the main curtain wall projects in the Olympic Games not only have served as the stage to display the strength of the curtain wall corporations, but also as the battlefield for curtain wall companies from home and abroad to compete for their strengths. These curtain wall projects have featured in technologies of completely displaying the styles of the building, pleasant glazing, energy efficiency and comfort. In the future, leading critical technologies,

such as cable structure and glass structure in curtain walls designs, will make greater breakthroughs. By 2010, the mainstream technologies for curtain wall industry in China will reach the international advanced level.

When we look back at the achievements we've made for recent years, Chinese people are sure to be proud. The National Grand Theater—World's First Large Titanium Panel Curtain Wall Project, which adopted 0.44mm titanium composite board with enduring metal gloss for centuries. The thermal insulation and sound proof performances are high enough to ensure a constant temperature inside, and absolute quietness inside even with heavy rains outside. New Poly Building adopted the most featured cable structure in the world for the glass curtain walls, with not only the design breakthroughs and records challenged, but also with pioneered construction technologies in China. At the same time, the project adopted a large quantity of materials of high tension, high regulation, and high standard, for the first time in the world. The difficulty in installation was obvious in a high tensile force of 1828t for the main cable, and the asymmetric cable structure design made each and every panel of glass installation extremely difficult. The CCTV Tower project used aluminum thermal profiles entirely, four pieces of insulating laminated glass, with high thermal insulation property, and high sound proof property of over 40dB, which ensure the special requirements of

interior sound and video collections and editing. The swimming center for Beijing Olympics, Water Cube, is located in Beijing Olympic Park, and the curtain wall project measures 177 m in width, with ETFE membrane structure design, over 3700 air pillows, 10 m in its largest span. Since each pillow is isolated as a unit, the pumps for air filling are controlled by computers in order to ensure even air inside. This is the membrane project largest in area, highest in technology difficulty, and most complicated. Back then, China's Olympic Organizing Committee chose the membrane structure for the glazing, energy efficiency, and thermal insulation. Beijing South train station main station adopted 4186 PV panels for the roof, 6700m<sup>2</sup> in total, accounting for about 50% of the roof glazing, and the capacity of power is 320kW. Glass glazing roof can effectively enlarge the area for daylight, saving a lot of power utility fees, and the solar power PV panel can generate power to make it a truly energy efficiency product.

China will continue to be the heated spot for curtain wall industry in the world, and China now has already been able to develop independently products of its own IPR. Enterprise governance and culture with Chinese characteristics are displayed to a larger extent in unique designs and construction or installation plans for large curtain wall project bidding. For recent years, a large batch of eye-catching large curtain wall projects are about to be implemented. During the period of gaining momentum and setting arrows on the bow, China's curtain wall industry embarks on a phase toward mature development.

#### IV. Energy Efficiency in the Promotion of New Curtain Wall Materials

Based on State conditions in China, and the requirements of sustainable economic and social development, energy saving is a long term policy, and building energy efficiency is one of the basic state policies of development as well. Guiding Opinions on

Development of Energy-saving and Land-saving Residential and Public Buildings, enacted by Ministry of Construction, undoubtedly has brought vigor and favors to curtain wall industry, urging more new technologies and products that will fit into the development of curtain wall industry to come of age, as well as the development of new materials for new types of buildings. The guideline has improved the energy saving indexes for curtain walls, extended the range of applications of curtain walls to include marble, aluminum unit board, composite aluminum board, beehive aluminum board, micro-crystal glass, ceramics, clay board, resin wood fiber board, fiber reinforced concrete board, stone beehive board, etc., which have greatly extended the substances of curtain walls, deriving the units from single walls to new structures, handsome decorating materials that can reduce energy consumption while providing a fresh new visual impacts with multi-function building structures, evolving from the common old faces out of re-bar walls, brick walls, and porcelain walls. This surely is a significant revolution.

China's curtain wall industry has undergone a development of 25 years, and has cultivated a large pool of experienced technicians, which has won it a leading status in R & D. With the rich practical experiences, we have ranked in the top notch in the construction in the world. In 2007, curtain walls reached about 35 billion worth of export RMB, and the projects are applied in over 50 countries, like in Britain, Germany, Russia, Saudi Arabia, and America, etc.. The curtain wall industry in China has entered a stable and continuous trend of prosperity, and it is walking to the global area.

The implementation of the Standard for Energy Efficiency of Public Buildings is a prime timing for China to improve technologies, construction skills and to eliminate the weak and old, energy wasting products, while updating strong and energy efficiency products timely, and to renovate

or replace old walls. China's curtain wall industry has embarked on a journey in steady splendid development.

With the aim to reflecting the achievements made in recent years in curtain wall industry in China, we compose and edit this book. The chief editor of the book is Mr. Huang Qi, Deputy Secretary of China Construction Metal Structure Association, and the editors include Xie Haizhuang, Gao Xiaofeng and Chen Lipeng, with Shenyang YuanDa Aluminum Industry Engineering Co., Ltd, Wang Chun and Dong Miqu with Shenzhen Jinyue Curtain Wall Decoration Engineering Co., Ltd, Zhang Guixian, Qiu Yiwen, Guo Jianguo, with Shenzhen Sanxin Special Glass Technology Co.,Ltd, Wei Donghai, with Beijing JiangHe Curtain Wall Co.,Ltd, and Hu Zhongming, with Wuhan Lingyun Building Decoration Engineering Co., Ltd.

The confinement of the level of authors may unavoidably cause some omissions or mistakes, and suggestions from readers for improvement will be gratefully appreciated.

HUANGQI  
Beijing  
18, July, 2008

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## 文化建筑

Cultural Architecture





# 1 · 上海东方艺术中心

## 工程地址

上海市浦东新区丁香路425号

## 幕墙面积

15000m<sup>2</sup>

## 主体高度

36m

## 建筑设计院

法国保罗·安德鲁设计事务所  
(ADPi)

华东建筑设计研究院有限公司

## 建筑设计师

保罗·安德鲁 崔仲芳

## 幕墙设计单位

沈阳远大铝业工程有限公司

## 幕墙材料

12mm透明钢化玻璃+1.52mmSGP胶片+0.4mm穿孔镀锌钢板+1.52mmSGP胶片+15mm透明钢化玻璃

## 幕墙结构形式

点式玻璃幕墙



图1-1-1 东方艺术中心外景



图1-1-2 东方艺术中心近景

## 工程说明

上海东方艺术中心位于浦东新区行政文化中心，是由法国著名建筑师保罗·安德鲁设计、华东建筑设计研究院有限公司深化设计完成的世界一流音乐厅，建筑主体采用钢筋混凝土框架剪力墙结构，地上部分由形似花瓣的

五个独立的分区组成，屋面结构为大跨度双向钢桁架体系，总长约160m，宽约120m。利用伸缩缝自然划分为5个独立的区域：1区为入口大厅，2区为小演奏厅，3区为交响乐厅，4区为展厅，5区为剧场。

五个独立的分区外表面是复杂的双曲面玻璃幕墙，幕墙支

撑体系由独特的竖向椭圆形钢管与横向圆钢管共同组成，幕墙钢结构外侧附不锈钢单层索网以增强整体稳定性。玻璃配置为：12mm透明钢化玻璃+1.52mmSGP胶片+0.4mm穿孔镀锌钢板+1.52mmSGP胶片+15mm透明钢化玻璃，玻璃的安装采用埋头点驳式连接系统。



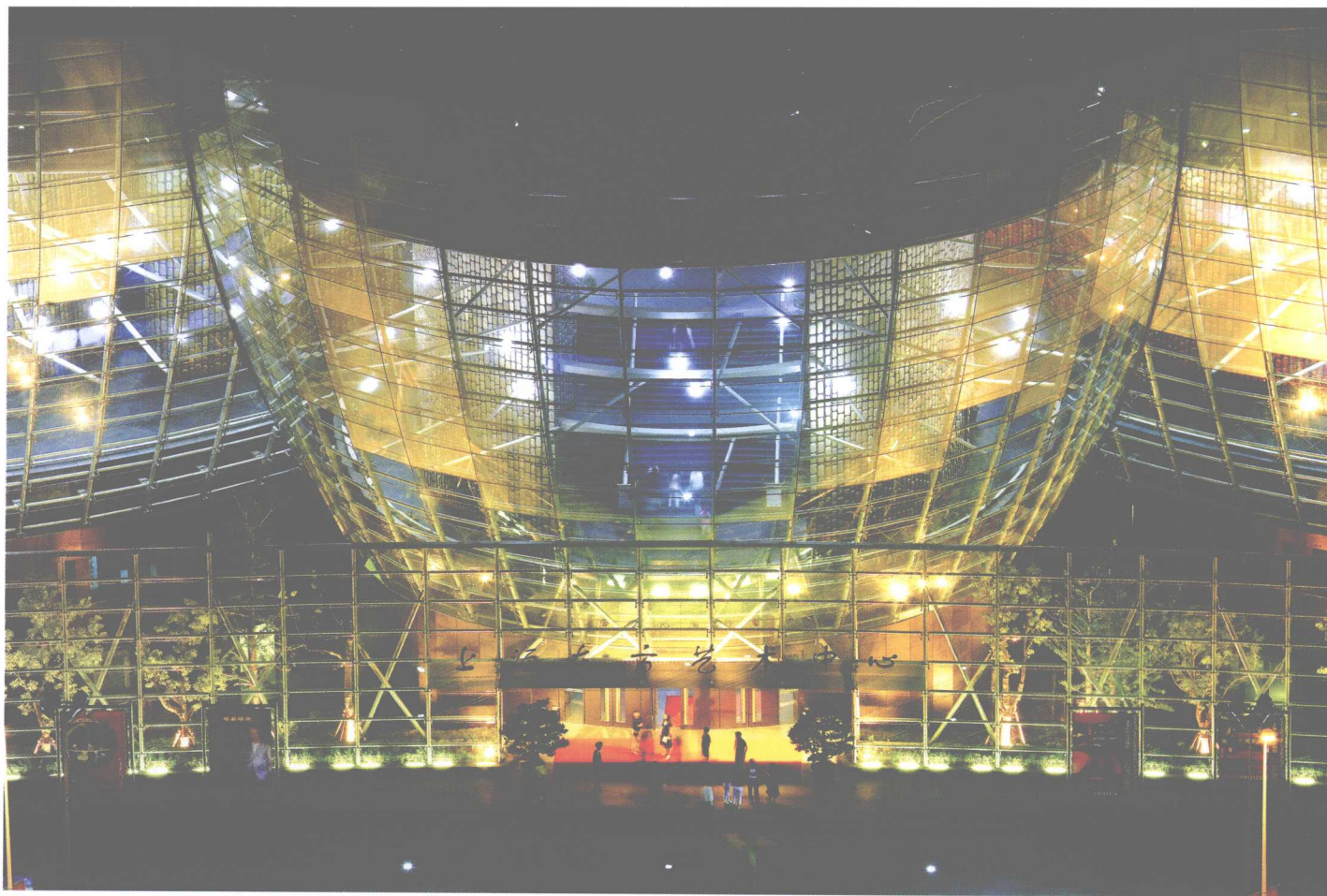


图1-1-3 东方艺术中心外墙局部

### 构造说明

五个独立的形似花瓣的幕墙支撑结构体系是由外加预应力索网的空间曲面钢结构构成（包括立柱、横杆、支撑杆及预应力索等），单个花瓣之间交界处三角区域设计为刚性连接区域（即：横杆与立柱之间采用刚性焊接连接方式），立面其他部分的横杆与立柱连接方式为铰接。每个单体钢结构体系立柱的上端支撑

于屋盖钢结构上弦，沿径向（水平）为固定铰接，竖向无约束，可自由滑动，环向为弹性蝶片约束；立柱的下端支撑于结构主体混凝土基础台座之上，沿径向（水平）与竖向均为固定铰支，环向为弹性蝶片约束；在钢结构的内部通过水平交叉分布的撑杆连接于核心筒混凝土结构或弧形钢结构梁上，其中2区、3区、5区中间部位在不同高度上设置水平抗震撑杆桁架，与核心筒混凝土