Title: **New Construction Technologies in Tianjin Jinta Mansion**

Authors:
Yaohui Yang, Professor Level Senior Engineer, China Construction First Group Construction & Development Co., Ltd.
Gao Junfeng, Professor Level Senior Engineer, China Construction First Group Construction & Development Co., Ltd.
Wang Jing, Engineer, China Construction First Group Construction & Development Co., Ltd.

Subjects:
Building Case Study
Construction
Structural Engineering

Keywords:
Concrete
Steel
Structure

Publication Date: 2012

Original Publication: CTBUH 2012 9th World Congress, Shanghai

Paper Type:
1. Book chapter/Part chapter
2. Journal paper
3. **Conference proceeding**
4. Unpublished conference paper
5. Magazine article
6. Unpublished

New Construction Technologies in Tianjin Jinta Mansion

天津津塔工程施工新技术


Yaohui Yang


Gao Junfeng


Wang Jing

Yaohui Yang, Gao Junfeng & Wang Jing

China Construction First Division Group Construction &
Development Co., Ltd.
17 Wanghualuxili Avenue
Chaoyang District, Beijing
China 100102

tel (电话): +86 10 64732670
fax (传真): +86 10 64729396
email (电子邮箱): yangyaohui@chinaonebuild.com, gaojunfeng@chinaonebuild.com, wangjing0552@sina.com
http://www.chinaonebuild.com

Yaohui Yang Master, MBA, Professor Level Senior Engineer. He won the honorary title of "Beijing Youth Job Expert" in 1998; was chosen as "National Excellent Project Manager" in 2002; won the title of "International Excellent Project Manager" in 2003. At present, he is working as deputy general manger of China Construction First Division Construction & Development Co. He has worked as a project manager of various projects, such as: China International Trade Center Phase II, Beijing LG Towers, China Petroleum Building, China International Trade Center Phase III, Tianjin Jinta Mansion and Shenzhen Ping An Mansion.

杨耀辉：硕士、MBA，一级注册建造师，教授级高级工程师，曾荣获“北京市青年岗位能手”、“全国优秀项目经理”、“国际杰出项目经理”称号。目前任中建一局集团建设发展有限公司副总经理。曾先后担任中国国际贸易中心第二期工程、北京LG大厦、中国石油大厦、中国国际贸易中心第三期工程、天津津塔、深圳平安等多个项目的经理。

Gao Junfeng Master, Professor Level Senior Engineer. He is working as Chief Engineer of China Construction First Division Construction & Development Co at present. He has worked as technical leader of various projects, such as : National Aquatics Center, Beijing Lucky Goldstar Tower, China International Trade Center Phase III, and Tianjin Jinta Mansion.

高俊峰：硕士、一级注册结构师，教授教授级高级工程师。目前任中建一局集团建设发展有限公司总工程师。曾先后担任国家游泳中心、北京乐喜金星大厦、国贸三期、天津津塔项目、合肥京东方第6代薄膜晶体管液晶显示器件项目等多个项目技术负责人。

Wang Jing Master, Engineer. Worked in Tianjin Jinta Mansion and Tianjin Kerry project department.

王晶：硕士、中级工程师。先后在天津津塔工程、天津嘉里工程技术部门工作。并参与了天津嘉里、深圳平安等项目的投标工作。

Abstract

The 73-story and 336.9 meter Tianjin Jinta Mansion is the tallest building in the world designed to apply concrete filled steel tube columns and pure steel plate shear walls. This paper introduces two new technologies applied in the construction of Tianjin Jinta Mansion. The lift-up pouring technology is adopted to assure the concrete quality. This paper analyzes the complexities of lift-up pouring technology in concrete mix, lifting interface design, lifting preformed hole design inside steel tube column, and selection and layout of lifting concrete pump and pump pipe. The installation of the steel plate wall, which distributes from basement to 236.5 meter level is another challenge in this project. Welding stress control, fastening accelerating construction speed, ensuring steel tube manufacturing and manufacturing accuracy are specifically considered in the method statement.

Keywords: Steel Plate Shear Wall, Concrete Filled Steel Tube Column, Lifting Concrete

摘要

天津津塔高336.9m，共73层，是目前世界上采用钢管组合柱和纯钢板剪力墙的最高建筑。文章主要介绍工程施工中的两项新技术。钢管组合柱采用顶升混凝土浇筑工艺，本文从混凝土配合比、顶升口设计、顶升预留孔设计、输送泵选择四个方面分析顶升施工难点并给出解决措施。钢板墙从底板安装到236.5m，最大厚度32mm，钢板剪力墙安装及焊接变形控制是施工又一难点。本文从焊接应力控制、加快现场施工速度、保证钢管柱加工、加工精度保证四个方面分析钢板剪力墙施工的难点，并提出了解决方法。

关键词：超高层　纯钢板剪力墙　钢管组合柱　顶升混凝土　焊接应力控制

Overview of the Project

Profile

Tianjin Jinta Mansion is located on the north side of intersection of Dagu Road and under-planned Xing'an Road. The project is a complex of office, apartment, entertainment, business, occupying over 20,000m2 of land, with 340,000 m2 of total floor area. It consists one high-class 336.9 meter high office building and one 105 meter high hotel service type apartment, and has become a landmark building of Tianjin, the highest building in Tianjin and even in North China (see Figure 1).

Design Feature

The main tower structure of Tianjin Jinta Mansion is the first supertall building to utilize the following systems: concrete filled steel tube column frames, all-welded pure steel plate concrete shear walls, and an outrigger rigid arm lateral force resisting system (see Figure 2). Concrete filled steel tube column frames are adopted in inner and outer cylinders of Tianjin Jinta Mansion, fifty-five pieces of concrete filled steel tube columns are arranged in plane surface, with the largest diameter of steel tube columns at 1,700mm, and the smallest diameter at 600mm. The thickest steel tube wall at 70mm, C60 high strength concrete is used to fill columns, with

工程概况

概况介绍

天津津塔工程位于和平区大沽路、规划兴安路交口北侧。建筑集办公、公寓、餐饮、商业为一体，占地面积2万多m2，总建筑面积34万m2。包括一栋336.9m的写字楼和一栋105m的公寓，是天津市标志性建筑，也是目前天津乃至整个中国华北地区的最高建筑，见图1。

设计特点

主塔楼结构采用钢管混凝土柱框架+全焊接纯钢板剪力墙体系+外伸刚臂抗侧力体系(见图2)，是目前世界上首次采用该体系的超高层建筑。工程内外框筒采用钢管混凝土柱框架，平面共布置了55根钢管混凝土柱，直径自下而上为1700～600mm，壁厚最厚70mm，柱内为C60高强混凝土，最高浇注高度达312.8m。钢管柱内隔板众多、节点复杂，是目前国内超高层钢结构最复杂的节点设计之一，也使津塔工程成为了目前国内乃至世界上钢管柱内混凝土浇筑难度最大的工程之一。核芯筒内部平面共布置15块钢板剪力墙，钢板最厚达32mm，最高安装到236.5m，是目前世界上钢板剪力墙安装高度最高的建筑，同时也是采用纯钢板剪力墙结构的最高建筑。

highest pouring height at 312.8 meter. Many dividing panels are set inside steel tube columns, which complicate connections with steel tube shear wall outrigger trusses. This is one of the most complicated joint designs for domestic super high-rise structures and makes Tianjin Tower one of the most complex concrete pouring projects currently in the country and the world. Fifteen pieces of 32mm steel plate shear walls are set at the internal plane of Tianjin Tower core cylinder. At its highest erection height of 236.5m, Tianjin tower is the tallest building in which steel plate shear wall is erected and pure steel plate shear wall structure is adopted.

Concrete-Filled Steel Tube Lifting Technology

Because of the complicated joint design inside the steel tube columns, especially the intersecting stiffening plates inside the columns, common pouring methods cannot ensure concrete quality inside the steel tube. Therefore, lifting concrete pouring approach will be adopted. The following is an analysis of the five aspects of the lifting construction technology: concrete mix, high-rise steel tube concrete lift pouring experiment, lifting interface design, lifting preformed hole design inside the steel tube column, and selection and layout of lifting concrete pump and pump pipe.

Concrete Mix

Performance requirements and control index of lifting concrete (Specification For Design and Construction of Concrete-Filled Steel Tubular Structure, 1990)

High strength.

Pumpability. Mixture of high strength concrete must have good segregation resistance and filling capability.

Smaller contractibility rate. To ensure pouring quality of concrete inside the tube, obvious contraction between concrete and side walls of steel plate cannot appear.

Higher flowability and smaller viscosity. As concrete inside the steel tube is poured with lifting technology, longitudinal and transverse dividing panels complicate the process. The flowing distance of the concrete inside the tube is long; therefore, the concrete is required to have higher flowability to ensure pouring quality and density.

Small loss of concrete in pumping duration. On the Tianjin Tower plane, fifty-five pieces of combined steel and concrete columns, with steel tube diameters ranging from upper to lower parts 1,700~600mm, lift three floors below the 30th floor at one time and six floors over the 30th floor. The maximum volume of concrete for each singular steel tube column amounts to over 40m^3. In consideration of the transportation of concrete, waiting, and pouring time, one lifting will take at least two hours. Therefore, to ensure pouring quality, concrete lifting must ensure smaller duration and long distance pumping loss.

Technology control measures of Lifting concrete. Based on performance requirements of concrete lifting inside the steel tube column and batching experience in similar projects, the following recommendations are made: control water to binder (cement) ratio of the concrete; choose high grade cement, binding material, sand and aggregates, and determine the best proportion through experiment; and add swelling agent and additives to ensure higher flowability, pumpability and smaller viscosity. Performance of lifted concrete reaches the following requirements: concrete strength over 60MPa, slump of 270mm, expansion of 650mm, no segregation at the time when it is taken from the tank, slump and expansion duration loss

Figure 1. Tianjin Jinta Mansion (source: Yadiel)
图1. 天津津塔（出自：Yadiel）

钢管混凝土顶升施工技术

由于钢管柱内复杂的节点设计，尤其是其内部存在的横纵交叉形式复杂的加劲板导致常规浇筑方法无法保证钢管内混凝土的质量，需采用顶升浇筑法。下面分别从混凝土配合比设计、顶升模拟实验、顶升口设计、顶升预留孔设计及混凝土输送泵及泵管的选型和布置五个方面分析介绍顶升施工技术。

混凝土配合比

顶升混凝土的性能要求及控制指标（钢管混凝土结构设计与施工规程，1990）。

高强度.

可泵性。高强混凝土的拌合物必须具有良好的抗离析性和填充能力。

较小的收缩率。为保证腔内混凝土顶升浇筑的质量，混凝土与钢板侧壁之间不能出现明显收缩。

较高的流动性和较小的黏度。钢管柱内部纵横隔板复杂，腔内混凝土流动距离较长，要求混凝土具有较高的流动性，以保证浇注质量和密实度。

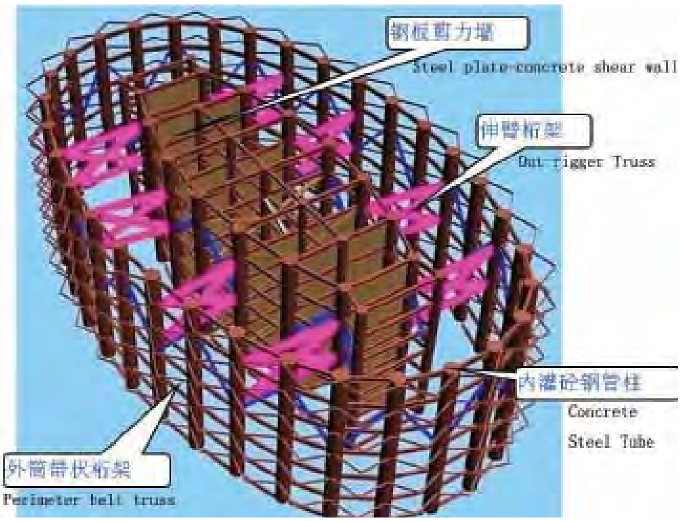

Figure 2. Schematic diagram of Tianjin Tower (source: Yang Yaohui Gao Junfeng &Wang Jing)
图2. 津塔结构示意图（出自：杨耀辉）

Figure 3. Section photo of test column (source: Yang Yaohui Gao Junfeng & Wang Jing)
图3. 试验柱断面照片（出自：杨耀辉）

Figure 4. Lifting interface with pump pipe connecting section (source: Yang Yaohui Gao Junfeng & Wang Jing)
图4. 与泵管连接端顶升接口（出自：杨耀辉）

no bigger than 10mm, and long distance slump loss no bigger than 10mm four hours later.

Super high-rise steel tube concrete lifting pouring experiment

Since there is no effective approach to ensure quality of concrete inside the steel tube column internationally, especially around complicated dividing panels, it is difficult to check if it is cast densely. Common international practices also require testing before application of such technology to determine key parameters and operating instructions of technology.

Therefore, prior to formal construction, choose two 1:1 symbolic steel tube columns and simulate practical pouring, make concrete filled steel tube lifting pouring experiment. After the experiment, it is found through cutting and breaking (see Figure 3): concrete of all cavities is very dense; concrete strength is in compliance with design requirements; no laitance layer exists in two pouring joint surface and no concrete contraction crack occurs between joint and tube wall.

Lifting Interface Design

In reference to the approach used in Taipei 101, a low-cost steel tube interface was selected, suitable for connection of various angles and easy operation. This interface will shorten connection time considerably, reduce waiting time when concrete is poured on site and ensure pouring quality.

How to connect with the pump pipe. Cut a section of 300 mm or so from one end of a standard pump pipe. One end should be fastened to the standard pump pipe and the other end should be welded with a steel tube and connected with the other lifting interface (see Figure 4).

How to connect with steel column. Keep about 120mm lifting interface at the inner side of the steel tube. Weld a piece of 200mm short pipe with the other end of the short pipe that is welded with a square steel plate to ensure connection with other interface with high strength bolts. In order to ensure force requirements of structure, weld an additional 26mm thick reinforcement steel plate at the opening in accordance with the ideas by the design unit (see Figure 5).

Lifting preformed design inside steel tube column

Three kinds of preformed holes are designed in this project. First, an exhaust opening (see Figure 6): preformed small 50mm circular holes on the transverse stiffening plate, convenient for exhausting of air below dividing panel during concrete pouring. Second, a grouting hole (see Figure 7): preformed 200~250mm circular holes on the transverse and longitudinal stiffening plates, in order for concrete to flow from one cavity to another. Third, an observing aperture: set one 10mm

经时泵送损失小。工程30层以下一次顶升3层，30层以上一次顶升6层，单根钢管柱一次顶升浇筑最大方量达40多m3。考虑混凝土的运输、等候和浇筑时间，单根钢管柱一次顶升需耗时至少2h。为保证浇筑质量，混凝土必须具有较小的经时和长距离泵送损失。

顶升混凝土技术控制措施。根据上述混凝土性能要求及以往类似工程顶升混凝土的配制经验，工程实施中主要通过控制混凝土的水灰比、选用优质的水泥、胶凝材料和砂石并选择最佳比例、控制收缩率、加入适量膨胀剂及外加剂等措施来保证混凝土具有较高的流动性、和易性以及较小的泵送和经时损失，根据天津当地的混凝土原材料研制出符合超高泵送性能的混凝土，最后津塔泵送混凝土性能达到了如下要求：出灌坍落度能够达到270mm，扩展度大于650mm，并且不能离析，4h坍落度经时损失不大于10mm，长距离泵送坍落度损失不大于10mm。

超高层钢管柱混凝土顶升浇筑试验

鉴于目前钢管柱内混凝土质量在国际上还没有比较有效的手段，尤其在复杂隔板周边的混凝土是否浇筑密实则更无法检测，国际上通常的做法要求在该工艺应用前先进行试验验证，从而确定工艺操作过程中的关键参数和操作要领。

津塔工程在正式施工之前选择两根典型的钢管柱1:1模拟实际浇注情况，进行顶升浇筑试验。试验结束后对钢管柱切割解剖（见图3）发现，各空腔内的混凝土均非常密实，混凝土强度符合设计要求；两次浇筑的结合面不存在明显的浮浆层；同时，结合面位置的混凝土与管壁间没有收缩缝隙。

顶升接口设计

津塔工程在参考台北101做法的基础上设计了一种价格便宜、适于各种角度连接、操作简便的钢管接口，可显著缩短接管时间，减少现场混凝土浇筑的等待时间，保证浇注质量。

与泵管如何连接。截取标准泵管端部一段约300mm长，一端与标准泵管连接，另一端则焊接钢板，与其它顶升接口连接（见图4）。

与钢管柱如何连接。在钢管柱内侧壁预留一直径120mm左右的顶升口，并焊接一段约200mm的短管，短管另一侧同样焊接一块方形钢板，保证与其他接口采用高强螺栓连接（见图5）。同时为保证结构受力要求，在开孔位置加强补焊一块26mm厚的钢板。

钢管柱内顶升预留孔设计

共设计排气孔、灌浆孔及观察孔三类预留孔，排气孔（见图6）在横向加劲板上预留，便于混凝土浇筑时隔板下空气排出；灌浆孔（见图7）在横向和纵向加劲板上预留，使混凝土能够从一个

Figure 5. Connecting end interface design with steel tube column (source: Yang Yaohui Gao Junfeng & Wang Jing)
图5. 与钢管柱连接端顶升接口（出自：杨耀辉）

circular hole at 1m along column body; this is used for observation of concrete lifting inside the steel tube and is also helpful for exhaustion of air from the steel tube.

Selection and layout of lifting concrete pump and pump pipe

Selection of pump and pump pipe. Through the oretical pump pressure calculation (technical specification for construction of concrete pumping, 2011) and pumping simulation test. After the overall comparison, the Zoom lion HBT110-26-390RS ultrahigh pressure concrete pump is selected. With its maximum at 26MPa, it fully meets pressure requirements for pumping lifting concrete. Additionally, with twenty percent reserved pressure and higher security, the φ125 high pressure pump pipe is to be used.

Layout of pump. There are two sets of ultrahigh pressure concrete pumps at the site for concrete lifting pouring inside the steel tube. One is for common use and the other is used as a backup; both are laid out at southeast corner of the site.

Layout of pump pipe. The horizontal pipe on the ground is no less than 60m long. Set transfer floors on the 31st and 46th floor on which a 20m horizontal pipe is prepared. Under the 30th floor, the ultrahigh pressure pump pipe will be adopted, with a wall thickness of 8mm and bearing pressure over 25MPa, pump pipe joint via flange connection. The vertical layout of the pump pipe is conducted along the steel column upward with pump pipe clamps welded on steel columns; the pump pipe's center distance is 400mm away from the steel column; the pump pipe clamps are laid out at the two ends of each section of the pumping pipe (see Figure 8).

Construction technology on pure steel plate shear wall

Construction difficult point analysis of pure steel plate shear wall

Welding stress control. As per the design, the steel plate wall and ambient steel column and girder are to be connected with pure welding. Welding under restricted conditions all around will surely produce welding stress on steel plate wall. In case that such stress is too large, it will affect structural security of the entire tower building. Controlling welding stresses is the biggest difficulty in the steel plate wall construction of Tianjin Jinta Mansion project.

Accelerate construction speed at site. There are 602 pieces of steel plate walls, 3,760 lines, 16,000m of welding seams in the entire core tube of Tianjin Jinta Mansion. Since the steel plate wall is hoisted at

Figure 6. Exhaust opening (source: Yang Yaohui Gao Junfeng & Wang Jing)
图6. 排气孔（出自：杨耀辉）

Figure 7. Grouting hole (source: Yang Yaohui Gao Junfeng &Wang Jing)
图7. 灌浆孔（出自：杨耀辉）

空腔进入另一个空腔；观察孔沿柱身设置，用于观察混凝土在钢柱内的顶升情况，同时也有助于钢柱内空气排出。

超高压混凝土输送泵及泵管的选型和布置

泵及泵管选型。经过详细理论泵压计算（混凝土泵送技术规程，2011）及泵送模拟实验，综合对比后，选择中联重科HBT110-26-390RS型超高压混凝土输送泵，其最大出口压力可达26MPa，完全满足泵送顶升混凝土的压力要求，并且有20%的压力储备，安全性更高。泵管使用直径125mm高压泵管。

泵布置。超高压混凝土输送泵共两台，一台正常使用，一台备用。两台地泵布置在场地的东南角。

泵管布置。地面水平管道≥60m；在31层、46层设置转换层，转换层楼面设置20m左右的水平管；30层以下采用超高压泵管，壁厚≥8mm，承载压力≥25MPa；泵管竖向沿钢柱向上布设，在钢柱上焊接泵管卡，使泵管卡中心距离钢柱表面400mm，泵管卡布置在每段泵管的两端(见图8)。

纯钢板剪力墙施工技术

纯钢板剪力墙施工难点分析

焊接应力控制。由于钢板墙与四周的钢柱、钢梁为纯焊接连接，在四周均有约束的条件下进行焊接必然会在钢板墙上产生焊接应力，这种焊接的应力过大会影响整个塔楼的结构安全，如何控制焊接应力是钢板墙施工最大难点。

Figure 8. Connection example of concrete pump pipe and steel column (source: Yang Yaohui Gao Junfeng &Wang Jing)
图8. 混凝土泵管与钢柱连接实例图（出自：杨耀辉）

a low speed, the welding quantity is significant. The structure's dead weight load borne by the steel wall shall be controlled and the steel plate wall welding will be postponed up to each of the fifteen floors of main structure. Therefore, acceleration of erection of the steel plate wall becomes the crucial factor to ensure structural progress and create conditions for follow-up construction.

Ensure steel tube column manufacturing. To ensure normal conveying forces of the steel plate wall while the steel plate wall is connected with the steel tube column, corresponding stiffening plates need to be set inside the steel tube column. However, the setting of a full-length stiffening plate inside the steel tube column may make it impossible to weld the inner wall of steel tube. Therefore, the welding of a steel plate wall inside a steel tube column becomes a technically difficult point of steel pipe manufacturing.

Ensure manufacturing accuracy. Manufacturing accuracy of the steel plate wall directly influences erection speed at site. This is especially true at the outrigger truss layer, when the steel plate wall and outrigger trusses are erected and are integrated as one structure. There are many interfaces and slight manufacturing deviation may make site erection impossible. Therefore, accuracy of the steel plate manufacturing is very important to site erection.

Welding stress control

Joint design. Connection joint design of steel wall and ambient frame column and truss girder (see Figure 9).

Optimize welding technology. Steel plate wall welding technology at typical layer. 1) The welding sequence principle of steel plate walls of the entire building shall be completed as follows: from bottom to top and floor by floor. The welding sequence principle of steel plate walls of the core tube at all floors shall be completed from center to all sides gradually. 2) The welding sequence of each line of the welding seam of the steel plate walls (Wang Xiangdong Gao Huajie, 2010) shall be

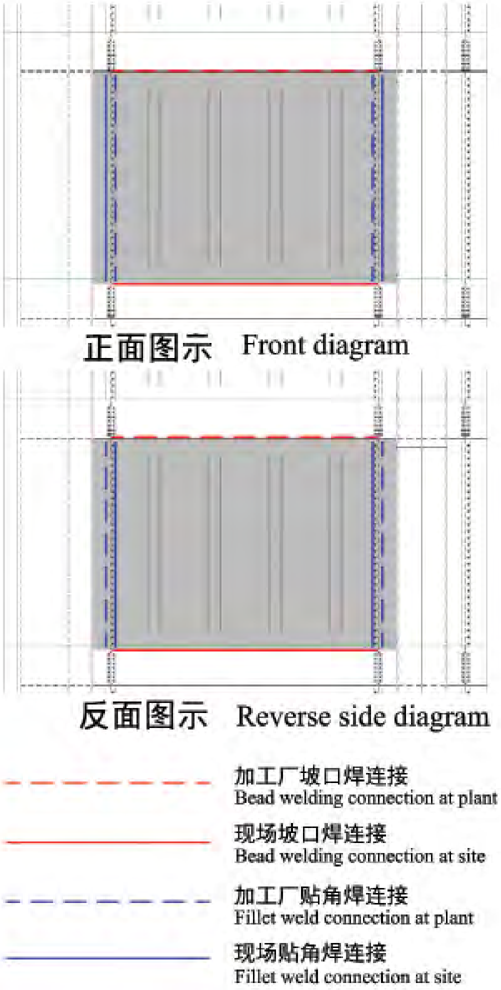

Figure 9. Welding seam joint design of typical floor steel plate wall (source: Yang Yaohui Gao Junfeng &Wang Jing)
图9. 标准层钢板墙焊缝节点设计（出自：杨耀辉）

加快现场施工速度。整个核心筒共602块钢板墙，3760道共16000m的焊缝，由于钢板墙吊装速度慢，焊接工程量大，同时由于设计要求控制钢板墙承受结构自重荷载，要求钢板墙延迟主体结构15层焊接，因此，如何加快钢板墙的安装和焊接速度成为保证结构进度和为后续施工创造条件的关键。

保证钢管柱加工。 钢板墙与钢管柱连接时为了保证钢板墙的正常传力，钢管柱内需设置相应的传力劲板，但是在钢管柱内设置通长的传力劲板会导致劲板与钢管内壁的焊接无法进行。如何保证钢管柱内钢板墙的焊接成为钢管柱加工的技术难点。

加工精度保证。钢板墙的加工精度直接影响现场的安装速度，尤其是在伸臂桁架层，钢板墙和伸臂桁架合成一体安装时，接口非常多，加工稍有偏差将导致现场无法正常安装，因此，如何保证钢板墙的加工精度对现场安装进度至关重要。

焊接应力控制

节点设计。钢板墙与周边框架柱、框架梁的连接节点设计见图9。

优化焊接工艺 。 标准层钢板墙焊接工艺。1）焊接顺序：整个大楼的钢板墙焊接顺序的原则为自下往上逐层焊接；各层核心筒钢板墙焊接的原则为自中心向四周扩散。2）钢板墙各道焊缝的焊接顺序（王向东、高华杰等，2010）：先焊底部，再焊左侧，最后焊右侧。3）每道焊缝的焊接工艺：两侧竖向焊缝焊接按照自上而下分段倒退焊接。底部横焊缝焊接须按600mm长进行分段倒退跳跃焊接。

伸臂桁架层钢板墙焊接工艺。一跨钢板墙的现场焊缝有6道，

Figure 10. Steel plate wall welding sequence at outrigger truss (source: Yang Yaohui Gao Junfeng &Wang Jing)
图10. 伸臂桁架层钢板墙焊接顺序（出自：杨耀辉）

completed first at the bottom, then the left side, and finally, the right side. 3) The welding technology of each vertical welding seam at the two sides should be top to bottom and backward welding. Take a typical floor as an example, two welders can be arranged at the same time to complete vertical welding. Each worker may weld three sections, after he completes one section he can be rotated to the next section.

Steel plate wall welding technology at outrigger truss layer. There are six lines of site welding seam in each steel plate wall at the outrigger truss layer with a welding sequences of each line of seam (see Figure 10).

Unit optimization of steel plate wall manufacturing to accelerate site construction progress

For the typical Layer. According to limit of transportation width to steel members, erect each steel plate wall as one unit followed by the top frame beam and steel plate wall as another unit (4.2m*6.65m) (see Figure 11). In order to reduce the site welding seam, four pieces of connecting plates at two sides of steel plate wall are divided into two groups and manufactured at the plant into one unit respectively with a steel column or steel plate wall.

Outrigger truss layer. The interconnected relationship between transportation, the site butt joint and difficulty of assembly between the outrigger and the steel plate wall is taken into consideration. Each steel plate is generally divided into two triangular units (upper and lower) with each unit's steel plate wall and related outrigger truss members and frame beam manufactured into one unit at the plant. Through the manufacturing of complicated truss members, the frame beam and steel plate wall into one unit, welding seams at the site are reduced considerably. While the unit is split at site, transverse seams are mainly adopted to reduce vertical seams.

Consider manufacturing optimization of steel tube column connecting with steel plate wall

They are designed as steel tubes with longitudinal splitting after optimization, the main rib runs through tube wall with a specific joint (see Figure 12).

Accuracy warranty

It is advised to take preassembly beyond normal measures to ensure manufacturing accuracy of each member, any deviation will be rectified at the plant at once. Horizontal assembly by unit will be adopted during preassembly to reduce the height of the assembly frame.

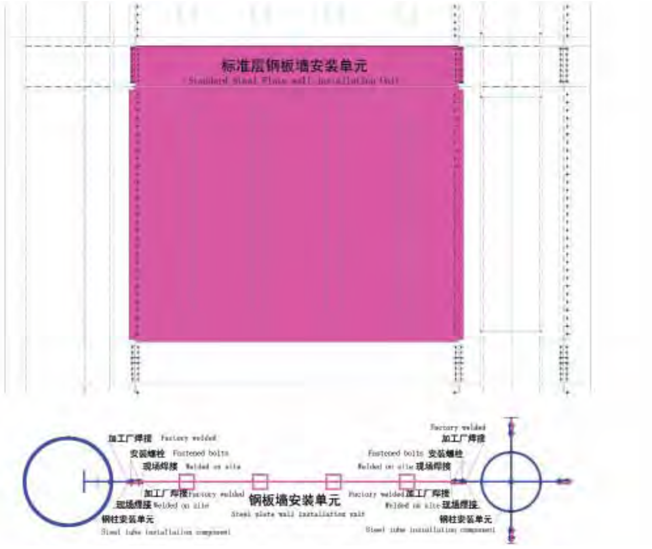

Figure 11. Unit division of steel plate wall at typical floor (source: Yang Yaohui Gao Junfeng &Wang Jing)
图11. 标准层钢板墙单元划分（出自：杨耀辉）

各道焊缝的焊接顺序见图10。

为加快现场施工进度的钢板墙加工单元优化

标准层。根据钢构件运输宽度4.2m的限制，将每跨钢板墙作为一个安装单元，并将顶部框架梁和钢板墙作为一个单元（4.2m*6.65m）（见图11）；为了减少现场焊缝，将钢板墙两侧的共四块连接板分成两组，分别与钢柱或钢板墙在工厂预先制作成一个单元。

伸臂桁架层。考虑到伸臂桁架和钢板墙的相互关系、运输限制、现场对接和焊缝的难易，将每一跨的钢板墙基本分成上下两个三角单元，每个单元的钢板墙和相关伸臂桁架杆件及框架梁在工厂制作成一个单元；将复杂的桁架杆件、框架梁和钢板墙加工成一个单元，大量的减少了现场焊缝数量；在拆分单元时，现场主要采用横向拼缝，减少竖向拼缝。

考虑钢板墙连接的钢管柱加工优化

优化设计为钢管纵向剖开,纵肋贯通管壁的节点形式。见图12。

加工精度保证

采取措施保证每个杆件的加工精度，同时还要求加工厂进行预拼装，如发现偏差，则在工厂内完成矫正。为降低拼装架的高度，采用分单元卧式拼装的方式进行预拼装。

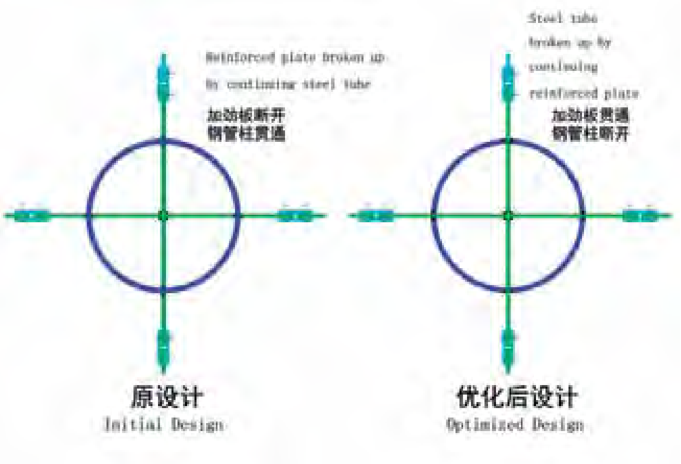

Figure 12. Center steel tube column optimization of core tube (source: Yang Yaohui Gao Junfeng &Wang Jing)
图12. 核心筒中心钢管柱优化（出自：杨耀辉）

Conclusions

Successful study and application of construction technology in Tianjin Jinta Mansion project effectively solved a number of construction complexities produced from lifting pouring of steel tube concrete and the first application of all welded steel plate shear walls in a super high-rise building, ensured project quality, saved on cost, accelerated the construction progress, and provided a precedent for similar projects.

结论

津塔工程钢管混凝土结构及纯钢板剪力墙施工技术的成功研究与应用，有效地解决了钢管混凝土顶升浇注和全焊接钢板剪力墙首次应用于超高层建筑中带来的多项施工技术难题，保证了工程施工质量，同时也节省了一定施工成本，加快了施工进度，为类似工程的实施提供了一些借鉴经验

References（参考书目）：

"Specification For Design and Construction of Conctrete-Filled Steel Tubular Structures" CECS28: 90, Harbin Institute of architecture and Engineering, Beijing,1992.

"Technical specification for construction of concrete pumping" JGJ/T10-2011,Ministry of construction of the people's Republic of China

"Welding Technology of Steel Plate in Tianjin Jinta Mansion" , CONSTRUCTION TECHNOLOGY, 2010, Wang Xiangdong, Gao Huajie