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Project Management Outline and Challenges

超高层项目管理要点及难点

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Design requirements between skyscrapers of 600 meters and 300 meters high are different, including construction costs, construction speed, construction technology, quality control and assurance, and safety precaution measures. Shenzhen Ping An Financial Center (PAFC) is one of the only 600+ meter high skyscrapers being built in China. The core-wall steel structure exceeded 400 meters by the end of May 2014. The construction of the tower structure will be completed in March 2015. The developer's management team has faced and resolved many difficulties. Some examples of management experiences are herein summarized.

高度超过600米的超高层项目在设计规范、建造成本、施工速度、技术难度、质量和安全管理要求等方面，与300米以下的建筑是有明显区别的。深圳平安金融中心是国内在建的高度达到600+米的超高层之一，2014年5月塔楼主体结构高度已超过400米，计划2015年3月土建结构封顶。建设方项目管理团队在各阶段已经面临并解决了诸多难题，总结了本项目部分管理经验。

Outline and Difficulties of Skyscraper Project Management

Shenzhen Ping An Financial Center is 660 meters high. The duration of tower construction is from mid-2012 to mid-2016 and the site area is about 19,000 m². The GFA is around 460,000 m². The foundation is mega piles with thick raft. The main tower structure is a hybrid system composed of core walls, outrigger trusses and mega columns. The construction cycle of a typical floor was 4 days. In this chapter, the authors discuss the master control and construction along with providing a critical path analysis and an analysis of challenges and risks.

Master Control Management of Skyscraper Project

By using information processing results, master control management will control the project from the macro- and micro-scale. This requires a type of knowledge-intensive communication and consists of management activities facing the decision maker.

Experience acquired from previous projects, the PAFC management company established a master control management department to carry out the project management of the PAFC project.

The Necessity of Project Master Control Management

Because of the following main characteristics, PAFC developed the following master control management practices,

Tight Construction Period

Since April 2012, the initial construction of the tower structure commenced with the target completion date of April 2016. This required the construction cycle for a typical floor to be 4 days.

Massive Investment

The total investment amount is about 9.5 billion RMB. In order to realize the return targets of this investment, the project is to be completed in the mid-2016 as per the master program.

超高层项目管理要点及难点

深圳平安金融中心高660米，塔楼主体计划工期为2012年中至2016年中，占地约1.9万平方米，建筑面积约46万平方米。采用巨型桩筏基础，主体结构采用核芯筒、伸臂桁架加巨柱的钢混组合结构体系。塔楼主体结构的标准楼层已实现4天/层的速度兴建。本文将从以下几方面展开探讨：总控管理、施工关键路径分析、挑战与风险。

超高层项目总控管理

项目总控管理从总体上和宏观上利用信息处理成果对项目进行控制，项目总控是一种知识密集型、面向项目管理高层决策者的沟通/管理活动。

深圳平安金融中心管理公司由之前的专案经验中获取经验，建立一个总控部门开展总控管理工作。

项目总控管理的必要性

深圳平安金融中心项目之所以要采用项目总控管理，是因为本项具有以下主要特征：

施工工期紧

本项目塔楼主体开工至竣工的计划工期为2012年4月至2016年4月，要求各道主要工

High Requirements on Construction Technology

The main constructor encountered difficulties such as using climbing formwork to work at extreme heights. Also, concrete pumping to these heights required enormous pressure. Additionally, the usage of structural steel is near 10,000 tons and every steel component weighed more than 90 tons complicating the control of different elastic shortening between core-wall and mega columns. Finally, the verticality of the lift shaft of a height to over 550m proved difficult. All these difficulties had to be resolved in association with the main contractor to determine risk in advance and solve related design or construction schemes and response measures.

High Standard of Project Handover

To be considered a success by its developers, the Zhan Tianyou prize, the Luban prize of Quality Standard and LEED Golden Level of Energy Saving and Environment Protection are required for this project.

Busy Vertical Transportation

An expansive amount of structural steel members, curtain wall units, fitting out materials, construction waste, commercial equipment etc. will occupy the transportation of hoisting machines and tower cranes. All the hoisting machines and tower cranes will be constantly occupied, therefore, transportation at night needed to be arranged accordingly. Some of the lift shafts will be occupied by the temporary elevators. After the temporary elevators are dismantled, the installation of a permanent lift would be installed. After dismantling the temporary ground reinforced concrete supports for hoisting machines, the main contractor would confront the difficult task of material stacking and turning over.

High Safety Risks

Surrounding metro stations created high pedestrian traffic for the bus stations and bars surrounding the project site. Consequently, there are serried tower cranes



Figure 6.6. PAFc is a hybrid structural system composed of core walls, outrigger trusses and mega columns. (Source: Ping An)

图6.6. 平安金融中心属于混合结构体系，包含了核心筒、伸臂桁架和巨型柱（来源：平安）

序在标准层按照4天/层的速度保持合理步距同步爬升。

投资规模大

总投资约95亿人民币。业主项目管理团队和各参建团队，须按照总控计划目标于2016年中竣工，方可实现投资回报目标。

技术要求高

土建面临高空爬模施工、高空/高压泵砼浇筑，钢结构总量约10万吨，钢构单件重超过90吨，核心筒与外框钢构件压缩变形差异控制复杂，约550米高速电梯井道垂直度要求高等。需要提前预判风险，并编制相应设计/施工方案和应变措施。

交楼标准高

质量标准要达到詹天佑奖和鲁班奖标准，节能及环保标准要达到LEED金级标准。

繁忙的垂直运输

大量钢构件、大量幕墙单元板、大批精装材料、大量施工垃圾和大型机电设备等将占用施工电梯及塔吊运输时间，导致塔吊和施工电梯运输非常繁忙，需要合理组织电梯夜间运输。部分电梯井道被临时施工电梯占用，施工电梯拆除后正式电梯安装工期长。地面首道临时的加强混凝土支撑拆除之后，承包商在材料堆放/周转更加困难。

安全风险大

项目周边地铁、公交、办公、酒吧人流量大。大型塔吊设备布置密集。超高层多楼层、多工序、多人员的繁忙交叉施工，导致临边防护、高空防坠风险大。

项目总控管理的具体工作

制定总控计划

总控部门编制的总控目标计划，作为项目管理团队各部门及各参建单位的绩效考核依据。

实际进度监控

总控部门按月度、季度、年度将实际完成进度与目标计划进行对比跟踪，考核结果将作为各部门工作绩效和参与单位的履约绩效的主要考核及奖罚依据。

on site. Multiple trades worked simultaneously resulting in a protective barrier for floor edges and holes. Protective measures were also taken working at great heights.

Concrete Works of Project Master Control Management

Master Planning

The master plan from the master control department included a target plan, and a KPI audit basis of the PAFC internal departments and the related contractors.

Progress Monitoring

The master control department monitored the actual progress monthly, quarterly and yearly in order to achieve the target plan. The monitoring results will become KPI's for all related departments. As a basis of award or penalty of all related contractors' performance of contract analysis.

Balance between the Master Plan and Department Work Plan

The master control department collected the detailed plans from departments and contractors along with making sure the detailed plans would be consistent with the master plan.

Information Analysis

By means of correspondences, (i.e. meetings, e-mail, site inspection, and liaison) all important information collected will be analyzed to find any problems or risks. This information will then be prepared in a report to inform and to suggest solutions for senior management's review.

Progress Report

The master control department will report program and progress updates to senior management bi-weekly, monthly, and quarterly for their review and decision-making. This will include information on design, tender, fabrication, construction etc.

Construction Critical Path Analysis of Skyscrapers

Skyscrapers, usually located downtown, create a limited site area. Considering the construction of the building structure and, working at height, reasonable construction sequences should be kept to structures, curtain walls, decorations, and lifts, so that the effective overlapping construction processes can be organized between contractors. This characteristic of skyscrapers results in the difference between skyscrapers and residential projects or complex development projects. The critical path of skyscraper construction will gradually change as the main building construction progresses.

Installation of Steel Structure up to 10/F

For installation of steel structures up to 10/F, it is observed that the critical path of the tower crane manufacture and installation, and climb formwork be both installed and tested (see Figure 6.7). Model selection and associated installation of the appropriate tower crane needs to be planned and designed in advance to ensure the tower crane can be transported to site as per plan for site installation. Highly efficient and safe climbing formwork systems need to be selected according to the main structure system and be transported to the site for plan installation.

Installation of Steel Structure between 10/F-30/F

For installation of steel structures between 10/F-30/F, it is observed that the critical path of steel construction and climbing formwork of core wall be planned. During this planning stage, reasonable construction sequences should be kept between the construction sequences of core-wall steel and climb formwork from top to bottom. Steel structures of frames, slab concrete of frames, slab concrete of core walls and concrete of mega columns should also be planned top to bottom in order to avoid restrictions between each other of the construction sequences.

平衡部门专项计划和施工计划

总控部门收集汇总各专业部门专项年度工作计划和施工单位的年度施工计划，与总控目标计划进行平衡对比，确保其符合总控计划要求。

信息提炼分析

透过文件、图纸、会议、邮件、现场巡查、沟通等方式，全方位收集项目管理重要信息，经过整理、分析，若发现问题或潜在风险，及时报告并建议，供领导层决策。

编制进度报告

总控部门定期按双周、月度、季度编制各部门、各参建单位的相关设计、招标、加工、施工等工作进度报告，供各级领导审阅或决策。

超高层施工关键路径分析

超高层项目选址通常都位于市中心繁华地段，故施工场地受限，单体建筑的施工楼层向高空纵向提升，塔楼结构施工工序之间以及结构与幕墙、机电、精装、电梯等专业施工需要保持合理步距，以便高效组织交叉施工。该特点即是超高层建筑物有别于多个住宅项目或商业综合体项目的原因，超高层的施工关键路径是随着塔楼主体结构施工进度而逐步转变的。

核芯筒钢结构安装到地面10层以前

10层以内的钢结构安装、其关键路径为塔吊制造及安装、核芯筒爬模体系安装及测试(见图6.7)。需提前设计规划好塔吊选型及预埋安装方案，并确保塔吊按计划运抵现场并完成安装。需根据塔楼结构体系选择高效安全的核芯筒爬模体系，按计划运抵现场并安装。

核芯筒钢结构安装到10至30层期间

10层到30层之间的钢结构安装、其关键路径为核芯筒钢构安装及墙体爬模施工。该阶段尽快为从上到下的核芯筒墙体钢结构及爬模、外框钢结构安装、外框楼板浇筑、核芯筒楼板和巨柱浇筑这几道工序拉开合理的步距，以免各工序之间相互牵制。

核芯筒钢结构安装到30层以上

30层以上的钢结构安装、其关键路径为外框楼板和巨柱。该阶段各道工序的合理步距已拉开，钢结构安装已进入正常高效阶



Figure 6.7. The goal of PAFC was to build one floor in four days, requiring appropriate tower cranes and climbing formwork (Source: Ping An)
图6.7. 平安金融中心的目标是一天建造四层楼，这需要合适的塔吊和爬模来实现 (来源: 平安)

Installation of Steel Structure 30/F and Above

For the installation of steel structures 30/F and above, it is observed that the critical path of the concrete works frame slabs and mega columns be sequenced. During this stage, reasonable construction sequences have been formed. Steel works enter the state of high efficiency, but the progress of frame slab and huge columns will possibly limit the commencement of the curtain wall, M&E work, decoration etc. During this stage, the coordination and organization focus is to keep the same climbing speed of each construction sequence, and try to achieve 4 days per floor. This creates conditions for curtain wall works to start in large areas as planned.

Installation of Curtain Wall Glass to 30/F and Above

For installation of curtain walls 30/F and above, it is observed that the critical path is to organize reasonable overlap construction sequences for brick walls, M&E works, decorations, specialty works, etc. During this stage, it's necessary for the main contractors and other contractors to make good use of design and construction coordination. Also, to ensure overlapping construction sequencing of all specialties should be organized efficiently.

After Complete Concreting of Frame Slab and Mega Columns

After topping up of the main structure, it is observed that the critical path is to remove the temporary elevators and install the permanent lifts simultaneously. As for lift installation in skyscrapers, due to lift shaft height, high installation accuracy and high standards of testing installation duration is long. So, lift handover schemes and shaft partition installation schemes need to be planned in advance.

In order to independently start the critical path of the main tower structural works, the temporary lateral supporting systems for basement construction and the podium structures against the main tower structure were designed to be independent during design stage.

Challenges and Risks of Skyscraper Project Management

As described above, project characteristics in section necessitate project master control management and skyscraper project management. Challenges and risks, planning, and analysis in advance, considering related schemes and measures for facing the challenges and decreased the risks confronted in the project.

段，外框楼板和巨柱的土建进度将可能限制幕墙、机电、精装单位的进场时间。该阶段需重点协调组织各道工序同步等效爬升施工，在标准层力争实现4天/层的速度，为外幕墙按计划开始大面积安装创造条件。

外墙玻璃安装到30层以上

30层以上的外墙玻璃安装、其关键路径为各楼层区间合理组织墙体砌筑、机电、精装等专业单位交叉依序施工。该阶段需要总包等各方充分发挥各自设计协调和施工协调职能，确保各单位在各自的楼层区间内高效完成交叉依序施工。

外框楼板和巨柱砼浇筑封顶后

在封顶之后，关键路径为核芯筒内施工电梯与正式电梯分批交叉拆除和安装。超高层电梯安装因井道高、安装精度和测试标准高，导致电梯安装周期长，需要尽早策划电梯井道移交方案和电梯井分段安装等方案。

为了确保塔楼主体结构的关键路径可以独立先行施工，需要在设计阶段将基坑临时支撑、地下室结构、在设计时间时裙楼结构与塔楼主结构分隔设计。

超高层项目管理中的挑战与风险

如前“项目总控管理的必要性”部分所述项目特征，超高层项目管理面临以下几方面的挑战和风险，需要提前规划、预判，



Figure 6.8. The highest risk in skyscraper construction is falling materials, meaning a large portion of resources needs to go towards safety management (Source: Ping An)

图6.8. 高层建筑施工中风险最高的是坠落问题，意味着在安全管理上需给予足够的重视（来源：平安）

Project Progress Challenges

Construction speed of tower structures is controlled according to the installation of tower cranes, the assembly of core-wall climbing formworks, fixing of dense rebar, welding of steelwork etc. The construction speed was around 10 to 15 days per floor under 50 meters. After reasonable construction sequences were formed the construction speed was accelerated to 6 to 8 days per floor between 50 and 150 meters. The construction speed was accelerated to 4 days per floor between 150 and 400 meters. Due to the transportation distance increase, it was expected that transportation efficiency of both tower crane and temporary elevators was low. The construction speed was expected to be 5 days per floor between 400 and 550 meters. At the end, owing to the removal of the tower crane and the formwork of core wall the construction speed was estimated between 7 to 10 days per floor above 550 meters.

Whether or not the above-mentioned construction speed could be achieved depended on unavoidable forces of the outside environment, vertical transportation capacity of tower cranes and temporary elevators. The influential degree of site storage and transportation during the demolition of the lateral supporting structure also affected speed. Additionally, speed depended on the efficiency of climbing framework of the core-wall and mega columns, choices of high quality concrete, rebar, steel, materials, welding, material choices, etc.

The PAFC was a large-scale, complicated and highly difficulty project with a special progress bonus set up for all related contractors and consultants. The bonus scheme was based on achieving milestone targets, creating an incentive to be as efficient as possible.

Contract Purchase and Cost Control Risks

The PAFC project involved many specialties that would total more than 100 companies. These included design consultants, supervising engineers, contractors, and material suppliers. It was necessary to work out a procurement plan according to the project master plan trying to simplify the procurement process and improve the procurement efficiency. Of course it was necessary for the design consultant to provide detailed and accurate drawings according to the master plan, so that the subsequent construction progress of the whole project could be fulfilled.

制定相应迎接挑战、降低风险的方案或措施。

项目进度挑战

超高层塔楼主体结构施工速度大致如下：50米以下因塔吊和爬模安装、钢筋密集、钢结构焊接量大等原因，施工速度只有10至15天/层。50米至150米区间因需要逐步拉开各道工序的合理步距，施工速度为6至8天/层。150米至400米区间，因各道工序等步距依序作业，施工速度可以达到4天/层。400米至550米区间因高区的塔吊和施工电梯运输降效，导致施工速度预计只有5天/层。550米以上的塔冠部分因塔吊轮换拆除、爬模拆除等，导致施工速度估计降低到7至10天/层。

上述各高度区间的施工速度能否实现，取决于天气条件、外界不可抗力、塔吊和施工电梯的垂直运输能力、地面临时支撑结构拆除对塔楼四周的堆载和运输的影响程度等。还取决于核心筒和巨柱爬模体系的爬升效率，取决于优质混凝土、钢筋和钢材等材料的选择，取决于大型钢构件分段加工及合理设置现场焊缝，取决于电梯井道隔墙的材料和施工方案，取决于进口石材等的供货周期等。

平安金融中心是大型、复杂、高难度的项目，设置了专项进度奖励资金，根据各自里程碑节点目标，对各参建单位实施奖励，以便各方共同高效完成项目任务。

合同招标及成本控制风险

平安金融中心项目涉及的专业众多，设计顾问、监理、施工单位和供货单位等总计超过100家，需要按照项目总控计划要求编制详细的招标计划，并尽量简化招标流程提高招标效率。当然也需要设计顾问按计划提交尽可能详细准确的招标图纸和技术资料，以便满足后续项目整体施工进度。

目前在建的国内乃至国际超过660米的超高层项目为数不多，项目管理团队难免遇到招标合同中有部分预估、暂定项目，或者出现合同中技术条款或规范不明确、专业合同责任界定不明确等问题、专项方案不详细或不明确，将导致专业单位进场后提出变更申请或责任纠纷。需要项目管理团队中配置足够相关经验的专业人员，同时提前与同行业类似项目进行交流学习，尽可能减少合同定标后的成本控制风险。

Currently in China, and even world-wide, there are only several skyscrapers being built which are more than 600 meters high. It is difficult for the project management teams to avoid estimate and provisional items in procurement, or undefined technical clauses or specifications, undefined contract responsibility definition, unclear or not so detailed special construction schemes and so on. This would result in request for responsibility disputes. Therefore, it is necessary to appoint enough experienced competent people. Meanwhile, experience with each other or study from similar projects aids in decreasing the cost control risk after confirming the contractors.

These results in the monopolization situation all related main contractors, specialty contractors and providers during the procurement stage would result in developers passively accepting higher purchasing prices or face bad contract execution effects. Consequently, it is necessary for developers to strictly review the project achievements and qualifications of bidders, personnel allocation and reservation, and actual contract execution performance. In addition it is imperative to establish contract clauses for practical execution.

Project Quality Challenges

The PAFC considered seismic and wind resistance capability, energy saving and environmental protection index, maintenance or replacement of equipments during operation stage. BIM technology in design and operation management, and LEED system implementation will benefit the project quality standard.

Project Safety Risk

The highest risk during the skyscraper construction is from falling materials. Reasonable core wall and frame structure systems should be selected during the design stage. Selecting safe and highly efficient climbing formwork during construction stage is vital to the employee's safety (see Figure 6.8). Safety consciousness, responsibility and training were some important elements of project safety management. Sufficient full-time safety managers and funds are necessary too.

这些还造成总包、专业施工单位和设备供应商在招投标阶段容易形成垄断格局，建设方可能因合格承包商数量有限，导致招标价格偏高或者合同执行效果不佳。需要在招标阶段严格审查投标单位的项目业绩、人员配置及储备、实际履约表现等，严格制定合同条款并落实执行，必要时采取适当处罚措施。

项目质量挑战

平安金融中心考虑了抗震抗风性能、节能环保指标、设计使用年限内的设备维修或更换等因素。BIM技术的辅助设计和运营管理，LEED体系的推行等有助于提高超高层项目的质量水平。

项目安全风险

超高层施工过程中最大的风险是高空坠落，需要在设计阶段选择合理的核芯筒和外框结构体系，以便施工阶段配合选择安全高效的爬模体系(见图6.8)。全员安全意识、安全责任、安全培训是项目安全管理的重要内容之一，需要配置足够的全职安全管理人员和资金。