INTERPLAY BETWEEN DESIGN AND PROJECT MANAGEMENT – A CASE STUDY

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INTRODUCTION

In civil engineering works, the design of a structure is heavily influenced by the method of construction. It is important that whenever possible, the designer at the design stage should have some understanding of the construction method. This is the only way that a new structure can be built safely, efficiently and within budget. Very often, the final cost of the structure can be drastically reduced if the project team and the design team can work together to produce an efficient design. This explains the large number of contractor’s alternative design proposals in civil engineering works.

In building projects, it is common for the contractor to propose an alternative design in foundation works or in excavation and shoring system. However, in the superstructure, there are more constraints in the freedom of alternative designs. There are a number of reasons for this. The most important one in the private sector being the constraints due to the time required for approval by the Buildings Department. Design inputs from the contractors are very often restricted only to construction sequences and the design of temporary works.

This paper concerns a private residential project at Luen Wo Hui, Fanling, N.T. This is a case study of a project, in which the contractor’s design and the project manager team worked together to produce a scheme to meet the time and cost constraints imposed by the contract.

PROJECT OUTLINE

The project described is a private residential project at F.S.S.T.L. 127, Luen Wo Hui, Fanling, N.T. This is a project with 1,127,000 square metres of construction floor area. The contract comprised:

1. Three and a half levels of basement carpark measured 15m deep from the mean ground floor level with approximately 38,000 square metres of construction floor area.
2. Two levels of commercial podium approximately 13m above ground floor level with 21,000 square metres of construction floor area.
3. Four residential towers with 51,000 square metres of construction floor area.
4. A club house on the podium deck of approximately 2,700 square metres of construction floor area.

Figure 1 shows an elevation of the project. It can be seen that the number of stories for Towers One to Four varies from 31 to 32. The project also has four pedestrian bridges.

The basement is split in the middle. To cater for the parking of lorries, the east side of the basement has a higher headroom. For this reason, on the west side, there are 4 levels of basement and on the east, only three.
PROJECT DESIGN

The typical floors utilized a wall-column framed system. Each of the towers has a transfer plate at 29.9 mPD roughly the 4th level, to transfer the wall and column loads to columns at the podium and the basement. The foundation utilized a system of large diameter bored piles. The basement walls consisted of 1200mm thick diaphragm walls.

PROJECT CONSTRAINTS

The foundation and the diaphragm wall contracts were carried out by a different contractor. The purpose of this paper was not to describe the foundation and the diaphragm wall works but rather the planning aspect of the superstructure and basement contract. How does the planning of construction works by the contractor affect the design of temporary and permanent works?

The first constraint imposed by the contract was the contract period. The project must be completed within a contract period of 715 days. This was a tight schedule. It included the issue of occupation permit and the certificate of compliance. Figure 2 shows the preliminary programme developed by the contractor at the planning stage.

The second constraint was the requirement that the pile cap for columns at grid lines C2-C3 and C8-C9 must be completed before Towers 1 and 2 were allowed to be built beyond the 21st floor. According to the project foundation consultant, without the combined pile caps, the foundation could only take an equivalent wind load of up to the 21st floor at Towers 1 and 2. For the safety of the building, the basement at the west side must be excavated down to the pile cap level for the construction of the pile cap at an early stage. This operation is shown in Figures 3a and 3b.

In general, for top-down construction, such as the present case, ideally, the basement and towers should be completed at about the same time to reap the full benefit of top-down construction. Because of this structural requirement, the basement must be completed well ahead of the towers. This had major impact on the planning of the basement works.

PROJECT PLANNING

The contractor set out a number of major target dates for the project. The target dates were the date of the occupation permit inspection and the date of the issue of the certificate of compliance. Tied in with these major dates were the dates for fire service inspection, the handover of the transformer rooms to the power company, the completion of the last manhole, etc.

Another important date was the date when Towers 1 and 2 reached the 21st floor. This was the date when the pile cap at basement 3 must be completed.

INFLUENCE OF PROJECT PLANNING ON DESIGN

Throughout the project, there were many occasions where the contractor’s design team must be called in to assist the project team. In this particular project, the design team was stationed full-time on-site because of the large amount of design work called upon during construction. In this paper, I would only touch on a number of more important issues.
Access Routes for Vehicular Traffic (Figure 4)

A characteristic of the site was that the basement basically occupies the whole site area. To construct the towers, concrete trucks and other trucks carrying building materials had to travel on top of the ground floor slabs to arrive at the positions of the hoists and concrete pumps. Apart from some locations, the ground floor slabs were not designed for HA loading. The first task of the project and design team was to identify a suitable route on the ground floor slab to check for additional constructional loads. This called for additional steel reinforcements in the slabs. The design had to be approved by the consultant. Additional reinforcements were placed. The route was protected with a layer of temporary concrete on top to avoid damaging the slab. The route was properly marked on-site to confine all construction traffic to the reinforced area.

Basement Construction

Due to the difference in headroom, the west and east basements were constructed using different methods. The west basement was designed as a carpark for private cars. The headroom was 2.5m. The east basement was designed for trucks with higher headroom of 4.4m. Right at the beginning of the project, the project team decided that all ground floor and basement slabs should be cast on grade. The design team helped carry out a number of analyses, including the use of settlement analysis to justify the proposal. To ensure good quality of concrete finish, a thin timber board was placed on top of lean concrete prior to the placement of steel and concrete (Figure 5). The result was rather satisfactory. The finish was so good that the client decided to leave the concrete as fair-faced.

Another feature of the basement construction was that a number of openings were left on the ground floor and basement slabs for the movement of materials such as steel and the passage of ventilation pipes.

West basement

The construction of the west basement was critical because of the need to cast the pile caps before Towers 1 and 2 reached the 21st floor. The pile cap had to be completed on time to meet the superstructure programme. The scheme adopted by the contractor was to cast only enough slabs on each basement floor to provide stability to the basement walls. There was a large central opening on each floor first of all to provide enough headroom for excavating equipment. Secondly, the opening gave better ventilation to people working in the basement area. Thirdly, the scheme shortened the construction time for each floor. Fourthly, the opening allowed the contractor to use a semi-open cut method to reach for the pile cap locations at an early stage. The design team's assistance was required to determine the width of the cast slabs. These slabs acted as temporary ring beams for the basement wall. They should not be too wide, otherwise the effectiveness of the central opening scheme was reduced. They should not be too thin. The ring beams must be rigid enough to provide stability to the basement walls. For the first and second basements, soils were removed through the opening on the ground floor. From the third basement onwards, it became inefficient for the soils to be removed in this way. The soils were carried from the west to the east basement and removed through a soil ramp to be discussed in the construction of the east basement.

After completion of the pile caps, the basement slabs in the central opening were cast from bottom to top using conventional method. The west basement was completed about nine months ahead of the towers.

East basement
The east basement was designed for trucks. It had higher headroom of 4.4m. The construction scheme was to construct a ramp so that trucks might go down the east basement to remove the soils near the source of the excavated materials. The completed basement slabs allowed the concrete and soil trucks to queue within the basement. This was essential to guarantee the production rate of 1000 m$^3$ of soil per day. The design team was asked to check the floor loads and put in additional steel reinforcement, if necessary. There was a debate between the project and the design team on the choice of steel and soil ramps for the movement of trucks to different levels of the east basement. It would be too time-consuming to construct the final concrete ramp. A temporary ramp was required. For the construction of the temporary ramp, the design team finally adopted open cut as ramp for the first basement. For the second basement onwards, steel sheet piles were driven on both sides to construct a temporary soil ramp linking the first basement to the second and third basement. This proved to be rather efficient. I mentioned that starting from the third level of the west basement, it was more efficient to bring the excavated soil from the west into the east basement to be removed there. A link was built behind the sheet piles for the moving of soils from the west into the east. (see Figure 6). The design team played an important role in the design of the soil ramp structures.

Even though the east basement did not have the same problem as the west, where there was an early date to complete the pile caps, there was still an urgency to complete this part of the basement. Many plant rooms including the machine rooms of the basement and podium lifts were located on the 3rd basement floor. This must be completed and handed over to the building services subcontractors at least 4 months before the issuance of occupation permit for the installation of various equipment.

**TRANSFER PLATES**

Each of the towers had a transfer plate at 29.9 mPD, above the club house but below the 1st floor level of the towers. Due to the size of the transfer plate, each of the plates had to be cast in two layers. The design team worked with the project team on the additional shear reinforcements that was required because of the two-pour method.

The next question to be answered was the temporary support system for the transfer plates. There were two options. The first was the use of proprietary steel props going all the way down the floors below until enough floor slabs could be utilized to support the weight of the plate when it was cast (Figure 7). The advantage of this option was the ease of installation and dismantling. The disadvantage was that whole areas of the floor slabs below were sterilized for a period of time. We are not talking about one floor but several floors. The second option was to use a system of steel beams bolted to the columns as a support (Figure 8). The advantage of this option was that it took longer time to construct and dismantle. On the other hand, there was no effect on other work below. Views were divided. It was finally decided that for Towers 1 and 2, steel props were used. To avoid affecting the excavation work, the ground floor slabs were checked for the additional loads. Where necessary, steel beams were used to bridge over the opening. The idea was not to put props into the basement where excavation was in progress. For the remaining two towers, the steel beam support system was used.

The different method of construction provided a sort of experiment on the two methods of construction. The one adopting a steel prop system was a lot more efficient. It was at least 14 days faster than the one using steel beams. The scheme was also cheaper. In both cases, there was heavy reliance on the design team to provide design input.

**OTHER ASPECTS AND CONCLUSION**

There were many other design issues provided by the design team during the construction stage. I do not want to include them here except to say that for large and complex building projects, contractor’s design team is becoming an essential part of the project management organization. If one looks at a building contractor’s organization chart, it is not unusual to see the designer’s role being relegated to a minor and unimportant role. Very often, the design team is only called in when there are problems arising on-site or
when it is required by the consultant to justify certain remedial works. It is reactive. On the other hand, if the design team can take on a proactive role, helping the project team to plan ahead right at the beginning of the contract, there is a good chance that the project can be completed more efficiently. It can help reduce costs and prevent accidents. A final note before I end my paper is that, the project I presented was completed on time and within budget.

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Figure 5