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Risk Management of Piled Foundation Projects

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Abstract
Risk exposure in foundation projects is substantially higher than other types of construction projects because subsoil conditions can never be precisely predicted. The objectives of this study are to identify the risks perceived by project consultants in piled foundation projects, assess the potential impact of identified risks, examine their attitudes towards risk allocation through contract provisions, and finally assess whether the contingency sum allowed is adequate to cover the potential risks. The data for this study was primarily gathered through the use of a questionnaire, together with telephone interviews. There were 60 completed project cases returned by end December 2006. It is found that significant risks are largely allocated to the contractor and employer under the design-and-build contract and traditional contract respectively. It is also found that project consultants have over-estimated the contingency sum by 1.784% in the design-and-build contract and under-estimated the same by 4.511% in the traditional contract. This study provides a useful clue on the risk management of piled foundation projects.

Keywords:
Risk Management, Piled Foundation, Traditional Contract, Design-and-Build Contract, Contingency Sum

1. Introduction

In Hong Kong most employers try to transfer all of their risks to contractors. Their project consultants usually modify the standard contract conditions and add special conditions to the contract documents so that the contractors have to accept risks associated with unforeseen ground conditions, third party's lawful interference, delay by nominated subcontractors, etc. Most piled foundation projects are based on a separate design-and-build contract, whereby the contractors have to take full responsibility for both design and construction and site investigation reports are only given in good faith without any guarantee on its accuracy. In theory the contractors can make an extra allowance in their tender prices to cover any unreasonable high risks. However, when construction works are scarce in the market, contractors have tended not to price all risks involved. But they seek to submit claims to mitigate their loss if the risks are materialised, giving rise to costly contractual disputes. Some contractors have even cut corners with substandard workmanship and other malpractices (such as shortened pile depth), resulting in costly and wasteful rectification (CIRC, 2001).

While project consultants are not a party to the contract, they ordinarily advise and prepare contract documents that apportion risks between the employer and contractor. As any significant default by the contractor is still ultimately the employer's risk, it is in the interest of both parties to adopt the appropriate contract with an equitable allocation of risks. Therefore the objectives of this study are to identify the risks perceived by project consultants in piled foundation projects, assess the potential impact of identified risks, examine their attitudes towards risk allocation through the relevant contract provisions, and finally assess whether the contingency sum allowed is adequate to cover the potential risks.

2. Literature Review

Risk and uncertainty are inherent in all construction works, particularly in piled foundation works where there are many uncertainties encountered in underground conditions. While the geotechnical investigation can help reduce the risk of these uncertainties, it cannot definitely reveal all underground conditions to be encountered during the construction stage. Depending precisely upon the contract conditions signed between the contracting parties, these uncertainties may result in contractual claims from the contractor due to unexpected high water table, unforeseeable underground obstructions, deeper bedrock levels, excessive ground movements and settlements, and damage to nearby utilities, underground structures or buildings. Therefore effective risk management is very crucial for the success of a foundation project.

Risk in construction is generally perceived as those events that influence the project objectives of time, cost and quality. Risk management is a systematic process consisting of three basic steps: risk identification, risk analysis and risk response (Buchan, 1994; Tweeds, 1996). PMI (2000) suggests the risk management process consisting of four phases: risk identification, risk quantification, response development and risk control. It is widely recognised that the greatest degree of uncertainty is occurred at the early stage of the project when the relevant project consultants are appointed. The project consultants have an overall responsibility for identifying, assessing and allocating the risks at an early stage of the project (Tweeds, 1996). This study thus focuses on the risk management from the project consultant's perspective.

Risk identification is the first and most important step in the risk management process and is defined as the process of systematically and continuously identifying, categorizing and assessing the initial significance of risks associated with the project (Al-Bahar and Crandall, 1990). If a risk cannot be identified, it cannot be controlled, transferred or otherwise managed. Early identification of risk enables the project consultants to focus their attention on risk response strategies, for example through the choice of an appropriate contract strategy (Perry, 1986). Risk identification techniques can be classified into three main types: identification conducted solely by the risk analyst, identification by the analyst interviewing the project consultants, and the analyst leading a working group which may consist of brainstorming, nominal group technique and Delphi (Chapman, 1998). Some authors have attempted various means of classifying risks associated with construction projects. These are commonly classified into the categories of the force majeure, physical, financial, economic, political, legal, environmental, design and construction risks. However there is no previous study on the classification of potential risks associated with foundation projects.

Risk analysis is to assess the effects of those major risks identified on the project objectives. There are two essential approaches of risk analysis: quantitative and qualitative. Quantitative approach includes subjective probability, decision analysis, sensitivity analysis and Monte Carlo simulation, whereas qualitative approach includes checklists, brainstorming, direct judgment, risk ranking and descriptive analysis. Past research indicates that risk analysis depends mainly on intuition, judgement and experience and formal risk analysis techniques are rarely used due to a lack of knowledge and to doubts on the suitability of these techniques for the construction industry activities (Akintoye and MacLeod, 1997; Shen, 1997).

Risk response is in form of one or a combination of actions, namely risk avoidance, risk reduction, risk transfer and risk retention (Perry, 1986; Tweeds, 1996). The project consultants should normally try to avoid or reduce the identified risks where possible by, for examples, carrying further detailed site investigation, changing some designs, considering alternative construction methods, etc. Customarily risks arising from damage and/or injury to the construction works, workmen and third party are transferred to the insurer and contractor' non-performance is covered by a surety bond under standard contract conditions. Therefore, amongst all risk response and mitigation measures, the most important risk allocation technique is through the appropriate contract strategy. The project consultants' attitudes towards risk allocation directly affect the main contract arrangement as well as its individual contract conditions. This is thus an important area for research.

3. Research Framework

In Hong Kong most buildings are high-rise in nature and are normally supported by deep piled foundation. The piled foundation is customarily executed by a specialist contractor under a separate contract so as to allow more time for project consultants to design and document the main building works during the foundation construction stage. It is well recognised that risk exposure in foundation projects is substantially higher than other types of construction projects. Therefore project consultants should properly manage potential risks associated with foundation projects.

Based on the analysis of the duties, responsibilities and liabilities of the employer and contractor under the Hong Kong Standard Form of Building Contracts (which is modelled on the JCT standard forms), some contract documents for piled foundation projects as well as extensive literature review on risk classifications, the potential risks which may occur in foundation projects are identified as follows.

- Differing bedrock levels
- Unforeseeable site conditions including soil stability and strength, ground water, boulders, existing utilities and foundations
- Delay in obtaining relevant approvals and consents from the government
- Changes in ordinances, regulations and other statutory requirements
- Substandard materials and workmanship
- Variations of foundation designs
- Errors in description or quantity in the contract
- Damage and injury to persons and adjoining properties
- Damage of works by fire, lightning, typhoon, earthquake, flood, etc.
- Late handover of site to the contractor
- Under-recovery of liquidated and ascertained damages for non-completion
- Force majeure
- Inclement weather
- Civil commotion, local combination of workmen, strike or lockout
- Late consultant's instructions, drawings or other details
- Opening up for inspection or testing of any works, materials or goods
- Contractor's inability to secure essential labour, plants and materials
- Determination of contractor's employment due to his bankruptcy

- Delay by discovery of antiquities
- Fluctuation in labour and material costs

Based on the decision theory, risk can be assessed from two main criteria: the consequence of an undesirable event and the probability of occurrence of that event, which will be used to capture the project consultants' perception on potential risks associated with foundation projects. The impact of each risk is obtained by multiplying its consequence and probability of occurrence. The possible consequences of each risk can be measured in terms of time, cost and quality. However, for the purpose of this study, it is only measured in terms of cost which provides a good indication of the impact of any particular risk.

The above 20 risks are fundamentally allocated between the employer and contractor through the appropriate contracts such as the traditional contract, design-and-build contract, management contract and construction management contract. The contracts commonly used for foundation projects in Hong Kong are the traditional and design-and-build contracts. Under the traditional contract, project consultants are responsible for advising and preparing the detailed foundation design and contract documents. The bills of quantities are prepared based on the engineer's design and other technical information and some of items are provisional subject to remeasurement. The contractor is only responsible for construction methods, sequences and safety precautions by virtue of his experience, qualification, expertise and ability to control. Under the design-and-build contract, the contractor is responsible for both detailed design and construction of the entire foundation project based on the loading plans and performance specifications prepared by the structural engineer appointed by the employer. The schedule of quantities and rates prepared by the contractor is not subject to remeasurement except variations instructed by project consultants. Between these two contractual approaches, there are also different amendments of individual conditions of the standard building contract, further modifying the risk allocation between the contracting parties. It is thus important to assess the project consultants' attitude to risks as well as whether the contingency sum allowed is adequate to cover the retained risks.

4. Data Collection Procedures

The data for this study was primarily gathered through the use of a questionnaire. The questionnaire targeted to be completed by those professionals involved in the early design stage of a building project, including the project manager, architect, structural engineer and quantity surveyor. The questionnaire was dispatched through the monthly newsletter of the relevant professional institutions in September 2006. In order to increase the response rate, each respondent was followed up by a telephone call. At the same time, they were also asked whether they would like to accept telephone interviews. In other word, data was also collected through telephone interviews. There were 60 questionnaires completed by end December 2006.

In this study, the sample unit is based on the foundation project rather than the respondent. Thus, in theory, the respondent is allowed to fill in more than one questionnaire if he/she has had experience in more than one foundation project. However, in order to maintain balanced samples, each respondent was only required to complete not more than two questionnaires. When answering the questionnaire, the respondent was requested to make reference to a specific foundation project in which he/she had directly involved.

The questionnaire consists of three sections. The first section of the questionnaire was to collect the respondent's personal data including his/her job titles (i.e. project manager, architect, structural engineer or quantity surveyor) and years of experience to ensure that he/she was appropriate for completing the questionnaire. The second section was to collect the respondent's views on the possible consequence and probability of the 20 identified risks. The respondent was reminded to take an impartial position to give their professional judgement, disregarding the eventual risk allocation among the employer, contractor or third party. In order to make the judgement less subjective, the possible consequence of each risk is assessed and expressed as a percentage of the contract sum, excluding the contingency allowance. This allows meaningful comparison among projects with different scales. Similarly the probability of occurrence is assessed quantitatively ranging from 1% to 100%. The third section was to collect the respondent's view on the contract strategies (i.e. traditional contract or design-and-build contract) adopted as well as their attitudes (i.e. retain by the employer or transfer to the contractor) towards the 20 identified risks when drafting the relevant contract provisions. The respondent was also requested to fill in the contingency sum expressed as a percentage of the contract sum.

5. Data Analyses and Findings

Table 1 shows the expected mean values of risks with the relative importance indicated in the bracket. The impact of each risk is obtained by multiplying its consequence and probability. It is found that if all risks happen, the total impact which amounts to 18.50% of the contract sum is very significant.

Table 1: Consequence, Probability and Impact of Risks Perceived by Project Consultants

Risk Factors	Consequence of Risk	Probability of Risk	Impact of Risk
Differing bedrock levels	12.50 (1)	0.65 (1)	8.125 (1)
Unforeseeable site conditions	10.50 (2)	0.20 (6)	2.100 (2)
Variation of foundation designs	7.50 (5)	0.25 (5)	1.875 (3)
Fluctuation in labour and material costs	3.00 (12)	0.55 (2)	1.650 (4)
Late consultant's instructions, drawings etc.	5.25 (7)	0.30 (4)	1.575 (5)
Inclement weather	2.00 (15)	0.40 (3)	0.800 (6)
Substandard materials and workmanship	6.50 (6)	0.10 (8)	0.650 (7)
Errors in description or quantity in the contract	5.00 (8)	0.08 (9)	0.400 (8)
Under-recovery of liquidated damages	4.50 (9)	0.07 (10)	0.315 (9)
Opening up for inspection of any works or materials	1.50 (17)	0.15 (7)	0.225 (10)
Damage of works by fire, typhoon, etc.	8.50 (4)	0.02 (14)	0.170 (11)
Late handover of site to the contractor	2.50 (13)	0.06 (11)	0.150 (12)
Delay in obtaining relevant approvals and consents	3.50 (11)	0.04 (13)	0.140 (13)
Contractor's inability to secure essential labour, plants or materials	2.25 (14)	0.05 (12)	0.113 (14)
Determination of contractor's employment	10.00 (3)	0.01 (15)	0.100 (15)
Damage and injury to persons and properties	4.00 (10)	0.01 (15)	0.040 (16)
Local combination of workmen or strike	2.25 (14)	0.01 (15)	0.023 (17)
Changes in ordinances, regulations etc.	1.75 (16)	0.01 (15)	0.018 (18)
Force majeure	1.00 (18)	0.01 (15)	0.010 (19)
Delay by discovery of antiquities	0.50 (19)	0.01 (15)	0.005 (20)

Two risks which are perceived to have an impact of more than 2% on the project cost are "uncertain bedrock level (8.125%)" and "unforeseeable site condition (2.100%)". While site investigation is normally carried out in all piled foundation projects and because most piles are end-bearing on sound bedrocks, "uncertain bedrock level" is perceived to have the most significant impact on foundation projects. Besides bedrock levels, the amount of artificial underground obstructions (such as existing foundations and utilities) and natural boulders also affect the construction of most foundation systems. Thus "unforeseeable site condition" is perceived to have the second most significant impact on foundation projects. These two ground condition related risks totally account for 10.225%.

Three risks which are perceived to have an impact of more than 1% but less than 2% on the project cost are "variation of foundation designs (1.875%)", "fluctuation in labour and material costs (1.650%)" and "late instructions and drawings (1.575%)". "Variation of foundation designs" is partly because the foundation design is not wholly finalized when awarding the foundation contract and partly because after the award of the foundation contract, there is certain change in the superstructure design which leads to the corresponding change in the foundation design. Closely related to this risk is "late instructions, drawings or other details" issued by project consultants. The contractor may incur direct losses and expenses which is normally recoverable from the employer. While "fluctuation in labour and material costs" is largely predictable, this is an inevitable risk in its estimate.

Five risks which are perceived to have an impact of more than 0.2% but less than 1.0% on the project cost are "inclement weather (0.800%), "substandard materials and workmanship (0.650%)", "errors in the contract (0.400%)", "under-recovery of liquidated damages (0.315%)" and "opening up for inspection of any works or materials (0.225%)". Foundation projects are particularly prone to the effect of inclement weather. While there is a past record of "inclement weather", there is no exact science to forecast weather conditions. "Substandard materials and workmanship" is perceived to have a certain impact on the project because some foundation contractors have cut corners with substandard workmanship and other malpractices resulting in costly and wasteful rectification. On the other hand, many foundation contractors are very conscious to submit claims and even appoint claim consultants to look into any grey areas in contract documents. As any contractual claim is an uncertain to the project, "errors in the contract" is also perceived as a risk. "Under-recovery of liquidated damages" is closely associated with "variation of foundation designs" and "late instructions and drawings" because once there are certain delays caused by project consultants, the contractor may claim that most delays are caused by the employer, though some of which are due to their own fault. Any dispute in respect of a delay or extension of time is resolved through negotiation or arbitration. It may end up with a certain compromise between the employer and contractor, resulting in "under-recovery of liquidated damages". "Opening up for inspection of any works or materials" is closely associated with the situation of "substandard materials and workmanship". In order to avoid substandard materials and workmanship, the project consultants request for more inspections and tests. Unless it is covered under the original contract, the employer has to pay for the additional cost incurred unless the inspections or tests show that the work or materials are not in accordance with the contract.

The remaining ten risks which include "damage of works by fire, typhoon, etc.", "late handover of site to the contractor", "delay in obtaining relevant approvals and consents", "contractor's inability to secure essential labour, plants or materials", "determination of contractor's employment", "damage and injury to persons and properties", "local combination of workmen or strike", "changes in ordinances or regulations", "force majeure" and "delay by discovery of antiquities" have the possibility of occurrence of less than 10%. Its total impact only accounts for 0.769% of the project cost and is therefore not significant.

Table 2 shows the allocation of the 20 risks grouped under the design-and-build and traditional contracts. It is found that 40 and 20 foundation projects adopted the design-and-build contract and traditional contract respectively. In other word, design-and-build is the most popular contract used for foundation projects in Hong Kong. As noted from the above findings, the first ten risks which accounts for 95.843% of the total impact on the project cost determine the allocation of major risks between the employer and contractor, whereas the remaining ten risks are less important no matter how these risks are allocated.

Table 2: Risk Allocation between Employer and Contractor

Risk Factors	Design-and-Build		Traditional Contract	
	Retain by Employer	**Transfer to Contractor**	**Retain by Employer**	**Transfer to Contractor**
Differing bedrock levels		40 (100%)	20 (100%)	
Unforeseeable site conditions		40 (100%)	5 (25%)	15 (75%)
Variations of foundation designs	38 (95%)	2 (5%)	20 (100%)	
Fluctuation in labour and material costs		40 (100%)		20 (100%)
Late consultant's instructions, drawings etc.	40 (100%)		20 (100%)	
Inclement weather	2 (5%)	38 (95%)	7 (35%)	13 (65%)
Substandard materials and workmanship		40 (100%)	1 (5%)	19 (95%)
Errors in description or quantity in the contract	5 (12.5%)	35 (87.5%)	17 (85%)	3 (15%)
Under-recovery of liquidated damages	10 (25%)	30 (75%)	5 (25%)	15 (75%)
Opening up for inspection of any works or materials	4 (10%)	36 (90%)	10 (50%)	10 (50%)
Damage of works by fire, typhoon, etc.	3 (7.5%)	37 (92.5%)	3 (15%)	17 (85%)
Late handover of site to the contractor	40 (100%)		20 (100%)	
Delay in obtaining relevant approvals and consents		40 (100%)	18 (90%)	2 (10%)
Contractor's inability to secure essential labour, plants or materials		40 (100%)		20 (100%)
Determination of contractor's employment		40 (100%)		20 (100%)
Damage and injury to persons and properties	3 (7.5%)	37 (92.5%)	3 (15%)	17 (85%)
Local combination of workmen or strike		40 (100%)		20 (100%)
Changes in ordinances, regulations etc.		40 (100%)	4 (20%)	16 (80%)
Force majeure	3 (7.5%)	37 (92.5%)	3 (15%)	17 (85%)
Delay by discovery of antiquities	15 (37.5%)	35 (62.5%)	20 (100%)	

It is observed from the Table 2 that the most significant risks are largely allocated to the contractor and employer under the design-and-build and traditional contracts respectively. On the other hand, the remaining ten less important risks are largely allocated to the contractor under both the design-and-build and traditional contracts. This reflects the project consultants' attitude that unless the risk allocation affects the fundamental spirit of the respective contract, they generally transfer the risks to the contractor in both design-and-build and traditional contracts.

The risks retained by the employer should normally be covered by the contingency sum. Table 3 shows the mean contingency sum allowed under the design-and-build and traditional contracts. The potential impact of each risk is calculated based on the respondent's judgement as indicated in Tables 1 and 2. As indicated in Table 3, the mean contingency sums allowed under the design-and-build and traditional contracts are 5.50% and 8.75% respectively. It is found that the project consultants have slightly over-estimated the contingency sum by +1.784% in the design-and-build contract, whereas they have under-estimated the same by -4.511% in the traditional contract. Therefore, should the traditional contract be used for foundation projects, the project consultants should pay more attention to the contingency allowance which should be in line with the risk allocation between the employer and contractor.

Table 3: Contingency Allowance under Design-and-Build and Traditional Contracts

	Design-and-Build	Traditional Contract
Contingency sums	5.500%	8.750%
Potential risks retained by employer	3.716%	13.261%
Differences	+1.784%	-4.511%

6. Conclusions

Risk exposure in piled foundation projects is substantially higher than other construction projects. This study identifies a list of potential risks associated with foundation projects, together with the project consultants' judgements on its possible consequence, probability and impact. The first five risks which are perceived to have the largest impact on the project are "uncertain bedrock levels", unforeseeable site conditions", "variation of foundation designs", "fluctuation in labour and material costs" and "late instructions and drawings". It is found that significant risks are largely allocated to the contractor and employer under the design-and-build contract and traditional contract respectively. It is also found that project consultants have over-estimated the contingency sum by 1.784% in the design-and-build contract and under-estimated the same by 4.511% in the traditional contract. This study provides a useful clue on the risk management of piled foundation projects.

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