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DEVELOPMENT OF GUIDELINES FOR IMPLEMENTATION OF BORED PILE FOUNDATION WORK BASED ON RISK ANALYSIS

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ABSTRACT

Foundation specialist contractors already have guidelines for carrying out bored pile work. However, in its implementation there are risks that could potentially lead to delays. This is because in carrying out bored pile work there are risks that are not visible in the ground. Therefore, existing implementation guidelines need to be developed based on risk. This study aims to identify and analyze the potential risks that will occur, as well as the responses that need to be taken in the form of preventive and corrective actions, so as to develop guidelines for the implementation of risk-based bored pile work. The method used in this research is a qualitative analysis and Multi-Attribute Utility Theory (MAUT) analysis. The dominant risk factors were found, namely the existence of utilities in the ground, improper age of the tool, collapse of the surface soil around the borehole, changes in the work implementation schedule from the owner and low labor productivity. Therefore, the risk response is to carry out Ground Penetrating Radar (GPR) and area mapping to find out the utilities that are in the ground, replace tools that are more appropriate, use preliminary casing, carry out careful planning and bring in an experienced workforce. It is hoped that the guidelines for implementing risk-based bored pile work can be used by specialist contractors to minimize the impact of negative risks that may occur in the implementation of bored pile foundation work.

KEYWORDS *guidelines; bored pile; risk; delays*

INTRODUCTION

Foundation is one of the building structures located at the bottom of a building which functions to transmit construction loads to the soil layer below the foundation (Muluk et al., 2020). Foundation in a construction building plays an important role because it acts as a barrier or supports the load of the building above it to be passed

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on to the subsoil below (Matondang et al., n.d.). Bored pile is a drilled pile foundation installed into the ground by drilling the ground first, then filled with reinforcement and cast concrete (Hardiyatmo, 2010).

Foundation work is a vital part of a construction project and has a high complexity in its implementation, so it is necessary to pay close attention to the risks that arise at this stage to ensure that the project completion time does not exceed the time agreed upon by the parties involved in the contract (Assaf & Al-Hejji, 2006). There are two factors that affect foundation work which are categorized into 2, namely internal factors and external factors. Internal factors are factors that affect foundation work, namely project planning, land, foundation construction, materials, labor and equipment, while external factors are external factors that affect foundation work, including the project owner (owner), factors from contractors and consultants, the country's political situation and conditions and the environment around the project (Puro, 2006). Even though the foundation specialist contractor already has guidelines for carrying out foundation work, they still often experience problems or problems in carrying out work because foundation work has high complexity. Constraints or problems in the implementation of foundation work include the lack of certainty about the structures in the ground, unskilled and unproductive workforce, delivery of materials that are often late, and equipment that cannot work according to plan.

One example of the phenomenon is the dominant risk factors for bored pile work in the Jatigede Sumedang Dam Left Slope Reinforcement project are rain, productivity not as expected, landslides, surface soil collapse around the borehole and also limited access roads (Magna et al., 2017). Other dominant risk factors include low labor productivity and delays in ordering tools (Rizkiyanto, 2018). The dominant risk factors for bored pile work that have an impact on time are tool damage and soil collapse around the drilled hole [8]. If these dominant factors are not anticipated and managed properly, they will certainly have an impact on time which can result in delays in completing work.

PT. X is a foundation specialist private contractor company in Indonesia. In the period 2016 - 2020 there are more than 35% of projects annually that experience delays as in the table below.

Table 1
Bored Pile Work Delay Data at PT. X in 2016 - 2020

No.	Years	Number of Projects	Number of Delays Projects	Percentage of Delays Projects
1	2020	7	3	42.86%
2	2019	13	5	38.46%
3	2018	15	6	40.00%
4	2017	6	3	50.00%
5	2016	9	4	44.44%

Based on project delay data and bored pile work implementation guidelines at PT. X, it can be seen that the guidelines for carrying out bored pile work owned by PT. X needs to be reviewed based on risk analysis so as to minimize negative risks that may occur. Because the implementation guidelines do not yet have detailed guidelines on how to anticipate and handle if a risk occurs. The implementation guideline is still incomplete in terms of handling if there are risks that occur such as if there is a soil slide in the hole while drilling is in progress, tool damage and limited access roads which are one of the dominant risk factors as mentioned in previous studies in on. What actions should be taken to overcome these dominant risk factors are not listed in the implementation guidelines currently owned by PT. X.

This research is important to do considering that the implementation of bored pile foundation work has several risks such as obstacles that are not visible in the ground, differences in soil structure from soil investigation data, damage to heavy equipment and others, which will have a delay impact on the work schedule. Currently, PT. X does not yet have specific guidelines for anticipating and dealing with the risks of bored pile work implementation, so it is important to do research so that various risks can be identified so that they can be used to develop guidelines for carrying out bored pile work and improve project time performance.

Risk events are very important because they can have a direct impact on the performance of work completion time by PT. X, it is necessary to carry out risk management for bored pile work to identify and analyze the potential risks that will occur, as well as the responses that need to be carried out in the form of preventive and corrective actions. Based on this risk management data, it will then be developed into a guideline for the implementation of bored pile foundation work based on risk analysis to improve the implementation guidelines already owned by PT. X before.

Project risk management is to increase the likelihood and/or impact of positive risks and to reduce the likelihood and/or impact of negative risks, in order to optimize the chances of project success (Marsya, 2017). Qualitative risk analysis is the process of prioritizing the risks of each project or further action by assessing the likelihood of their occurrence and their impact and other characteristics (Duncan, 2005). The main benefit of this process is that it focuses efforts on high priority risks. Risk analysis as one of the research variables that will be carried out is the dependent variable that is influenced by other variables. Variables that influence it include the impact and frequency of risk events that occur, as well as response to risk.

The processes in developing guidelines for the implementation of risk-based bored pile foundation work in this study are as follows.

1. Identification of Risk Factors

The risk identification process in this study will be carried out in the following order.

a. The first risk identification is carried out by means of a literature study with the research object being the activity of carrying out bored pile foundation work as shown in Table 2.
b. The results of the identification of the literature study were reviewed by experts to find out whether these risk factors could be used as variables in research to determine the dominant risk factor in the implementation of bored pile foundation work.

c. After being reviewed by experts, the risk factors were used as variables in a survey conducted on people who are experienced in the field of bored pile foundations.
d. The primary data from the survey were then tested and processed to obtain the dominant risk factors in this study.

Table 2
Risk Factors for Bored Pile Foundation Work

No.	Risk Source Category	Activity (Risk Event)
1	Project Planning	Delay in design information
2		Errors in planning and specifications
3		Image approval delays
4	Earthworks	Unstable subgrade condition
5		There is ground water disturbance
6		Retaining wall collapse
7	Foundation Construction	Limited access roads to work
8		Error in measuring the coordinates of the drill point
9		Error setting excavated land
10		Surface soil collapse around the borehole
11		There are utilities in the ground
12		Incorrect casing installation
13		Straight drilling
14		Faulty stringing
15		Error installing tremi pipe
16		Concrete pouring error
17		The amount and quality of concrete is not appropriate
18	Material	Material changes in form, function, and specifications
19		Delay in delivery of materials
20		The volume of material sent to the site is not enough
21		Lack of material storage space
22	Labor	The scheduling of the workforce needed is not good
23		Low labor capability
24		Lack of workforce
25		Low labor productivity
26	Equipment	Delays in ordering tools
27		Delay in mobilizing equipment to the location
28		Insufficient amount of equipment used
29		Tool age is not worth it
30		Equipment malfunction
31	*Owner*	Late payment from the owner
32		Owner involvement
33		There is additional work
34		Licensing delays
35		There is a change in the work implementation schedule from the owner
36	Factors from Contractors and Consultants	Error in interpreting drawings and specifications
37		Ineffective planning and scheduling
38		Poor qualifications of the contractor's technical staff

No.	Risk Source Category	Activity (Risk Event)
39		There are coordination and communication problems with the owner
40		Delays in carrying out final inspection and certification by third parties
41		Poor Quality Assurance / Control
42		Poor planning, implementation and management
43		Poor subcontractor management
44		There is no time control information
45		Project funding is not smooth
46	State Political Situation	There are changes in policies/regulations that affect project activities
47		Rise in fuel prices
48	Conditions & Environment Around the Project	Traffic jams around the project site
49		Problems with the surroundings
50		Weather, rain or flood

2. Risk Analysis

In this study the identified risk factors were then analyzed. using qualitative analysis. Furthermore, determining the level of risk in each risk identification. The risk level is in the form of a matrix which is the multiplication of the impact of the risk event and the likelihood of the risk occurring (risk frequency).

It is difficult for everyone to accept the level of severity of risk, so it is necessary to convert it into a utility value. Multi Attribute Utility Theory (MAUT) is a scheme in which the final evaluation of an object x, V(x) is defined as the weight summed with a value relevant to the dimension value, the expression commonly used to call it is the utility value (Schäfer, 2001). MAUT is used to convert from multiple interests into numerical values on a scale of 0-1 with 0 representing the worst choice and 1 being the best, this allows direct comparison of the various sizes (Puspitasari et al., 2013). Weighting is based on the importance of each existing criterion, with the largest to the smallest weight with an interval of 0-100 (Hadinata, 2018). Then the sum of each criterion becomes the final value of each alternative criterion.

3. Risk Response Planning

The next stage is to develop a risk response plan based on the risk level of the risk analysis matrix. Risk responses can be in the form of reducing the consequences of the occurrence of risks and reducing the frequency of possible occurrences of risks. The risk response is composed of actions to reduce the level of risk from cause and effect if the identified risk event occurs.

The risk responses obtained in this study were based on existing literature studies. However, not all responses obtained from the literature study can be included in the list of responses that must be made. Therefore, a survey is needed and validated by experts to determine how much influence each of the proposed risk responses has so that a list of risk responses that can be implemented will be obtained which will then be developed to become a guideline for implementing risk-based bored pile foundation work

RESEARCH METHOD

Risk management on bored pile foundation work is carried out through several stages. First, identify the risks that have the potential to affect the time performance of the research object so that the factors that influence the performance of bored pile foundation work are known. The second stage is risk analysis through qualitative data analysis so that risks and responses to these risks can be identified. In the final stage, a study was carried out to obtain guidelines for the implementation of risk-based bored pile foundation work to improve performance during construction projects.

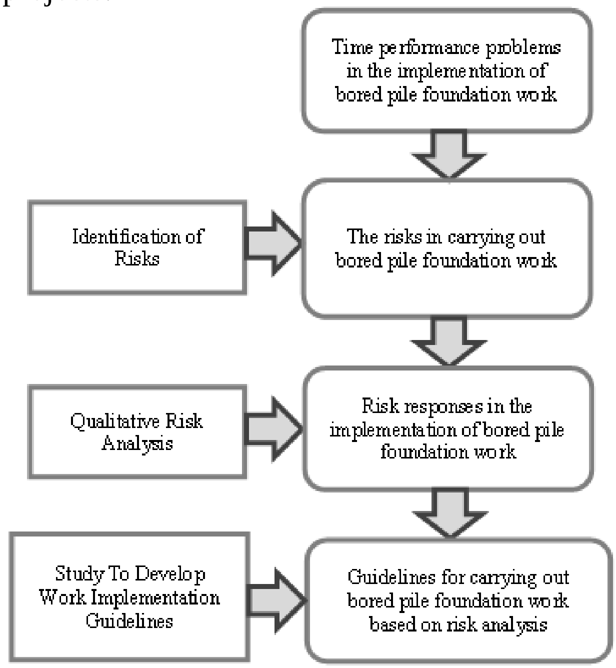

Figure 1
Research Conceptual Framework

RESULTS AND DISCUSSION

Dominant Risk Factors

To answer RQ 1 regarding the risks that can affect the execution time of the bored pile foundation work at PT. X. Based on the 50 variables that have been validated by experts, then data collection is carried out using a questionnaire on the respondents. After statistical analysis was carried out in the form of a validity test, there were 18 invalid variables and 32 valid variables. Then a qualitative risk analysis and MAUT analysis were carried out which resulted in a risk ranking. Of the 32 variables, there is 1 variable with an extreme level and 10 variables with a high level which are categorized as dominant risks that affect the execution time of bored pile foundation work as can be seen in the following table.

Table 3
Variable Risk Level

Var.ID	Variable (Risk Event)	Final Score	Rank	Risk Levels
X3.5	There are utilities in the ground	90.67	1	Extreme
X6.4	Tool age is not worth it	69.61	2	High
X3.4	Surface soil collapse around the borehole	66.13	3	High
X7.5	There is a change in the work implementation schedule from the owner	64.13	4	High
X5.4	Low labor productivity	61.74	5	High
X5.3	Lack of workforce	61.68	6	High
X2.3	Retaining wall collapse	58.65	7	High
X8.10	Project funding is not smooth	58.28	8	High
X8.7	Poor planning, implementation and management	56.30	9	High
X6.1	Delays in ordering tools	52.47	10	High
X8.9	There is no time control information	52.37	11	High
X9.2	Rise in fuel prices	49.70	12	Moderate
X6.3	Insufficient amount of equipment used	49.03	13	Moderate
X5.2	Low labor capability	45.76	14	Moderate
X6.2	Delay in mobilizing equipment to the location	45.40	15	Moderate
X3.3	Error setting excavated land	40.15	16	Moderate
X4.2	Delay in delivery of materials	39.46	17	Moderate
X5.1	The scheduling of the workforce needed is not good	38.49	18	Moderate
X8.8	Poor subcontractor management	37.42	19	Moderate
X1.2	Errors in planning and specifications	32.45	20	Moderate
X8.6	Poor Quality Assurance / Control	31.81	21	Moderate
X1.1	Delay in design information	31.48	22	Moderate
X8.3	Poor qualifications of the contractor's technical staff	29.91	23	Moderate
X3.11	The amount and quality of concrete is not appropriate	27.18	24	Moderate
X3.9	Error installing tremi pipe	26.58	25	Moderate
X3.7	Straight drilling	19.74	26	Low
X8.2	Ineffective planning and scheduling	18.54	27	Low

X8.4	There are coordination and communication problems with the owner	18.04	28	Low
X4.1	Material changes in form, function, and specifications	16.45	29	Low
X3.6	Incorrect casing installation	16.34	30	Low
X3.8	Faulty stringing	15.51	31	Low
X8.5	Delays in carrying out final inspection and certification by third parties	2.67	32	Low

Risk Responses

To answer RQ 2 regarding what responses need to be done to manage the risk so that when the bored pile foundation work is carried out at PT. X is not too late. Furthermore, an analysis of the risk response to the dominant risk factors consisting of causes, effects, preventive actions and corrective actions will be carried out by validating the results of the literature study by experts who have experience in carrying out bored pile work. Data on risk causes, risk consequences and risk responses to dominant risks based on the results of a literature study can be seen as follows.

Table 4
Risk Responses

Var.ID	Variable (Risk Event)	Preventive Measures	Corrective Action
X3.5	There are utilities in the ground	Can do Ground Penetrating Radar (GPR) first to find out objects buried in the ground and it is necessary to carry out an inventory of utilities in the work area	Perform mapping of areas where there are utilities in the ground, then coordinate with supervisors and planners to review the foundation layout
X6.4	Tool age is not worth it	Check the feasibility and age of the equipment to be used before being mobilized to the location	Make a more appropriate tool replacement, and immediately send the replacement tool to the location
X3.4	Surface soil collapse around the borehole	Carry out ground investigations accurately	Can use preliminary casing to prevent soil collapse around the borehole
X7.5	There is a change in the work implementation schedule from the owner	Do more mature planning in accordance with the wishes and needs of the owner	Propose additional implementation schedules to the owner and make adjustments to schedule planning

X5.4	Low labor productivity	Conduct coaching and debriefing to workers before the implementation of work	Bringing in an experienced workforce to mobilize workers who are still lacking in experience, as well as increasing working time to catch up on work progress
X5.3	Lack of workforce	Calculate and evaluate the volume of work appropriately so that the number of workers needed is appropriate and provide workers who are experienced and competent in their fields	Increase the number of workers and work time, as well as clear supervision from the foreman or supervisor from the contractor
X2.3	Retaining wall collapse	Carry out better and more accurate planning, and use competent personnel according to their areas of expertise	Re-check the design, and make improvements
X8.10	Project funding is not smooth	The contractor must carry out a cost management plan before starting the project to complete the work	Evaluate the cost of carrying out the work with the initial planning
X8.7	Poor planning, implementation and management	Recruiting skilled workers in accordance with their areas of expertise	Recruit permanent professional staff for each expertise in project implementation and routinely carry out regular coordination to evaluate the implementation of work
X6.1	Delays in ordering tools	Scheduling properly the procurement and ordering of tools, as well as making schedules for detailed tools	Communicate continuously with the procurement of equipment
X8.9	There is no time control information	Make an agreement between the contractor and the owner regarding reporting on the progress of work implementation to monitor the time of completion of the work	Conduct routine coordination meetings every week to evaluate work progress and discuss implementation problems/obstacles in the field that may affect work completion time

Development of Implementation Guidelines

To answer RQ 3 regarding the development of guidelines for the implementation of bored pile foundation work based on risk analysis at PT. X. Development of guidelines for implementing risk-based bored pile foundation work is carried out by directly validating the results of data processing and determining the response to the dominant risk in bored pile foundation work based on answers from RQ 1 and RQ 2 so that a new guideline is obtained in the implementation of effective bored pile work used because it can minimize risk and can improve time performance as can be seen in the following table.

Table 5
Guidelines Development Recapitulation

No.	Variable (Risk Event)	Development Guidelines
1	There are utilities in the ground	1. Conduct a Ground Penetrating Radar (GPR) first to find out objects buried in the ground and it is necessary to carry out an inventory of utilities in the work area before carrying out work (Arief & Sumargana, n.d.). 2. If utilities are found in the ground, it is necessary to map the area. 3. Then coordinate with the owner, planner and supervisor to review the bored pile layout based on the results of mapping the utility area in the ground.
2	Tool age is not worth it	If the equipment has arrived at the destination location, it is necessary to re-check the number and condition of the equipment, if there is a shortage and equipment is damaged due to the mobilization process, coordination is immediately carried out with the equipment procurement party.
3	Surface soil collapse around the borehole	Conduct a soil investigation if there is no soil data at the work location (Prayogo & Saptowati, 2017)
4	There is a change in the work implementation schedule from the owner	1. Coordinate with the owner regarding work implementation schedules, payments and design information. 2. Planning the time and cost control of the implementation of the work.
5	Low labor productivity	Planning the qualifications and the number of workers needed.
6	Lack of workforce	Planning a schedule for evaluating the ability and number of workers.

7	Retaining wall collapse	Check for potential collapse of retaining walls.
8	Project funding is not smooth	Perform time and cost control planning for the implementation of the work.
9	Poor planning, implementation and management	1. Planning to control time and costs for the implementation of the work. 2. Planning the qualifications and the number of workers needed.
10	Delays in ordering tools	1. Planning a delivery schedule and calculating the number of tool requirements. 2. Place an order for tools based on the planned delivery schedule and the amount that has been made. 3. Monitoring the mobilization of equipment so that it is according to the delivery schedule by coordinating with the expeditionary party.
11	There is no time control information	Planning a coordination meeting schedule with the owner to monitor the progress of the implementation of the work and the constraints that occur both technical and non-technical.
12	Late payment from the owner	1. Coordinate with the owner regarding work implementation schedules, payments and design information. 2. Planning a coordination meeting schedule with the owner to monitor the progress of the work implementation and the constraints that occur, both technical and non-technical (Sebayang et al., 2018)
13	Delay in delivery of concrete	Planning the delivery schedule for materials such as iron and concrete in accordance with the specifications and quantities needed.

CONCLUSION

Based on the results of research on the development of bored pile work implementation guidelines, it can be concluded as follows:

The dominant risk factor for bored pile work. Based on the results of this study it can be concluded that in the implementation of bored pile work there is a dominant risk factor that has an impact on time performance.

Formulation of risk response as a strategy for managing dominant risk factors in the implementation of bored pile work, in the form of data on risk causes, risk consequences and risk responses in the form of preventive actions and corrective actions on dominant risks which will serve as the basis for developing guidelines for implementing bored pile foundation work.

Guidelines for the implementation of bored pile foundation work based on risk, which is a development of existing guidelines based on the results of risk analysis that has been carried out to obtain dominant risks that affect time performance, so that a risk response is obtained to manage these dominant risks during implementation of bored pile foundation work.

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