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Research Article

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Foundation Quality Management in Six Jakarta Inner-City Toll Roads Project Section A of Kelapa Gading – Pulo Gebang

Alfiyan Rismawan[1], Wahyu Indra Sakti[2]

[1]Student of Magister Program in Civil Engineering, Universitas Tarumanagara
[2]Lecturer of Magister Program in Civil Engineering, Universitas Tarumanagara

Abstract Adequate infrastructure availability was needed to support various economic, industrial, and social activities. One of the most important aspects to support those activities was the construction of road infrastructure. To increase the service and availability of transportation sector, the provincial government of Jakarta was currently constructing six Jakarta inner-city toll roads projects. The research of this project, specifically section A of Kelapa Gading – PuloGebang, was the development stage 1 that was started from STA 21+881 until STA 31+168. Start point began from Boulevard Barat road to Bekasi Raya road. Since this project used overpass construction, it had to fulfill the technical terms and conditions. Quality control was implemented considering that the infrastructure would be used by many people. The structural work that was being done and being observed in this research was foundation work. To prevent foundation failure, strategic step was needed in the stage of foundation work. On the other hand, the quality assurance from the embedded poles must cover two main aspects which were axial compressive load and integrity of poles. This research brought the topic of foundation work quality management in the project, so that the research was carried out by doing direct observation and structured interview. There were 5 kinds of works for drill pole constructions and 4 methods of foundation testing. From the observation and interview, it was expected that the result could be used as an evidence-based decision making so that the research result could be utilized as the quality assurance program of foundation work.

Keywords foundation quality management, terms and conditions, bored pile construction, testing method, evidence-based decision making, quality assurance

1. Introduction

Background of the Study

Adequate infrastructure availability is needed to support various activities. To increase the service and availability of transportation sector, the provincial government of Jakarta is currently constructing six Jakarta Inner-City Toll Roads. Since this project uses overpass construction, it has to fulfill all technical terms and conditions. One of structure works which is currently being done and becoming the observation object of this research is the foundation work. Foundation is an important part in the structure and construction work that is firstly done yet must fulfill all the terms and conditions.

In fulfilling all the terms and conditions, good planning is the key to avoid the working stages that are inefficient and incorrect which can fail the achievement of the objective. Therefore, foundation quality management is significant to be applied. From that perspective, the researcher raised the issue of foundation quality management.

The project of six Jakarta inner-city toll roads, especially in section A KelapaGading – PuloGebang, was stage 1 of the construction that was started from STA 21+881 until STA 31+168. Start point began from Boulevard

Barat road to Bekasi Raya road. The object of observation in this research was the work on STA 23+504 until STA 24+226 of 772 m. There were 225 foundation points which the construction was set for 150 working days.

In understanding the problem, this research used direct observation and structured interview. Generally, the research began with the review of literature about quality management which was followed by understanding the implementation of quality management in six Jakarta inner-city toll roads project and action analysis which could be done towards the problem found. Furthermore, this research could be used as the quality assurance program, especially for the continuity of the foundation project.

1.2. Problem of the Study

Based on the background of study abovementioned, the problem of this research was how does the foundation quality management in six Jakarta inner-city toll roads projects, what were the implementation of foundation quality management, also what action would be taken for the implementation of foundation quality management?

1.3. Objective

This research aimed to know the foundation quality management in six Jakarta inner-city toll roads projects, to know the implementation of foundation quality management, also to explain what action would be taken for the implementation of foundation quality management.

1.4. Delimitation of the Study

In order to achive the objective of the study, the study delimited its focus on:

1. Object of the reaserch was limited to the foundation work in one of the toll road segments from six Jakarta Inner-City Toll Road projects, which is the Section A Kelapa gading – Pulo Gebang.
2. The quality management which was observed was quality assurance applied by Consultant and Contractor of the foundation.

1.5. Significance of the Study

The benefits to be achieved or obtained from this study include the following:

1. Theoretical benefits, this research is expected to be able to provide information on foundation quality management implemented by Consultants and Contractors of Foundation in six Jakarta Inner-City Toll Roads Project.
2. Practical benefits, this research is expected to portray the process of sustainability of toll road development, as well as to provide recommendations for actions that should be considered and improved from the implementation of these activities, especially on the sustainability of foundation work.

2. Review of Literature

2.1. Construction Project

According to Ervianto [1] a construction project is a series of activities that are only held once and are generally short-term. In this series of activities, there is a process that maintains project resources into a result in the form of buildings. The process that occurs in a series of activities certainly involves the parties involved, both directly and indirectly

2.2. Quality of Human Resources

Human resources are an important part of the construction process, especially in achieving project goals. According to Mutis and Gaspersz [2] the key to achieve quality success lies in the people, because the quality which becomes the selling point in the service business is a human quality that spurs search, credence and experience qualities (various qualities in the scope of discovery, trust and experience). The good quality human resources will produce good products.

2.3. Project Management

Based on Project Management Institute (PMI) in Project Management Body of Knowledge (PMBOK), project management is science and art which are related to lead and coordinate the resources consisting of humans and materials by using modern management techniques to achieve predetermined goals, namely the scope of quality, schedule, and costs, and to fulfill the wishes of stakeholders.

2.4. Quality Management

Gasperz [3] stated that quality management system is a set of documented procedures and standard practices for management systems that aim to ensure the suitability of a process and product (goods / services) to the needs or requirements which are determined by the customer or organization. The quality management system defines how organizations consistently implement quality management practices to meet customer and market needs.

According to Soeharto [4], the main purpose of quality assurance is to take the actions needed to give confidence to all interested parties (customers) that all actions needed to achieve the level of quality of the object (product) have been carried out successfully. The project quality assurance program is prepared in accordance with the interests of each project that is different in its scope and intensity. The quality assurance program also accommodates desires and requirements imposed by authorized bodies or organizations, such as the government. A quality program arranged in a document includes at least the following.

1. Systematical planning which gives detail and explain about the steps which will be taken to achieve target quality in each project stages
2. Arrangement of limit and specification criteria, also quality assurance which will be used in engineering design, material buying, and construction
3. Arrangement of organization and personnel filling for quality assurance activity.
4. The making of quality assurance implementation procedure which covers monitoring, checking, testing, measuring and reporting the results.
5. Identification of equipment which will be used.
6. Identification of activity parts that need support from third parties as well as the role and approval from the government.

According to Mutis & Gasperz [2], there are 6 aspects which become the quality measurement covering performance, features, reliability, service ability, conformant, durability, aesthetics and quality which are perceived. These attributes would be the basis of research instrument for quality.

2.5. Construction of Six Jakarta Inner-City Toll Roads Projects

The work which is currently being done is foundation work. The foundation is an important part of the structure and construction work that is first done on but must meet all the terms and conditions. As an application in one of the additional road networks, the construction of the six Jakarta Inner-City Toll Road Project uses an overpass. The foundation must be able to support the planned flyover construction.

Section A KelapaGading - PuloGebang is planned to be 9.44 km long. Construction of phase 1 of this work starts from STA 21 + 881 to STA 31 + 168. There are 17 Piers built from STA 23 + 504 to STA 24 + 226 with a length of 722 m. From the 17 Pier, there are 225 foundation work points which are set for 150 working days.

2.6. Technical and Constructon of Foundation

According to the Technical Specifications of Freeways and Toll Roads at the Ministry of Public Works and Public Housing (Minisry of *PUPR*) Directorate General of *Bina Marga* (2015), the construction of concrete drill pole must includes cast-in-palace concrete drill poles which are made with a reverse circulation drill which must be made in accordance with the drawingspecifications. The loading test also includes in what is needed to determine the carrying capacity of the concrete drill pole foundation.

The concrete drill pole construction based on the regulation of Ministry of Public Works and Public Housing was then used by Main Contractor (KSO Jaya Konstruksi-Adhi Karya), as the guideline of quality assurance implementation of the six Jakarta Inner-City Toll Road Project. There were three references of the used quality assurance namely regulation of Ministry of Public Works and Public Housing as the basic guideline for the Main

Contractor, Work Instruction which was used by Contractor of Foundation Specialist, also regulations of testing standars which was used by Consultant of Foudation Testing Specialist. The standard used was ASTM D1143-90 for Static Loading Test, ASTM D4945-96 for Pile Driving Analyzer, ASTM DD5882-16 for Pile Integrity Test, and ASTM D6760-08 for Cross-Hole Sonic Logging [5-8].

2.7. Quality Assurance of Foundation

Hardjasaputra [9] explained that strategic steps are needed in construction stage to avoid foundation failure, while to ensure the quality of foundation poles from the embedded foundation poles, it is needed axial compressive load and integrity of poles. Number of poles tested can be done based on the applied local regulation or based on the agreed quality assurance.

According to Hertlein [10], quality assurance practice that is implemented for inner foundation will be different because of the requirement. Quality assurance is a documented procedure to ensure the quality of the design and construction process, with the aim of eliminating work defects. Quality assurance is a quality management tool used by construction team.

3. Research Method

3.1. Research Stage

This study was carried out by exploratory study approach which consisted of literature study, field observation, documentation and expert interview. In short, the stages can be seen in the following Figure 1:

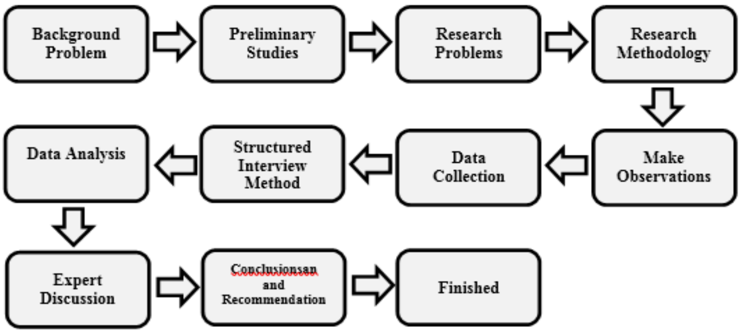

Figure 1: Research Stage

3.2. Location of Research

This research was done in Jakarta province by reviewing the contruction project of 6 Toll Roads, specifically Sunter - Pulo Gebang route that the construction had been started from Kelapa Gading.

3.3. Research Instrument

The research instrument was a tool used by researchers to collect data. The instruments used were structured interview sheets, observations, and documentation. The use of research instruments was adjusted to the data which would be collected.

3.4. Data Collection Technique

Primary data collection was done by observation and structured interview, and the secondary data was collected through the reports of project work, literature study, website of foundation testing regulation (ASTM), website of Department of Public Work and Public Housing (*PUPR*), Central Bureau of Statistics (BPS), and other related departments in this research.

3.5. Indicator of the Interview

Since this research focused on the foundation quality management in Project of six Jakarta Inner-City Toll Roads, so the interview indicator was based on the evidence-based decision making, as stated in the ISO 9001:2015 of quality management [11-12].

3.6. Topic of the Interview

The topic of the interview based on interview indicators was the quality of the foundation and decisions taken from the results of work and testing. The topic of the interview given to the respondent was about;

1. Standard of Operating Procedure (SOP) on bored pile work.

2. Term and condition, the result of work and competent party for decision making.
3. The taken actions toward the problems found in foundation work.

In order to obtain the answer of indicator, the interview respondents were those whose work were related to the foundation quality management.

3.7. Respondent of the Research

Respondent of the research was the elements of construction actors involved in quality management in the construction of six Jakarta Inner-City Toll Roads Project:

1. Expert of Building Construction Expert Team (*TABG*) to obtain the response and opinion of the experts.
2. Project Manager, PT Indonesia Pondasi Raya, to know the terms and condition, Stardard of Operation Procedures (SOP), work result and the competent parties for decision making.
3. Quality Control Manager, Site Manager and the implementer KSO Jaya Konstruksi – Adhi Karya, to know the actions taken for the problems found in six Jakarta Inner-City Toll Roads Project.

3.8. Data Analysis Method

The analysis was carried out by the data obtained from the observation result as well as the structure interview. The stages are shown in Figure 2 below:

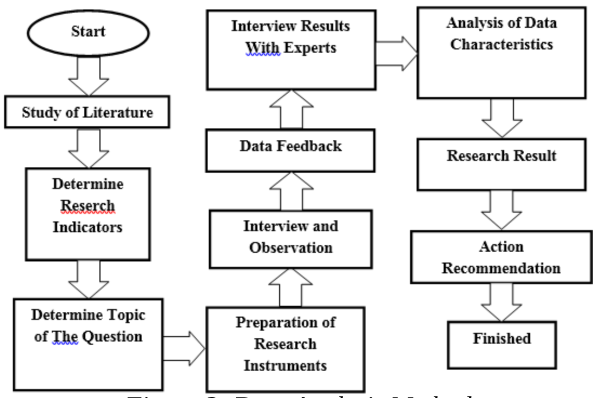

Figure 2: Data Analysis Method

3.9. Foundation Construction Work Stages

Analysis of the stages of construction in foundation work must be assessed to determine the extent to which the application of quality was applied. There were 5 works that were observed, namely:

1. Implementation permit.
2. Coden test.
3. Bored pile rebarand casting permit.
4. Casting work.
5. Bored pile casting.

3.10. Foundation Testing Stages

The two main aspects of quality assurance were the axial bearing capacity of the poles and the integrity of poles; thus, the results of foundation tests must also be assessed in anticipation of foundation failure. There were 4 tests observed, namely:

1. Static Loading Test.
2. Pile Driving Analyzer.
3. Cross-Hole Sonic Logging.
4. Pile Integrity Test.

4. Analysis

4.1. Foundation Planning

Foundation of bored pile in six Jakarta Inner-City Toll Roads Projects was made by the diameter of 120 cm with the depth of 40 m, yet the soil condition was not always similar which made the foundation depth was modified to be deeper than it was planned. The picture of construction for soil profile showed that the drill depth in research location was on the average of above 50 m with allowable design planning of 800 ton. For safety, the fulfilled requirement for each foundation was 150% from the carrying capacity permit or 1200 ton based on Technical Specifications of Freeways and Toll Roads at the Regulation of Ministry of Public Works and Public Housing (Minisry of *PUPR*) Directorate General of *Bina Marga* in 2015.

4.2. Analysis Foundation Work

Analysis of foundation construction on six Jakarta Inner-City Toll Roads Projects was done by field observation and by studying the report from Foundation-specialist Contractor to Supervisor Consultant. There were 2 observed location of which at Stationing (STA) P8.40 and P8.42, with 5 works observed as follows:

1. Implementation Permit.

   Implementation permit was the first requirement that must be done by the Contractor od Foundation Specialist before starting the construction. There were the total of 140 foundation works for 28 foundation point carried out but there was none of existing utility map as work document. The following id the preparation list table:

Table 1: Preparation List

Work Document					Labor				
No.	Description	Availabel	Not Available	Information	No.	Description	Availabel	Not Available	Information
1	Shop Drawing	✓			1	Chief Supervisor	✓		1
2	Working method	✓			2	Supervisor	✓		1
3	Safty	✓			3	Foreman	✓		1
4	Environment	✓		Need Polimer	4	Worker	✓		12
5	Permit (If Needed)				5	Engineer	✓		2
6	Utility Existing		✓		6	Surveyor	✓		2
7	Material Test	✓			7	Ass. Surveyor	✓		4
					8	LAB, Tecnicion	✓		2
					9	Mechanical	✓		2
					10	Operator/Driver	✓		4
Equipment					Material				
No.	Description		Total		No.	Description		Total	
1	Rigbor and Silo		1		1	Polimer			
2	Service Crane		1		2				
3	Excavator, Ponton, Dump Truck		1		3				
4	Koden Test		1		4				
5	Welding Machine and Genset		1		5				
6	Barbending and Barcutter		1		6				
7	Casing and Accessories		1		7				
8	Total Section and Waterpass		2		8				

2. Coden Test

   Coden test was the requirement of the drill work acceptance to ensure the depth of the hole based on the picture also it has a good verticality. There were 28 total drill points which were tested by coden. Based on picture for construction, there were 12 foundation points in STA P8.40 with the intended depth was 58,580 m but there were 2 which had not reached the intended depth. In STA P8.42, there were 16 foundation points with the intended depth of 57,919 m but 4 point had not reached the target yet. The following is the result of coden test:

Table 2: Coden Test Result

Coden Location	Depth in The Drawing (m)	The Results	Piling Number															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
STA P8.40	58.850	Depth (m)	59.0	56.5	59.7	59.0	59.9	59.3	59.3	58.9	59.7	58.8	57.2	59.9				
		Verticality	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
STA P8.42	57.919	Depth (m)	57.5	58.7	58.7	58.4	57.9	58.9	59.0	59.1	59.0	57.8	58.7	57.5	58.9	58.0	59.0	58.7
		Verticality	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Information: Check Mark (✓) Indicates Good Verticality

3. Bored pilerebar and casting permit.

   On the rebar process for bored pile, the requirements included rebar weight, number of twist and its length, also the matched number of coils. This requirement was applied to all poles. The rebar problem happened in STA P8.40 in which at the lowest section of No.8 bored pile basket, the main reinforced was finish so that the supposed size of D25 was replaced by D32. The terms of the rebar process are shown below:

Table 3: Terms of Rebar

Section	Main Bar					Stirrups					
	D	Total		Weight (Kg)		D	Total			Weight (Kg)	
		Bar	Long (m)	/12m	Total		Bar	Long (m)	Twist	/12 m	Total
1	D25	44	12	46.2	2032.8	D16	13	12	43	18.9	245.7
						D13	23		80	12.5	287.5
2	D25	22	12	46.2	1016.4	D13	15	12	57	12.5	187.5
3	D25	11	12	46.2	508.2	D13	15	12	57	12.5	187.5
4	D25	11	12	46.2	508.2	D13	15	12	57	12.5	187.5
5	D25	11	10.9	42	462	D13	12	12	45	12.5	150
			Total Weight		4527.6				Total Weight		1246

4. Casting work.

   Casting work is the recording and inspection of concrete materials used to conform to the required specifications. The require concrete quality was fc' 30 MPa with the required slump value of 18 ± 2 cm. Record and documentation of slump test was carried out to all concrete materials loaded by mixer truck before the casting process. The following are the result of the casting work:

Table 4: Result of Slump Test

Location	Mixer Truck Number											Volume (m³)	Slump 18 ± 2 cm
	1	2	3	4	5	6	7	8	9	10	11		
P8.40 No.1	19	17	18	16	18	17	16	17	18	16		68	✓
P8.40 No.2	18	19	18	19	18	17	17	17	17	17		68	✓
P8.40 No.3	18	17	20	20	20	19	20	19	17	18	18	73.5	✓
P8.40 No.4	20	19	19	20	18	19	20	19	20	18		68	✓
P8.40 No.5	20	18	20	18	19	18	20	18	18	18		68	✓
P8.40 No.6	17.5	20	18	19	20	18	19	20	20	19		67	✓
P8.40 No.7	18	20	18	19	20	18	18	20	18	19		68	✓
P8.40 No.8	18	18	19	19	18	17	19	17	19	19		67	✓
P8.40 No.9	19	18	19	19	18	20	19	19	19	19		67	✓
P8.40 No.10	19	19	19	20	20	18	19	19	19	20		67	✓
P8.40 No.11	20	19	20	19	18	20	19	19	20	19		68	✓
P8.40 No.12	18	19	18	19	20	18	18	20	20	20		68	✓
P8.42 No.1	19	18.5	18	19	19	18	19	19	20	17	20	73	✓
P8.42 No.2	19	18	19	18	18	19	19	18	18	20		68	✓
P8.42 No.3	17	19	19	18	19	20	18	18	19	18		68	✓
P8.42 No.4	17	19	20	17	18	19	18	19	18	20		68	✓
P8.42 No.5	20	19	18	19	18	18	20	17	19	18	19	68	✓
P8.42 No.6	18	19	20	19	19	19	19	20	19	18		68	✓
P8.42 No.7	16	16	18	20	18	17	16.5	17	16	19		68	✓
P8.42No.8	19	20	19	19	18	18	19	19	19	19		68	✓
P8.42 No.9	18	20	19	20	18	17	19	20	18	18		68	✓
P8.42 No.10	19	20	19	20	20	19	19	19	19	18		68	✓
P8.42 No.11	19	20	19	19	18	18	19	19	19	18	19	68	✓
P8.42 No.12	20	19	20	20	18	19	18	18	18	20		68	✓
P8.42 No.13	19	20	20	20	19	20	20	19	20	18	18	68	✓
P8.42 No.14	17	18	18	18	17	17	17	17	17	19	17	68	✓
P8.42 No.15	18	19	19	18	18	17	19	19	19	19	19	68	✓
P8.42 No.16	18	18	19	20	19	20	20	20	20	19		68	✓

5. Bored pile casting.

   Bored pile casting is an advanced stage of casting work. Recording that was done as a report covered the start time and time of completion of each activity. From the observations made during the casting process, there was no problem found because the work was done well according to the work instructions of the Foundation Specialist Contractor.

   To provide an overview of the data characteristics, further findings were described in the form of a diagram. The findings of the problem in the foundation work were found in the implementation permit as many as 28 findings, coden test was 6 findings, and rebar process was 1 finding.

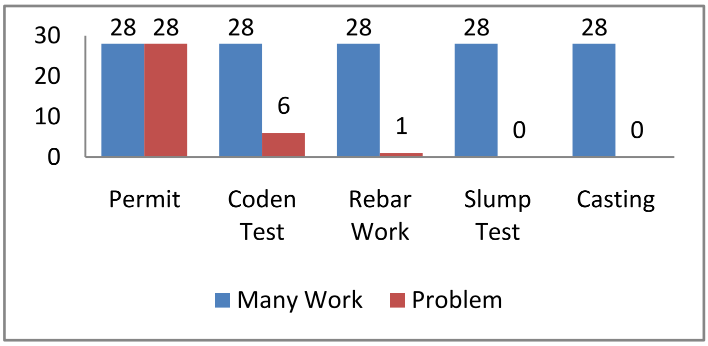

Figure 3: Diagram of Foundation Work Data Characteristic

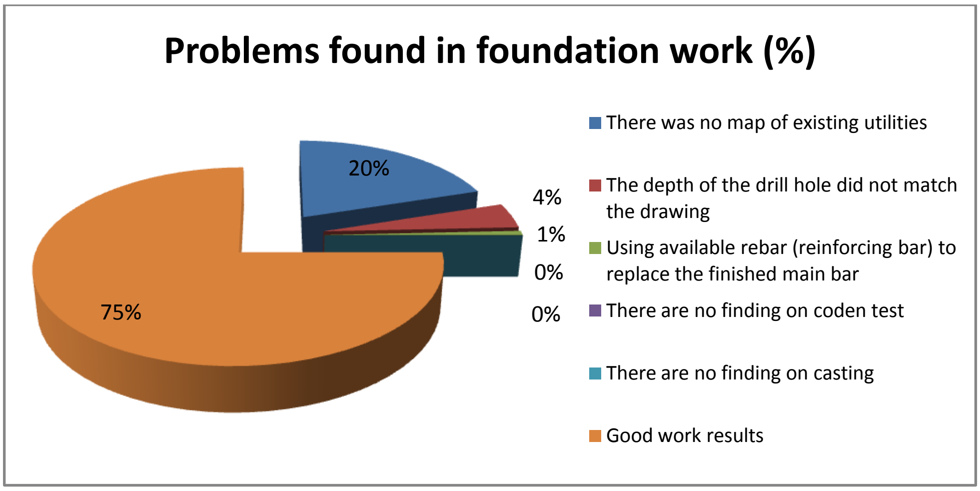

Figure 4: Diagram of Finding Percentage in Foundation Work

4.3. Analysis of Foundation Testing

Analysis of foundation testing was done by direct testing and studying the reports of test result. There were 4 testing methods which were observed of which:

1. Static Loading Test.

   This test included installation, testing and monitoring, and interpretation of test results. The test was carried out by a reaction system, which was the resistance system of the reaction pole group to the test pole. The comparison of the poles in the test was 4 poles of reaction against 1 test pole. The test was declared failure because when the maximum load was 1200 Ton or at a reading of 150%, the main rebar of the bored pile on the reaction pole was removed so the test could not be continued, the results are as follows:

Table 5: Loading Test Result

No.	Load	Cycle		Settlement			Information
	(Ton)	Step	%	Gross	Nett	Rebound	
1	400	I	50%	1.13	0.09	1.04	
2	800	II	100%	3.37	0.52	2.85	
3	1200	III	150%	5.69			Failur

2. *Pile Driving Analyzer.*

   PDA was a dynamic way of testing in which the test results were used as a condition for accepting foundation work such as static loading test. Data on the amount of pole carrying capacity recorded on PDA computers due to pole collisions obtained are as follows:

Table 6: Result of PDATest

Piling Number		Bearing Capacity (Ton)			
			CAPWAP		
		PDA	(Ru)	(Rs)	(Rb)
1	P8.32 No.7	1768	1785.8	1734.3	51.5
2	P8.57 No.5	1647	1704.8	1638.9	65.8
3	P10.01 No.8	680	965.4	858	107.4
4	P10.57 No.3	1048	1214	1028.5	185.2
5	P10.58 No.3	1120	1200.7	1184	16.7
6	P10.59 No.3	1078	1085	1035	50
7	P10.68 No.3	1007	1386	1362	24
8	P10.69 No.3	1558	1571	1524	47

From the 8 tested pole points, the pole P10.01 No.8 and P10.59 No.3 obtained from PDA or CAPWAP analysis were not fulfilling the term and condition for foundation carrying capacity that was 150% of carrying capacity permit or as much as 1200 ton. With the CAPWAP analysis of 965,4 ton, the result of the test met only 800 ton for the allowable design.

3. *Cross-Hole Sonic Logging*.
CSL was non-destructive which made use of ultrasonic wave. The characteristics which were transmitted and received by probe were recorded by *Cross-Hole* Analyzer (CHAMP) tool that was equipped with the automatic depth measurement tool which showed the result directly in the monitor. The recording data was then analyzed by using CHA-W application to know First Arrival Time (FAT) and ultrasonic wave energy curve. There were 4 classifications of CSL test, and the following table shows the CSL test classification as well as the result of 5 testing point obtained:

Table 7: Classification of CSL Test

Condition		FAT Increase (%)	Note	Energy Reduction (dB)
Satisfactory	G (Good)	0 to 10	and	<6
Anomaly	Q (Questionable)	11 to 20	and	<9
Flaw	P/F (Poor/Flaw)	21 to 30	or	9 to 12
Defect	P/D (Poor/Defect)	>30	or	>12

Table 8: Result of CSL Test

Piling Number	Location Form Top Pile (m)	FAT Delay (%)	Energy Reduction (dB)	Condition
P10.45 No.1	3 s.d. 3.5	20 - 26	-	P/F
	8.9 s.d. 9.2	24	-	P/F
	>11.2 Incomplete Date	-	-	-
	>43.8 No Data	-	-	-
P10.46 No.1	2.1 s.d. 2.5	>100	13.2	P/D
	2.8 s.d. 3.6	22 - 29	-	P/F
	>28.4 Incomplete Date	-	-	-
	50.3 s.d. 51.45	>100	57.8 - 58.7	P/D
	>52 No Data	-	-	-
P10.48 No.1	3.1 s.d. 4.1	27	-	P/F
	15.7 s.d. 30.85 Concrete Quality Cannot be concluded			-
	>30.85 No Data	-	-	-
P10.55 No.3	>4.4 Incomplete Date	-	-	-
	9.7 s.d. 10.3	44	7.8	P/D
	47.3 s.d. 47.9	35	9.1	P/D
	>47.9 Incomplete Date	-	-	-
	>48.6 No Data	-	-	-
P10.74 No.3	35.1 s.d. 35.5	42 - >100	6.8 - 60.9	P/D
	>35.5 Incomplete Date	-	-	-
	>35.6 No Data	-	-	-

The result of CSL test in 5 testing points showed the wholeness condition of foundation which required follow-up or improvement because all the poles tested showed the criteria of flaw and defect.

4. Pile Integrity Test.
This test was used to measure the pole integrity but by measuring the travelling wave from hammer impact (low-strain) on the upper part of foundation. Each impact given to the upper part of foundation was directly recorded by PIT tool in a form of graphic. The graphic record was analyzed further by PIT-W application. To measure the foundation integrity, the following test criteria was used:

Table 9: PIT Testing Criteria

Clasification	Good, uniform	Slight Damage	Damage	Broken
BTA	100%	80-99%	60-80%	<60%

PIT testing was done in 66 foundation points in 7 different location. The problem was found at P10.03 No.7 where the test detected the damage of the foundation at 3 m deep with BTA value 80%. Based on PIT testing, it showed damage condition.

The problem found in this foundation work was 28 cases in construction permit, 6 cases in coden test, and 1 case in rebar process. The cases are shown in the diagram below:

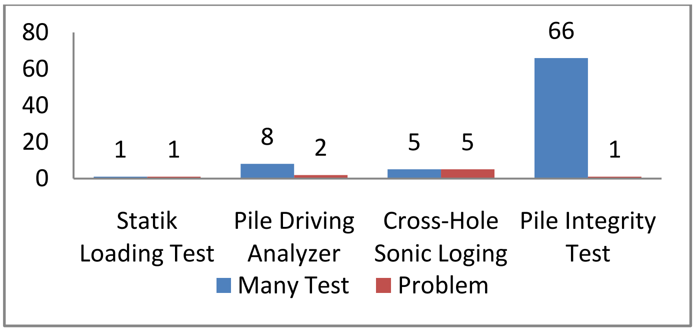

Figure 5: Diagram of Foundation testing Data Characteristic

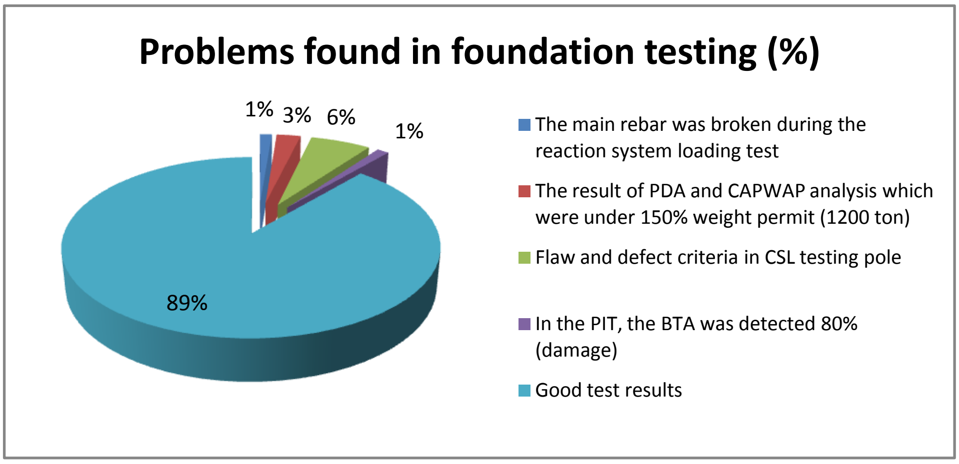

Figure 6: Diagram of Findings Percentage in Foundation Testing

4.4. Evidence-based Decision Making

From the observation of 108 foundation points, there were problems found which needed to be corrected by Human Resources Department in the project of six Jakarta Inner-City Toll Roads. The evidence-based decision making that was taken by quality management are as follow:

1. Problems found in foundation work:
   a) There was no map of existing utilities at 28 foundation points. Utility maps could not be easily obtained, because there was no department that coordinated together for utility networks. The project must be carefully evaluating utility networks, especially projects in big cities like Jakarta. The method still had to be examined visually, so the underground condition could be seen and then reported to the interested parties. To find out the contents of underground, tools such as metal detectors could be used. The trial pit was carried out on the project to find out the underground condition before starting the bored pile work which was done by digging the soil at a location with depth and excavation width of 2.5 m diagonally. Gas pipes must be treated specifically, because if the design interrupted the PGN gas network, the foundation point location on the drawing could be moved or shifted.

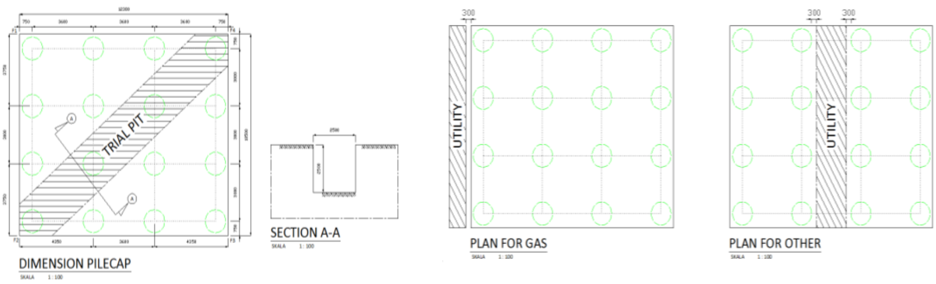

Figure 7: Trial PIT

b) There were 6 points which depth of the drill hole did not match the drawing. It should not be a problem with the depth of the pit when using a drill, because this tool could penetrate the hard soil layer. After being checked by the investigation of the land, it could be seen from the results of the investigation that the profile of the land was also the calculation of the results of the investigation. The excavation hole would determine the volume, there might be a difference in volume, but a slight difference would not be a problem. The key of this problem was to pay attention to the carrying capacity and volume of work. With this excavation, the carrying capacity must be achieved but the volume was also not loss. In the project, there was no excavation of the soil because the depth of the hole was already in the hard soil layer.

c) Using available rebar (reinforcing bar) to replace the finished main bar in making 1 point of iron basket. For this problem, the rebar capacity must be in the same quality. It was done by knowing how many main rebar, the size of the iron used, and the quality or the rebar. Then, we calculated the total area of foundation. If the total area of the main rebar (As) was 1000 mm², the total area of the replacement rebar (As') must also be 1000 mm².

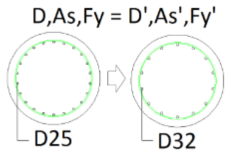

Figure 8: Conversion of Rebar Size

In six Jakarta Inner-City Toll Roads project, this problem was considered special or a dispensation. It could happen because of the miss planning due to lack of field coordination while the schedule had been set. The special condition must be approved by field consultant. The calculation is as follow:

$$
\begin{aligned}
D32 &= D25 \\
\tfrac{1}{4}\times\pi \times D^2 \times n &= \tfrac{1}{4}\times\pi \times D^2 \times n \\
\tfrac{1}{4}\times 3.14 \times 32 \times n &= \tfrac{1}{4}\times 3.14 \times 25^2 \times 22 \\
803.84 \times n &= 10793.75 \times n \\
n &= 10793.75 / 803.84 \\
n &= 13.42 \text{ bars, rounded into 14 bars}
\end{aligned}
$$

Thus, the 22 rebar which used D25 iron would be converted into 14 rebar which would use D32 iron. This rebar replacement was suitable because it was approved.

2. Problems found in foundation testing:

a) The main rebar was broken during the reaction system loading test, in 1 point. AS a result, the test must be repeated. The most important thing was it was not the foundation which failed, since the test was intended for the foundation and not the rebar so that if the rebar was broken, the test could be repeated. Still, the capacity of the foundation rebar must be calculated by determining the test using 2-pole and 4-pole resistance reaction. The welding of rebar also must be checked in case the rebar was broken in its connection. If it was broken due to the pull back, the calculation of the rebar capacity must be rechecked. If the calculation was correct, the weight plan might be too heavy. Hence, the retest could be done yet we needed to pay attention to its planning and implementation. In the field there was not retest done in the project because based on the Supervising Consultant, the pole drop was less than one inch.

b) The result of PDA and CAPWAP analysis which were under 150% weight permit (1200 ton) was at 2 points. The planning could be rechecked if PDA result had met the soil condition. The carrying capacity planning of the foundation was surely based on the soil condition, and the weight plan could be too heavy because the designer also had to consider the safety factor in its calculation. PDA testing must be more that one effort to be made as comparison of result, with the average result from PDA test. If there was a result that was lower than the common average, it could be known if the pole carrying capacity had not achieved and could be overcome by adding more poles. The actions which could be done in the project was correcting the planning calculation result. The load obtained from PDA could be accepted because the calculation of the load showed 200% multiplied by 549.1 Ton equaled to 1098,2 Ton.

c) There were 5 point of flaw and defect criteria in CSL testing pole, and the evaluation of report result was needed. In CSL report, there was profile picture from the tested poles. There was a concern to the necking existence, which was reduction of foundation cross section. Therefore, we must check the concrete strength if the concrete in laboratory and in foundation had the same strength. It was possible that the concrete was mixed with mud, so it had lower strength. Technically, it could be done by recalculating concrete carrying capacity by taking sample of concrete used in the foundation. The sample could be taken by coring. The higher the risk, the more testing done would be better. In the project, the sample of the concrete was not taken because of the duct tape in the CSL pipe connection was not good so that it reduced the wave transmission that resulted in the poor result.

d) In the PIT, the BTA was detected 80% (damage) in 1 point. The category of BTA 60-80% was damage while 80-99% was slightly damage. Thus, the foundation pole in one pile cap must be seen totally to take it into categories. Category of 80% or less was considered slightly damage, while 80% or more was categorized as damage. The action done was repairing the foundation especially for broken category that was under 60%. However, if the repairment could not be done like in BTA location where it existed in deep location, the technical consideration could be done. The action such as taking concrete sample was never be done in the project because there was none under broken category.

5. Closing

5.1. Conclusion

According to data analysis, it could be concluded that:

1. The quality assurance in the project of six Jakarta Inner-City Road Tolls was done based on the regulation of Ministry of Public Works and Public Housing Directorate General of *Bina Marga* about Technical Specifications of Freeways and Toll Roads, Work Instruction of PT Indonesia Pondasi Raya and the standards of foundation testing.
2. Based on the implementation of foundation quality management in six Jakarta Inner-City Toll Roads project, there were 5 reports of concrete drill pole construction and 4 testing method. The 5 reports were:
   a. Report of construction permit.
   b. Report of coden test.
   c. Report of bored pilerebar and casting permit.
   d. Report of casting work.
   e. Report of bored pile casting.

   For the 4 testing methods were:
   a. Static Loading Test.
   b. Pile Driving Analyzer.
   c. Cross-Hole Sonic Logging.
   d. Pile Integrity Test.
3. The research found 7 problems, which were:
   a. In the construction permit, there was no existing utility map in report.
   b. In the coden testing, the depth of the drill hole did not match the drawing.
   c. In the report of bored pilerebar, the available rebar was used to replaced the finished main rebar for making iron basket.
   d. The main rebar was broken during the reaction system loading test.
   e. The result of PDA and CAPWAP analysis was under 150% of permit load (1200 Ton).

f. There was flaw and defect criteria on the CSL test pole.
g. BTA 80% (*damage*) was detected on PIT.

4. The evidence-based decision making was taken in the implementation of foundation quality management in six Jakarta Inner-City Toll Roads project. The actions taken were:
   a. The utility must be examined visually, what was existed underground must be reported to the interested parties (utility owners). Tools such as metal detectors could be used to find out the contents under the ground. The pit trial was carried out before starting the bored pile work by digging the soil at the location of the pile cap with the depth and width of the excavation of 2.5 m diagonally so that it connected both sides of the pile cap tip. The findings of the utility network from the pit trial were determined by the Survey Team, then the coordinates were super-interposed to the design drawing. The action taken on the project was appropriate because a pit trial was conducted to find out the utility network before the drilling was carried out.
   b. For the depth of the hole which did not fit the drawing, the drilling could be done again. If the depth was reduced due to landfill or mud, cleaning must be done, yet if the soil layer showed a hard soil layer then the depth could be accepted. To find out the soil layer, it could be seen in the land investigation report, then checked the soil profile as well as the planning calculation from the results of the investigation. We must pay attention to the carrying capacity and volume of work, because with the excavation, the carrying capacity must be achieved but the volume was also not at loss. No action taken on the project because there was no problem that affected carrying capacity or volume.
   c. To replace the main rebar of the foundation, the rebar capacity must be achieved by looking at how many main rebar, the size of the iron used, and the quality or the rebar. Then, we calculated the total area of foundation. The total area of replacement rebar must be in the same size as the main rebar of the foundation which had been calculated and determined its quality. The rebar replacement could be done under the approval of the consultant, and the actions on the project was suitable because it had given approval from supervising consultant.
   d. For the main rebar which was broken during the reaction system loading test, we needed to pay attention to its planning and testing implementation. By the broken of the main rebar, the carrying capacity could not be interpreted so the test must be repeated. The most important thing was it was not the foundation which failed, since the test was intended for the foundation and not the rebar so that if the rebar was broken, the test could be repeated. Still, the capacity of foundation rebar must be recalculated. The actions on the project was not appropriate since the retest was not carried out.
   e. For the PDA result that was not achieved the carrying capacity, it must be seen the total testing result. There must be more than one PDA test so there would be a comparison of the result. By looking at the average of PDA testing, if there was a lower result than the average, it meant that the carrying capacity had not fulfilled yet, and the solution was by adding more poles. The other solution was rechecking the planning if the PDA result obtained has matched the soil condition. The planning of foundation carrying capacity must be suitable with the soil condition, and it could be that the calculated load plan was too heavy. The actions taken in the project could be accepted because the PDA test was done many times and PDA result was corrected again with the planning load calculation.
   e) The flaw and defect criteria in CSL testing pile or the detection of BTA criteria of 80% indicated the poor condition of pole integrity. The solution was by checking the concrete strength, if the concrete in laboratory and in the foundation gave the same result of strength. The sample could be taken by coring. In the project, the sample of the concrete was not taken because of the duct tape effect in the CSL pipe connection while the PIT was in broken criteria (result of integrity was >60%).

5. From the observation of Human Resources (HR), there were 3 elements of the project that became respondents, namely experts from the Building Construction Expert Team (TABG), Project Managers from contractors, Quality Control Manager, Site Manager and manager from KSO. There spondents' answers could show how an organization managed or regulated relationships with its environment. The conclusions of the respondents' answers were:
   a. Expert opinion was strategy awareness (strategic awareness) that required someone to be critical and had sensitivity so that it was always common to create strategies to overcome things. Expert opinion was an input to improve foundation quality management
   b. Project Managers faced obstacles in the implementation of utility permit, drilling and rebar, and test results which had not met the criteria. However, by carrying out the work Instruction properly, two main aspects of axial bearing carrying capacity and pole integrity could be achieved.
   c. KSO had a role in ensuring good quality management, even though a quality management program had been carried out, the process of re-correction of test results could be obtained especially with further testing of unmet testing criteria which needed to be applied.
6. Based on the foundation quality management that was carried out, there were 6 aspects that became the standard, namely:
   a. Performance, was related to the functional aspects of the foundation. Quality management activities aimed for strategic steps at the construction stage to achieve two main aspects, namely axial bearing carrying capacity and pole integrity. The results of the study by not re-testing the loading test and the absence of concrete samples in the integrity testing that did not meet the criteria indicated that the main aspects of bearing capacity and pole integrity had not been fully achieved. KSO as a project element responsible for quality must implement the better-quality program.
   b. Features, was related to the choices and development which in this case was foundation tests that had been carried out as part of the terms and conditions, but the corrections for repairment needed to be improved.
   c. Reliability, was related to functional failure, where there were 25% of 28 points on foundation work and 11% of 80 points on foundation testing. With the applied quality management, it should be able to reduce or eliminate the problems that existed.
   d. Service ability, was related to unmet functional aspects which would cause repair costs, and the greater the risk, the more testing would be done. Also, the repair would also be difficult. Thus, the cost of repairs and expert considerations needed to be taken into account.
   e. Conformance, was related to the level of conformity of specifications of the foundation. In this case, the carrying capacity and integrity of the poles had not been achieved.
   f. Durability, was related to the carrying capacity of the foundation. Even though the 1200 Ton load had not been reached but the results of the calculation correction showed 200% multiplied by 549.1 Tons which was 1098.2 Tons, so that the loading test result was acceptable because the CAPWAP analysis load results were above 1098.2 Tons. For integrity, there was still no corrective actions such as concrete sampling.
   g. Aesthetic, was related to appearance, excavation profile which had been tested with coden so that verticality guarantee and depth correction had been fulfilled.
   h. The perceived quality, combined with good quality management, would be resulted in users' security of the 6 toll road sections. Therefore, reducing the risk with the quality program must be applied.

5.2. Suggestion

From the research result and the conclusion abovementioned, there are some suggestions given, of which:

1. There is a need for an agency or deparmnet that coordinates the utility network, especially in Jakarta.

2. For drill depths that do not match the drawing, the depth of the excavation hole should be adjusted according to the drawing when using a drill because this tool can penetrate the hard soil layer.
3. Replacemnet of rebar should not be done because it shows that there planing is not well-prepared.
4. Welding and rebar strength must be carefully calculated in loading test if using a reaction system.
5. HR of the project must be aware of the quality.
6. Quality management training for project HR is needed.

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