A STUDY ON RELATIONSHIP BETWEEN SAFETY AND QUALITY PERFORMANCE IN FOUNDATION

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ABSTRACT

A model for relating the safety and quality performance in foundation is proposed in this paper. The project aims to study about the relationship between safety and quality performance in foundation by discussing few case studies and field data. The scope of the project is to 1. Identify the reasons for lack of quality in foundation 2. Justify the reasons by case studies 3. Obtain field data from different projects 4. Analyze the data and propose a model to show the relationship between safety and quality in foundation. The study concluded that safety in foundation can be improved by good quality foundation practice which is explained in the paper.

Keywords- Foundation Safety And Quality- Model- Reasons For Lack Of Quality- Code Provision- Field Study.

I. INTRODUCTION

Construction is one of the largest industries in the world subjected to many risks. Unfortunately many fatal accidents in the construction industry are caused due to failure in foundation. During the last few years, with major infrastructure development there is no proper study of safety and quality in the construction projects particularly in foundations. Neither owner nor worker or contractor care about safety on job sites. It was noticed that accident rates have increased in the past few years due to lack of safety and quality procedures particularly in foundation. Many organizations in developed countries have realized that the key to achieve project success is by providing good safety & quality. But still most of the construction projects in India are not practicing it.

II. CASE STUDIES

2.1 Visakhapatnam accident- The Hindu dated 18th Sep'2014

Figure 1. Four Buried Alive

A 40 foot retaining wall collapsed due to no shoring or timbering for the excavation and did not remove the excavated soil from site instead stored near the excavation which added the soil pressure increase and caused failure.

2.2 Delhi accident- The Hindu dated 29th June'2014

A four storey existing building collapsed due to the excavation for new foundation in the adjacent land which weakened the foundation of the existing building leading to the failure.

Figure 2. Ten Killed In Collapse

2.3 Lalitapark Accident- The Hindu Dated 22nd March'2012

Figure 3. Seventy One People Killed

A 15 year old three storey building, over which two new floors were constructed. The foundation had been weakened by the water damage from recent flooding. Hence the foundation could not bear the load of two new floors causing failure.

2.4 Ammankulam Settlement- The Hindu Dated 20th Apr'2010

The building is constructed in clay soil. Initial soil test result proved that it is unfit for construction. Still the project was carried out and a differential settlement up to 50cm was observed in one building and 25cm direct settlement in another.

Figure 4. Crack in Expansion Joint Due To Settlement

III. CODE PROVISIONS

IS 3764-1992 mentions that all trenches in soil more than 1.5 m deep shall be securely shored and timbered. All trenches in friable or unstable rock exceeding 2 m in depth shall be securely shored and timbered. No excavation or earthwork below the level of any foundation of building or structure shall be commenced or continued unless adequate steps are taken to prevent danger to any person employed, from collapse of the structure or fall of any part thereof. Foundations, adjacent to and below which excavation is to be made, shall be supported by shoring, bracing or underpinning as long as the trench remains open.

As per *IS 2950-1981* for satisfactory design and construction of foundation the possible effects of the new structure on the existing structures in the neighborhood is necessary.

IS 1080-1985 suggests for pad and strip foundation if the allowable bearing capacity is available only at a greater depth, the foundation can be rested at a higher level for economic considerations and the difference in level between the base of foundation and the depth at which the allowable bearing capacity occurs can be filled up with either:(a) concrete of allowable compressive strength not less that the allowable bearing pressure, or (b) in compressible fill material.

According to *IS 1904-1986* increase in moisture extent results in substantial loss of bearing capacity in case of certain types of soils which may lead to differential settlements. On sites liable to be water logged in wet weather, it is desirable to determine the contour of the water-table surface in order to indicate the directions of the natural drainage and to obtain the basis of the design of intercepting drains to prevent the influx of ground water into the site. It is necessary in clay soils, either to place the foundation bearing at such a depth where the effects of seasonal changes are not important or to make the foundation capable of eliminating the undesirable effects due to relative movement by providing flexible type of construction or rigid foundations. Some clayey soils are susceptible to shrinkage and cracking in dry and hot weather, and swelling in wet weather. Shrinkage of clay soils may be increased by the drying effect produced by nearby trees and shrubs. Swelling may occur, if they are cut down. No trees which grow to a large size shall be planted with in 8 m of foundations of buildings

As per *IS 3764-1992* workers shall be instructed to use safety devices and appliances provided to them whenever it is necessary to do so. Workers who are not aware of the hazards peculiar to the work shall not be permitted to proceed with the work without being properly instructed. They should preferably be under the close watch of a properly qualified person whose instructions shall be obeyed by these workers. In case any worker feels that he cannot perform a work safely, he shall immediately inform the supervisor of his inability to carry on with the work.

Safety helmets shall be worn by all persons entering trench where hazards from falling stones, timber or other materials exist. Appropriate safety footwear (rubber boots, protective covers, etc.) shall be worn by workers.

IV. STUDY AT SITE

The code provision for safe construction practice for foundation is not followed by many construction sites visited which lead to rework (poor quality) and accidents. The relationship between the rework and the accidents is studied from the field data which represents the quality and safety performance of foundation in the site. Data were collected from 20 construction projects. The construction work was in progress in all these projects and most of which were at foundation level. Hence the data will be more reliable to study. The project managers from these projects were asked to share their opinions regarding the performance of the case project and the information about the same. The following demographic data were obtained from each project: location, scope (in INR), worker-hours accumulated, type of project, and whether the labor force is open or union shop labor. In addition the author requested data about project performance, like the number of first-aid injuries, number of OSHA recordable injuries, number of defects, cost of rework, and number of worker-hours spent on rework. All data were ultimately obtained from project managers on active projects and the unit of analysis was the project. Although 20 projects provided data for the study, some could not provide safety and quality data for all measures. After eliminating projects that did not report either safety or quality data, there were 13 remaining data points.

4.1 Safety Performance

When collecting and analyzing safety performance data, the author adopted the Occupational Safety and Health Administration's definitions of recordable and first-aid injuries to ensure consistent metrics. The OSHA recordable injuries are defined as any injury that results in death, days away from work, restricted work or transfer to another job, medical treatment beyond first aid, or loss of consciousness. First aid injuries, on the other hand, are those injuries that require one-time treatment and subsequent observation of minor injuries such as cleaning wounds on the skin surface; applying bandages; flushing an eye; or drinking fluids to relieve heat stress.

The following are the two safety measures:

• INJ1—OSHA recordable injury rate (OSHA recordable injuries per 200,000 worker-hours); and

• INJ2—First-aid injury rate (First-aid injuries per 200,000 worker-hours).

Table 1. Summary of Project Demographies

Project name	Project type	Total project scope in INR	Number of worker-hours accumulated	Number of first aid injuries
Project 1	Residential	2,39,00,000	34,350	9
Project 2	Infrastructure	130,00,00,000	12,55,020	31
Project 3	Commercial	2,65,00,000	71,800	10
Project 4	Infrastructure	-	23,320	0
Project 5	Residential	86,00,000	16,420	5
Project 6	Commercial	5,70,00,000	45,400	8
Project 7	Residential	10,92,00,000	1,40,080	1
Project 8	Infrastructure	6,48,00,000	67,010	7
Project 9	Residential	3,38,00,000	29,780	4
Project 10	Infrastructure	35,00,00,000	1,58,020	11
Project 11	Institutional	16,50,00,000	66,080	8
Project 12	Residential	2,60,00,000	60,000	15
Project 13	Institutional	2,80,00,000	43,032	6

4.2 Quality Performance

Information about the total cost of rework, and the total hours related to rework was requested. The author was able to obtain complete rework data from 13 projects. The project managers reported data on the total cost of rework, which ranged from 28,000rs to 15,45,000rs. Finally, for 13 projects, the number of worker hours related to rework was obtained, ranging from 8 to 4,800 h. All of these values were converted to rates using the project scope and total number of worker hours accumulated as the denominators.

The following four quality measures were developed:

• Q1—Cost of rework per Rs,1crore project scope completed;

• Q2—Cost of rework per 200,000 worker hours;

• Q3—Number of worker hours spent on rework per Rs,1crore project scope completed; and

• Q4—Number of worker hours related to rework per 200,000worker hours.

Table 2. Summary of Quality and Safety Performance

Project name	**Number of OSHA recordable injuries**	**Total direct and indirect cost of rework in INR**	**Number of worker-hours related to rework**
Project 1	1	1,35,000	220
Project 2	5	15,45,000	4,800
Project 3	2	2,42,500	350
Project 4	0	-	-
Project 5	0	50,000	-
Project 6	0	1,98,000	320
Project 7	0	-	-
Project 8	1	1,54,500	384
Project 9	3	72,500	40
Project 10	4	2,38,000	740
Project 11	2	3,26,000	620
Project 12	1	28,000	8
Project 13	3	-	-

Table 3. Safety and Quality Metrics Data (Rate)

INJ 1	**INJ 2**	**Q1**	**Q2**	**Q3**	**Q4**
6	52	56485	786026	92	1281
1	5	11885	246211	37	765
6	28	91509	675487	132	975
0	0	0	0	0	0
0	61	58140	609013	0	0
0	35	34737	872247	56	1410
0	1	0	0	0	0
3	21	23843	461125	59	1146
20	27	21450	486904	12	269
5	14	6800	301228	21	937
6	24	50154	986683	95	1877
3	50	10769	93333	3	27
13	28	0	0	0	0

The data obtained from site were converted into metrics data for easy comparison and analysis of the same which is shown in table.3. The following procedure is used to convert the data into rates.

- Injury rate = number of injuries x 200,000 / total working hours
- Q1 = total cost of rework x 1,00,00,000 / total scope of work (in rupees)
- Q2 = total cost of rework x 200,000 / total working hours (in rupees)
- Q3 = total working hours related to rework x 1,00,00,000 / total scope of work (in hours)
- Q4 = total working hours related to rework x 200,000 / total working hours (in hours)

4.3 Hypothesis Development

Although a number of safety and quality measures are examined, these variables only measure two concepts. Both INJ1 and INJ2 examine safety from the perspective of worker injuries of varying severity. On the other hand the quality measure was deemed relevant to rework and it is evaluated by Q1, Q2, Q3 and Q4. With this the fundamental hypothesis was developed:

• H_0: There is a relationship between rework and safety.

This hypothesis has been restated as null and alternative hypothesis in Table 4 along with their independent and dependent variables.

Table 4. Summary of Hypothesis Development

Hypothesis	Null hypothesis	Alternative hypothesis	Dependent variables	Independent variables
H_0	There is no relation between rework and safety	There is a relation between rework and safety	Q1, Q2, Q3, Q4	INJ1, INJ2

V. RESULTS

As previously indicated, the primary objective was to test the hypothesis that there is no relationship between quality performance and safety performance. The empirical data was tested for correlations between the two safety performance metrics and four quality performance metrics.

Simple linear regressions were performed among the combinations of safety and quality metrics using quality metrics as predictors for the safety performance metrics. The coefficient of determination (r^2), which provides the strength of the linear correlation, was calculated. This measures the proportion of variance in one metric that is explained by the variation in the other metric, given a linear relationship. It was considered that coefficient of determination values greater than 0.50 were significant because the mathematical model explains over half of the variability in the response variable. At last, the associated p-values in the correlation analysis were calculated. Table 5 shows the results of the analysis performed.

Keeping with scientific convention, the null hypothesis for each comparison was that there was no relationship between the predictor and response variables. Mathematically, no relationship would mean that the Pearson-r is equal to zero. The author selected an alpha of 0.05, to give a standard 95% confidence interval, and performed a two tailed test. The analysis results with any p-values less than 0.05 would result in rejection of the null hypothesis and the conclusion that a relationship does exist between the two measures.

Table 5. Summary of Emprical Data Analysis

Comparison	Coefficient of Determination (r^2)	*p*-Value (α=0.05)
INJ 1 versus Q1	.216	.673
INJ 1 versus Q2	.576	.023
INJ 1 versus Q3	.213	.171
INJ 1 versus Q4	.544	.009
INJ 2 versus Q1	.227	.195
INJ 2 versus Q2	.240	.411
INJ 2 versus Q3	.543	.019
INJ 2 versus Q4	.507	.030

5.1 Relationship 1: INJ1 versus Q2

A positive linear relationship was found, with an r^2 value of 0.576, between the recordable injury rate per 200,000 worker hours (INJ1) and the cost of rework per 200,000 worker hours (Q2). This can be observed in Fig. 5. This means a very strong positive relationship exists. As the number of rework hours increases, the recordable injury rate linearly increases. Further, the associated p-value is 0.023, so the null hypothesis was rejected. The sample size used to make this inference was small and hence the data should be considered suggestive rather than conclusive.

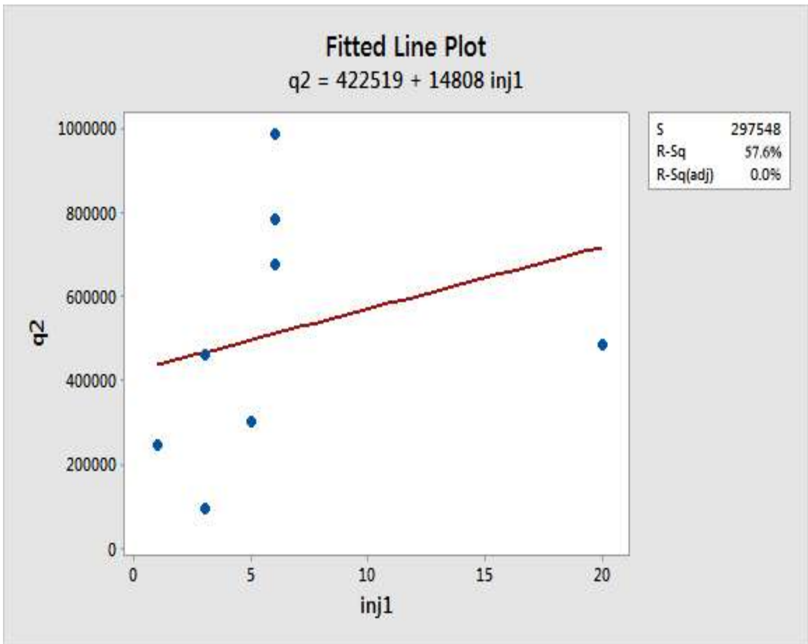

Figure 5. The recordable injury rate per 200,000 worker hours (INJ1) versus the cost of rework per 200,000 worker hours (Q2)

5.2 Relationship 2: INJ1 versus Q4

Next the relationship between the recordable injury rate per 200,000 worker-hours (INJ1) and the number of worker hours related to rework per 200,000 worker hours (Q4) was studied. The resulting r^2 value is 0.544 indicating a relationship, as shown in Fig. 6. Because the p-value is 0.009, the null hypothesis was rejected. Even, this is the same conclusion reached in the previous relationship. In addition, because of the sample size limitation, this inference can be taken as suggestive only.

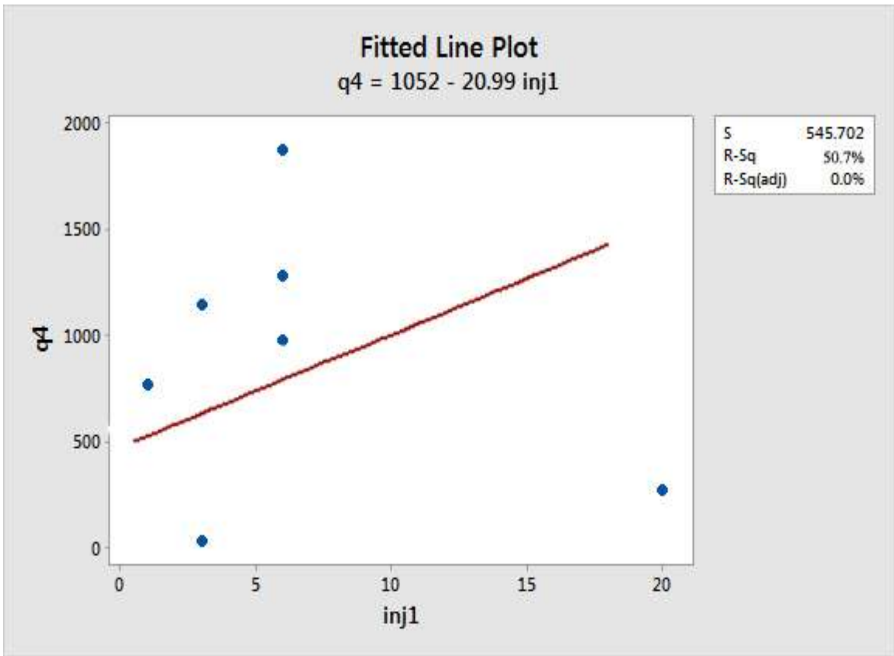

Figure 6. Between the recordable injury rate per 200,000 worker-hours (INJ1) versus the number of worker hours related to rework per 200,000 worker hours (Q4)

5.3 Relationship 3: INJ2 versus Q1

In the correlation shown in Fig. 3, a positive relationship was found between the first-aid rate per 200,000 worker-hours (INJ2) and the cost of rework per Rs,1crore project scope completed (Q1). The r2 value of 0.543 represents a strong relationship between these two metrics, meaning as the number of defects on a project increases, the number of first-aid injuries also increases, as depicted in Fig. 7. The associated p-value 0.019 led to a rejection of the null hypothesis.

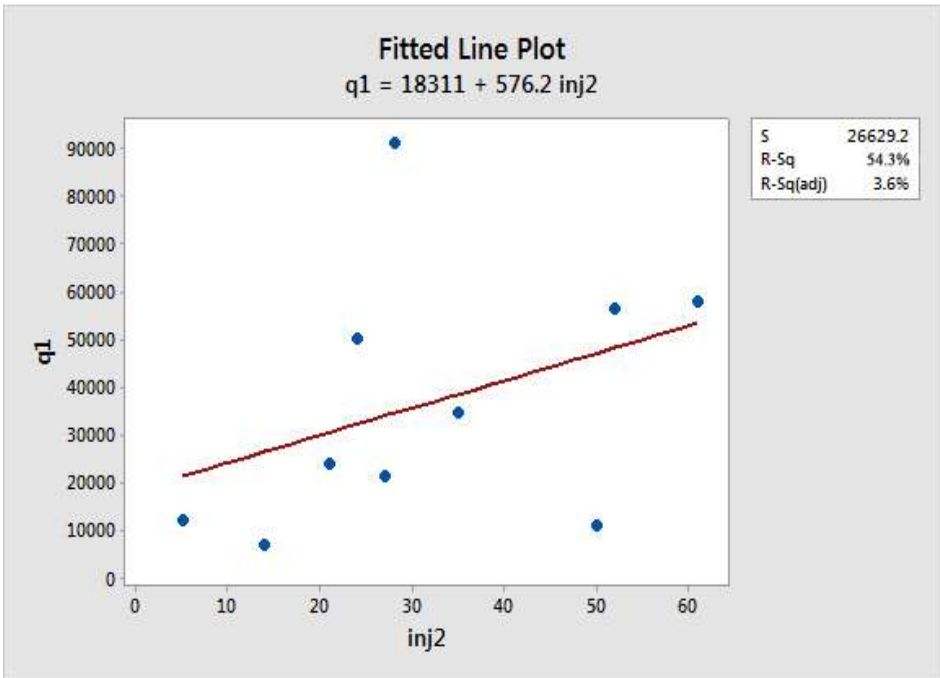

Figure 7. The first-aid rate per 200,000 worker-hours (INJ2) versus the cost of rework per Rs, icrore project scope completed (Q1).

5.4 Relationship 4: INJ2 versus Q4

The final realized relationship shown in Fig. 4 is similar to the previous in that a positive correlation exists between first-aid rate per 200,000 worker-hours (INJ2) and the number of worker hours related to rework per 200,000 worker hours (Q4). Again, this infers that, as the number of defects increases on a project, the first-aid rate increases as well. The r^2 value of 0.507 indicates that a strong relationship exists, and the p-value .030 led to rejection of the null hypothesis.

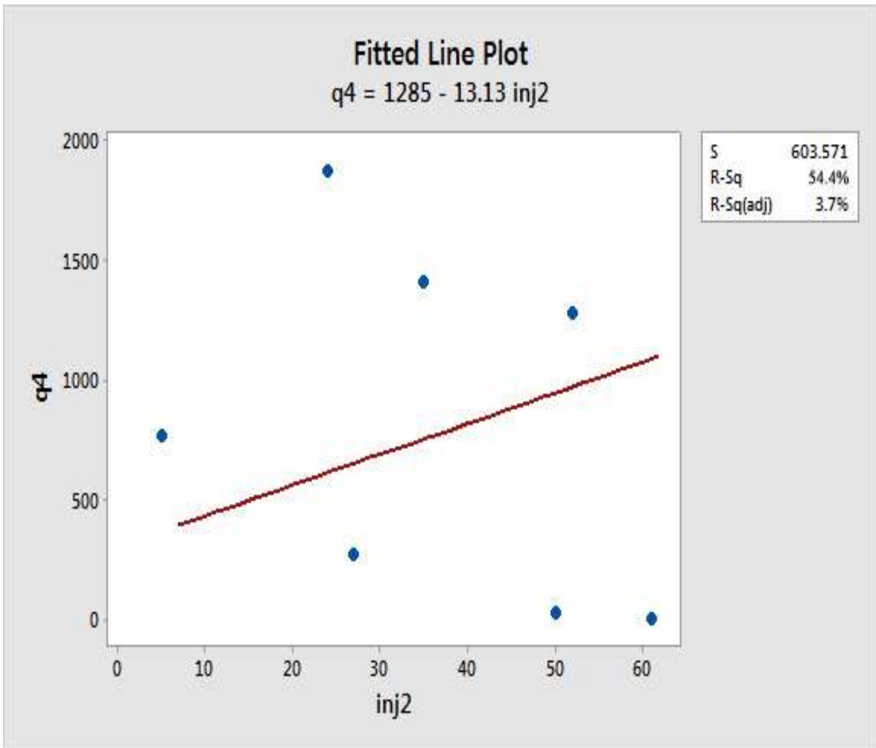

Figure 8. The first-aid rate per 200,000 worker-hours (INJ2) versus the number of worker hours related to rework per 200,000 worker hours (Q4).

On the basis of the empirical data analysis, it is evident that there is a relationship between construction safety performance and construction quality in foundation. The analysis returned four statistically significant relationships with p-values less than 0.05 that warranted the relationship between safety and quality in foundation. The following inference is made from the empirical data analysis.

Inference: The injury rate is positively correlated to rework, i.e. the construction quality performance improves with good safety practices in foundation.

VI. DISCUSSION

Safety and quality in the foundation construction are not separated from each other. The similarity and integration between will make the management process more effective. Fig. 9 represents how the relationship between safety and quality management of foundation can be integrated at construction field. The basic model shown in the Fig. 9 discusses the elements which constitute the process of both safety and quality management.

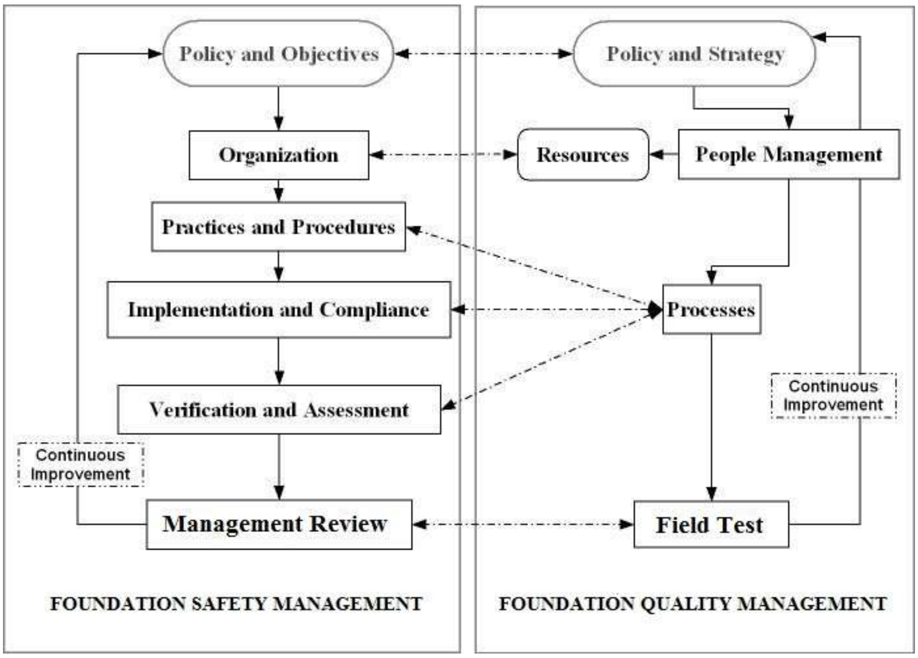

Figure 9. Proposed Safety and Quality Model

The similarity between the safety and quality management in foundation construction could be summarized in flow of management levels into four levels as follows in Table 6.

Table 6. Similarities between Safety and Quality Management Process in Foundation

	Safety Management	Quality Management
Level one	• Policy and Objectives	• Policy and strategy
Level two	• Organization	• People management • Resources
Level three	• Practices and Procedures • Implementation and Compliance • Assessment	• Processes
Level four	• Management review	• Field test

6.1 Level One

The important similarity of safety and quality in foundation is the fact that the implementation of both should begin by drawing up of a policy statement. At safety management it is policy and objectives, they call it policy and strategy at quality management. Integration of safety and quality management in foundation systems should be improved in the construction industry in order to develop a strategic approach at tackling problems. The model should start by setting up a policy and objectives that integrates both safety and quality in one pattern. Such policy will draw all necessary steps required for the good management implementation process.

6.2 Level Two

The organization of safety constitutes the top management, safety engineers, workers and other parties related to safety in a project. The organization should be formed with knowledgeable personnel who exhibit characteristics necessary to achieve safety objectives. Similarly resources of project and people management are essential components of quality management. The resources for project should be checked for safety in additional to quality. Similarly in people management the personnel must be allotted work in such a way that he does with maximum quality and safety. Training for both safety and quality in foundation construction must be given.

6.3 Level Three

Implementation and compliance of safety procedures and practices are inherent characteristics of good safety management. Compliance with local safety regulations and documenting incompliance penalties in contract forms. Verification and assessment processes are important for ensuring safety in foundation. Through assessment of accident reports, causes and consequences of safety violations are investigated and the method for removing hazards can be uncovered through investigation by safety engineer who is located at workplace. All these should be made standardized before the work commences by the safety department and these should be checked and processed continuously during the execution of project to achieve good quality and maximum safety.

6.4 Level Four

Management review of safety reports and accident reports of foundation accidents is necessary for the correction actions of safety procedures. The standardized assessment process and implementation procedure for execution of foundation works must be reviewed by the top management. Soil tests choosing the type of foundation must be as per the safety regulation which helps to achieve good quality. During and after execution continuous field tests are necessary to ensure the correct execution of work.

VII. RECOMMENDATION

The recommendation addresses the remedial action to solve the problem. Government should strengthen its legislation through the legislative council acts and clauses that would impose fines and penalties on institutions and companies which violate safety regulations. Develop more practical and effective safety policies which mainly address clear safety regulations and clauses. Effective construction techniques for foundation and excavation should ensure providing a safe place to work, a work environment conducive to safe work practices.

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