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Safety Management in Surface Excavation

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ABSTRACT

Excavation has been recognized as one of the most hazardous construction site activities by OSHA. The fatality rate in this activity is 112%larger than this rate for general construction meanwhile the fatality rate in construction is three time more than this rate in overall industry. Current statistics on the fatal accidents which caused by excavation projects necessitates preliminary studies and precautionary actions to resolve the problem. Therefore, the investigation and revision of safety management strategies have been brought up in order to ensure the health of the project prior to commencement of any excavation work. This study will present the key safety factors in excavation site and identify common hazards in excavation activities as well as making an assessment and providing means to offset the impacts of them on sites.

KEYWORDS: safety management surface excavation.

1. INTRODUCTION

The construction industry is known as one of the major economic sector in most countries and this industry, as one of the most hazardous industry, can directly influence the total GDP in every societies. Construction industry consists of various types of activities and each type of project has its unique aspects and risk; however excavation work is one of the most dangerous practices. Excavation is one of the most important activities in construction industry. In the past several decades, with the urbanization and development of construction industry, depth of excavations grow deeper and deeper. What's more, these excavations are usually located in densely populated area and more and more problems of property damage and person injury are encountered and also sometimes it is carried out in complicated safety consideration. In addition the nature of excavation work is different from other type of construction. Besides the obvious issue associated with soil and water, holes in the ground create access and confinement problems. The sizes of equipment required to break up and move the earth in conjunction with the proximity to associated worker on the ground create particular problems. The unknown aspect of what is already buried prior to digging, the size and handling requirements of what is being constructed inside the hole, and the ground surface staging and activity within the confines of public activity are different from other construction activities. All these conditions require using advance safety method and techniques construction technology. [2, 5, 10].

1.2. BACKGROUND OF STUDY

It is hard to talk about excavation safety without talking about the Occupational Safety and Health Administration (OSHA) and shoring. Both of these terms are synonymous with excavation safety. In 1971, OSHA issued its first standard related to excavations and trenching. Since that time, OSHA has changed the standard in an effort to reduce injuries and fatalities. On October 31, 1989, OSHA issued a final revised standard for excavation and trenching1. The revision updated the previous standard by simplifying many of the existing provisions, adding and clarifying definitions, eliminating duplicate provisions and ambiguous language, and giving employers added flexibility in providing protection for employees. In addition, the standard provided several new appendices. One appendix provided a consistent method of soil classification. Others provided sloping and benching requirements, pictorial examples of shoring and shielding devices, timber tables, hydraulic shoring tables, and selection charts that provide a graphic summary of the requirements contained in the standard. In 2002, the Occupational Safety and Health Administration (OSHA) began a review of its Excavations Standard under Section 610 of the Regulatory Flexibility Act and Section 5 of Executive Order (EO) 12866 on Regulatory Planning and Review.

Nevertheless there are a lot of articles which have studied about safety on excavation. Jeffrey Lew and Dulcy Abraham discusses the existing OSHA's excavation and trenching standards, specifically describing the requirements and the roles of a competent person, and other issues in OSHA Standard 1926. In 2009 L. Chen a , X. Gu & X. Long from china prepare statistical analyses on 342 actual excavation accidents in China are performed based on different accident causes, types of excavation supporting systems and excavation depths. Their frequency distributions are obtained to better understand the problem. Then, the FTA (Fault Tree Analysis) theory is introduced and the fault trees of the soil

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nailing system and cement soil retaining wall for safety assessment are established. Javier Irizarry and Carlos Arboleda provides an Analysis of Safety Issues in Trenching Operations. In 2012 Paul Fok, Bian Hong Neo, Dazhi Wen and Chepurthy Veeresh present the key elements of the risk management process for design and construction. It also demonstrates that the risk management process for temporary works design for deep excavation. [1, 9, 12, 13]

1.3. PROBLEM STATEMENT

Construction is one of the most hazardous industries for whom involve it. According to the statistic report, the death rate in the construction sector was three times more than this rate in all work environments. Below diagram shows the Twenty year trend in worker fatalities. [18]

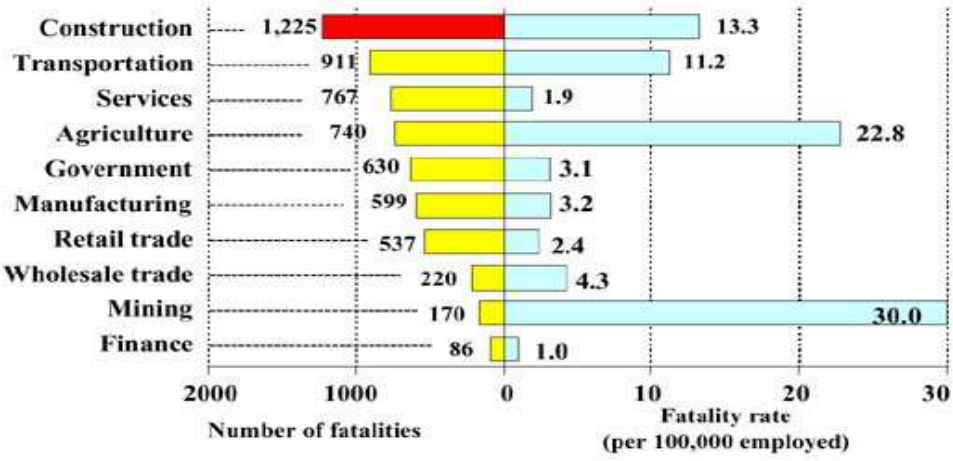

Figure 1 Number and rate of fatal occupational injuries, by industry sector

Excavation also is known as a major hazardous activity in construction industry. Hunter introduces excavation activity in one of the top six hazardous activities in construction industry. Pie chart below gives us some information about fatality rate in construction by occupation. As can be seen, 18% of this rate is in excavation work. The fatality rate in excavation activities is 112% larger than this rate for general construction (OSHA).

There are two separate aspects to work in an excavation-constructing the excavation and constructing the work that caused the excavation to be opened in the first place or that which is to be buried inside the excavation. The latter is considered production work. The owner and project design engineer focus all their attention on the production work and not of the logistic of the excavation. From safety aspect it is important to note that when a design engineer is focused on the production work which is her or his primary function, excavation safety issues on secondary to that.

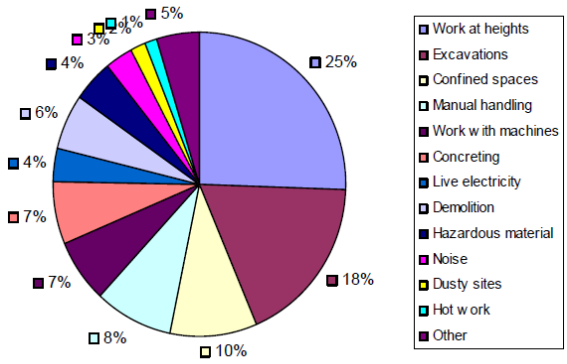

Figure 2 Fatality rate by activity sector

1.4. AIM OF STUDY

The aim of this study is to investigate aspects of safety in excavation to propose ways to reduce the accidents during excavation work and improve the level of safety performance in excavation activities. To prevent accident, a company should know how to identify and be aware of all potential accidents that can happen during normal business operations. The objectives of this study are followed as:

1. To identify common hazard during excavation work;
2. To assess the risk of each hazards which are in excavation work;
3. To propose appropriate control methods to manage safety in the worksite.

1.5. SCOPE OF STUDY

OSHA defines excavation as any human-made cut cavity, trench, or depression in the earth s surface, formed by earth removal. But, in this study when we talk about surface excavation which is a trench such as surface excavation of a large rectangular hole in order to establishing a foundation of building or a building with underground level. This study will only focus on the safety management issues in the surface excavation site by identifying, eliminating, substituting and reducing construction hazards up to acceptable level in developing countries.

2. LITERATURE REVIEW

The goal of reviewing the literatures is to collect information which are related to the topic include Excavation (types and methods) and safety management and data with statistic of accident occur during excavation work as well as safety regulations. Literature review consists of information which is gathered through books, journals and web sites on internet as well as previous researches.

2.1. EXCAVATION

Definition and classification of excavation: 'Excavate' word means dislodging the rocks from its first place. This consists of two functions: digging the ground and its removal. This will be done to any formation that is present within the earth layer. This function can make open positions or excavations of different shapes, dimensions and styles at the ideal location. The position could be a hilly geography or simple ground. It could be located in an urban land or at the suburb. It could start at, over or under the ground level and extend in any direction: horizontally, vertically or willing. Generally, determined by locale, the excavations can be arranged in tow type, Surface Excavation and Underground Excavation. [10]

Excavation Method: material, its properties & volume to be excavated play significant role in determining method of excavation. For rocks like strong intrusive igneous rock & weak unconsolidated sediments such as soils, method of excavation is usually blasting & normal excavation (back-hoe), respectively. For materials of intermediate strengths (some sedimentary & metamorphic rocks), their method of excavation depend on the volume, common method include ripping & blasting.

2.2. SAFETY MANAGEMENT

For prevention of accident we need to a methodical approach. From 2008 with distribution of HIRARC guideline, offer the guideline for accident prevention. The HIRARC process is a systematic method of identifying, evaluating and performing to risk occasions at the lowest cost during the life cycle of a project. A risk management process by consists of the following steps: Hazard identification, Evaluate the risk, Prepare risk control, Implement and Review. In 2003 Abdul Rahim Abdul Hamid and Bachan Singh identified and highlighted the hazards that are most commonly found at our construction sites. [7]

a) Hazard identification: The objective of identifying hazard is to emphasize on the important operations of projects, that is, those tasks appearing major risks to the safety and health of workers as well as showing all those hazards relevant to particular equipment due to energy resources or working situations.

b) Risk assessment: Risk is the designation of possibility and severity of the accident series in order to assign value and to priorities hazards. It can be performed by qualitative, quantitative or semi quantitative method. Risk is calculated by following formula:

L x S = Relative Risk (L = Likelihood, S = Severity)

Also in order to analysis the risk which uses frequency and severity, representing result in a risk matrix is very helpful. Project Risk Management Handbook in second edition offered two candidate matrices for threats, using the non-linear and linear impact scoring, are shown as follow: [15]

Option 1: PxI Matrix for Significant Focus on High and Very High Impacts (Non-linear Impact Scoring)					
Probability	Threats				
5	5	10	20	40	80
4	4	8	16	32	64
3	3	6	12	24	48
2	2	4	8	16	32
1	1	2	4	8	16
	1	2	4	8	16
	Impact on Selected Objective				

Option 2: PxI Matrix for Moderate Focus on High and Very High Impacts (Linear Impact Scoring)					
Probability	Threats				
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Impact on Selected Objective				

Figure 3 Tow option for risk matrix

c) Control the risk: Control is the removing or inactivation of a risk in workplace. Common methods for controlling the risk are elimination, substation and isolation which the former is most effective method.

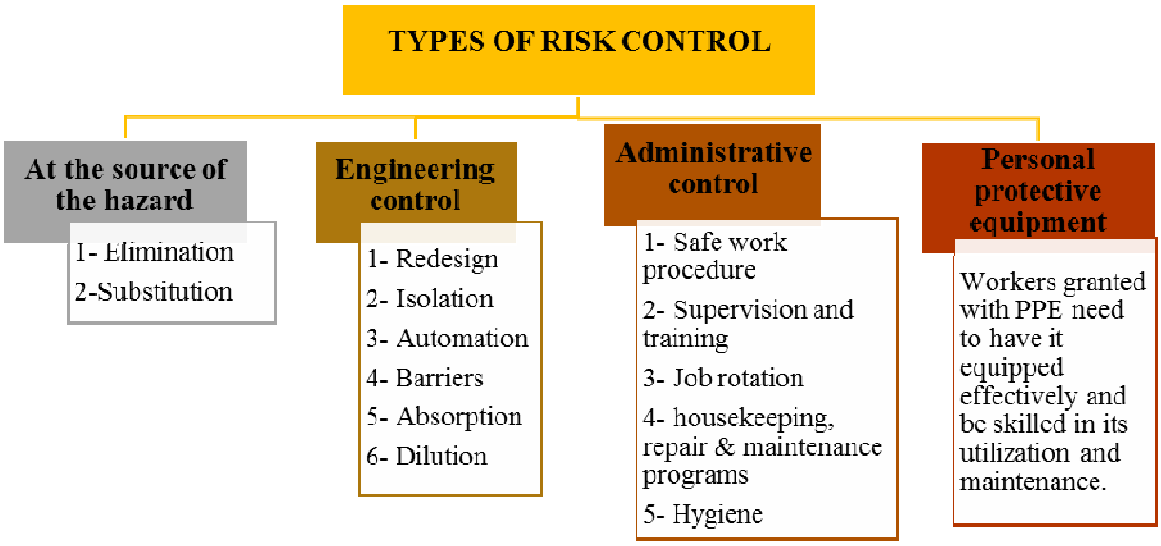

Figure 4 Types of risk control

The research methodology covers the identification of problem and scope of study and objectives at the first phase through reviewing the literature. Second phase leads to achieve the first objective, identifying common hazard in excavation. Hazards were identified by reviewing literature, accident statistic and discussion with supervisor. In next step, we collect information about each hazard include frequently, severity and control methods. Data collection will be collected from selected area of study by interviewing with expert. The interview is structured which is orally administrated questionnaire. It is known as a "systematic goal oriented process". And final fourth phase will be of data analysis and conclusion and recommendations. Collected data will be analyzed to develop a conclusion of the study to achieve the last objective.

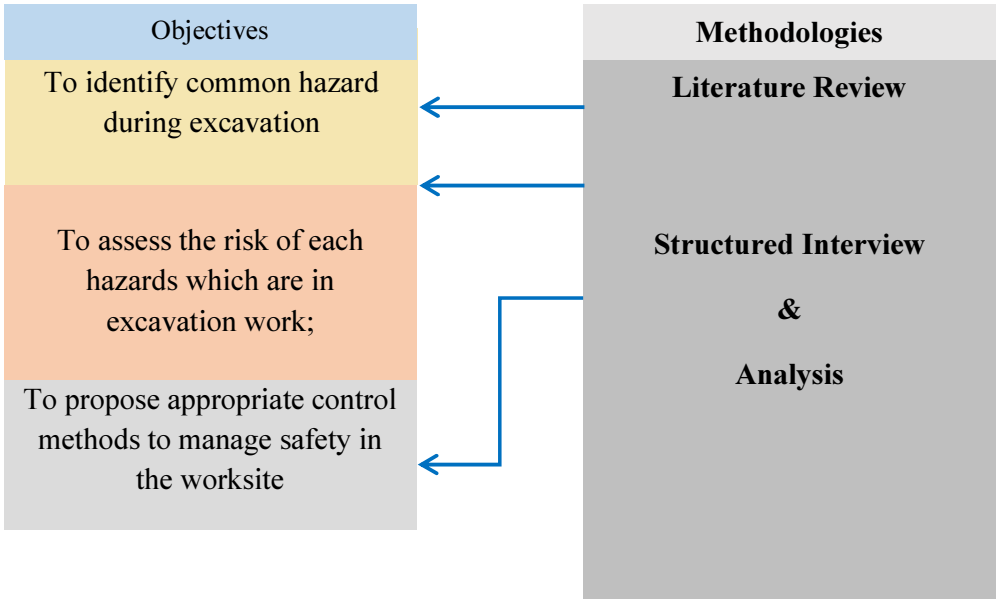

Figure 5: the research methods used to achieve the specific objectives

4. RESULT AND DISCUSSION

To achieve the first objective there are several books, guidelines, articles which introduce some potential of hazard in excavation activities such as Excavation and trenching standard (OHSAS18001 Documentation), a Guideline for Excavation Work by Manitoba University, Excavation & Trenching book prepared by Technical Learning College and etc. Beside these Statistic of Fatalities by Cause of Death in excavation work which is published by Occupational Safety and Health Administration is very helpful for identifying hazards.
At the first stage, subject matter has been studied through above literature to identify hazards in excavating process that is listed in table below.

Table 1 Major Excavation Hazards

1	Cave-in	**6**	Accident for third party
2	Machine accident	**7**	Explosion / Fire
3	Object falling	**8**	Access to excavation
4	Utilities (underground Services)	**9**	Flooding / Underground water
5	Fall into excavation	**10**	Asphyxiation / Noxious Fumes

In the second step, data was collected through structured interview amongst experts that background and experience shown in below diagrams.

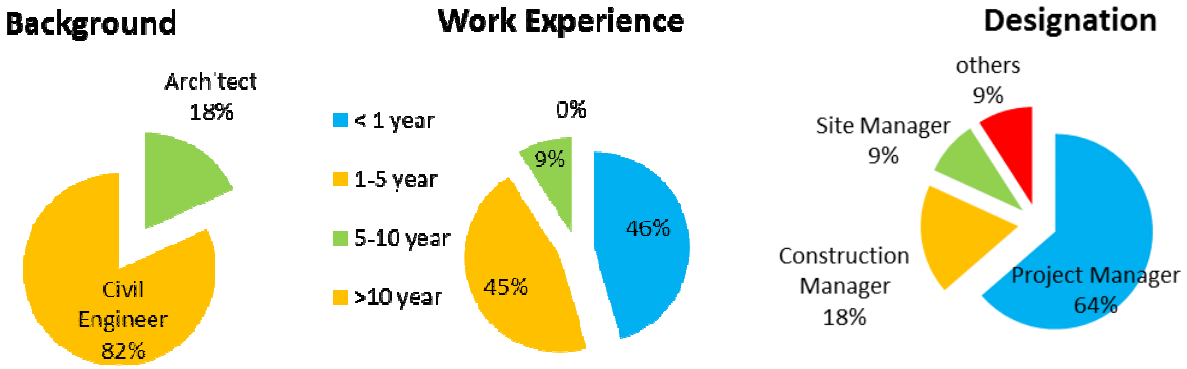

Figure 6 Respondent particular

In the first part of structured interview, frequency and severity of each identified hazard in excavation has been investigated that the results is used to assess the risk of each hazard through nonlinear method as depicted in below diagrams.

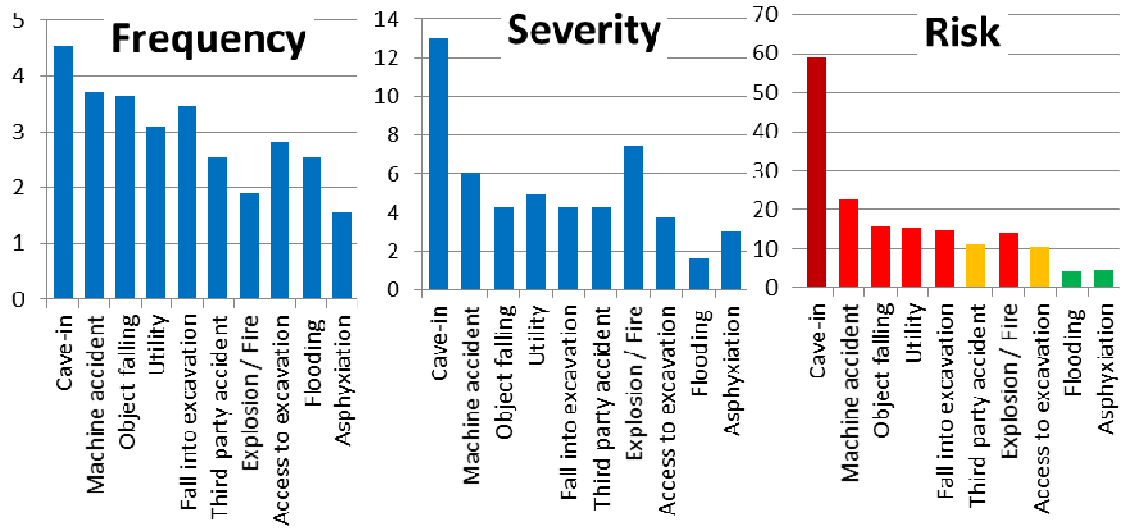

Figure 7 Risk Assessment

In Figure 7 according to definition mentioned in section 2 of this paper, cave-in assessed as extremely high risk hazard whereas machine accident, object falling, utility, fall into excavation and explosion consider as high risk and third party accident along with access to excavation are medium risk and finally flooding and asphyxiation are low risk hazard. To show the contribution of each hazard, risk pie chat is drown as below.

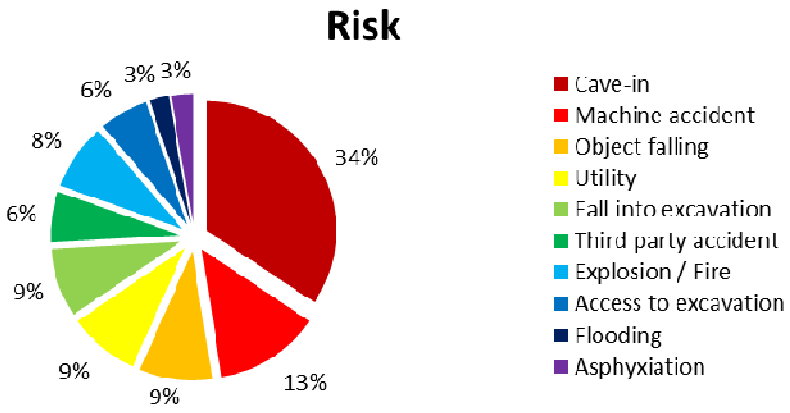

Figure 8 Risk Pie chart

The data in second part of interview has been analyzed to find the third objective of the study. As shown in chart below, each diagram peak depicts the best method of risk control for that hazard.

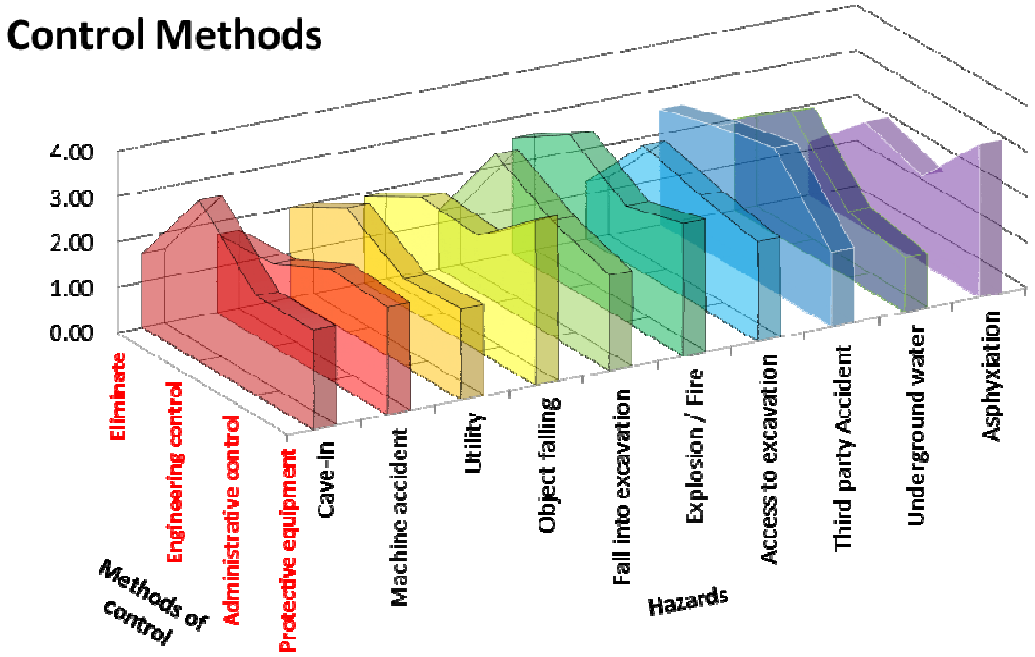

Figure 9 Risk Control Methods

This diagram revealed that the most appropriate method to control cave-in, underground utility, fall into excavation, explosion and underground water is engineering control. Meanwhile administrative control is the best method for machine accident and third party accident. And protective equipment is the best choice for control object falling and asphyxiation hazards as well.

In the other hand, respondents has been asked to define the phase of control (planning, design, construction) that is the best time to control the mentioned hazards and result is shown in diagram below. This diagram shows that eight out of ten hazards can be control in construction phase and two others can be control in planning phase.

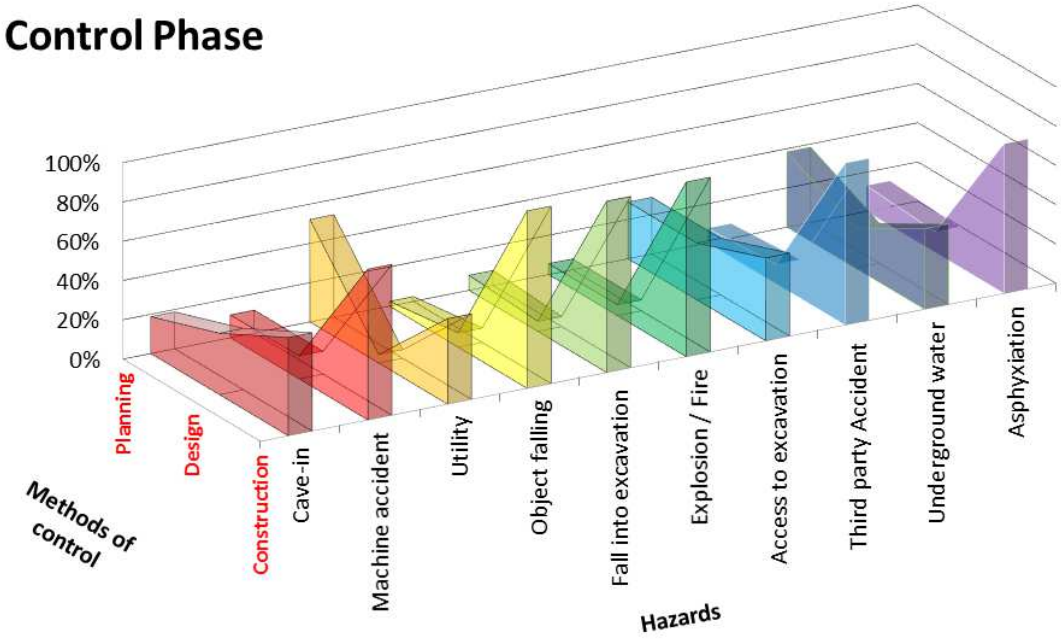

Figure 10 Controlling phase for hazards

5- CONCLUSION

In conclusion, this research has identified the major hazards in excavation project through critical literature work that is listed as in table 1 in section 4 of this paper as first objective of the study.

In next step risk assessment has conducted to find the impact of each hazard in excavation project as second objective of this study. As depicted in Figure 8 (risk pie chart) Cave-in identified as the most critical hazard amongst all mentioned hazards in excavation project.

Next step after assessing the risk for each hazards, is to propose an appropriate method to control that hazard as the third objective of the research. The analyses of structured interview with experts revealed that engineering control methods have the greatest impact to control the hazard in general that is shown in figure 11.

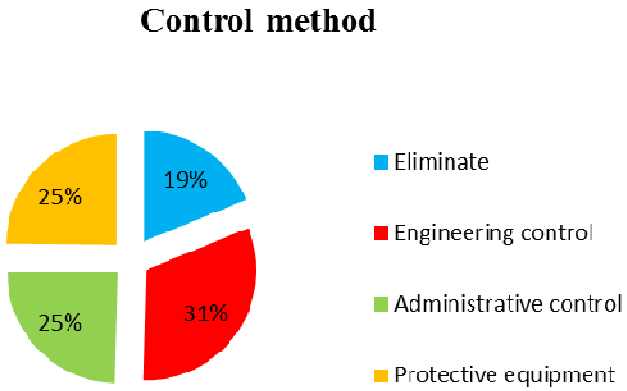

Figure 11 Methods of Control

Meanwhile, the best time to control the hazard is construction phase along the project lifecycle. As can be seen in Figure 12, construction phase is the most significant time to control the excavation hazard. However, in planning and design phase can control some portion or hazards as well as can be seen in below diagram.

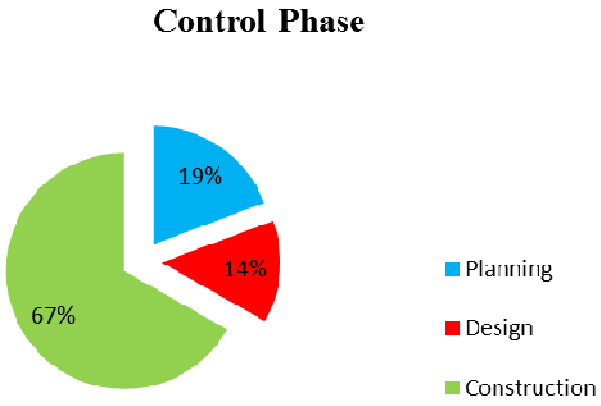

Figure 12 Control Phase

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