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Evaluation of Factors Affecting Safety of Excavation, and Their Relationships with Pit Stabilization: Case Study of Tehran

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ABSTRACT

Construction industry, due to the nature of constructional operations, is one of s high-risk industries especially by the end of the implementation and completion of the building structure and frame. For this reason, in this paper, we attempted to assess factors affecting safety of excavation, and their relationships with pit stabilization. This case study was conducted in the city of Tehran, and the construction site was Haghani pit, which is one of the most dangerous pits in Tehran, located in District 2. Survey process was conducted in four stages; before excavation, during excavation, after excavation, and finally, overall project scheduling. In the present study, factors such as: "the wall of building site and coupling to adjacent buildings", "the proper use of scaffolding and netting before demolition", "place of drainage wells, and blocking it before demolition", "choosing the right devices used in excavation operation", "detecting electrical and split installations before excavation", and "identifying type of soil and land for excavation" were proposed as effective factors in the safety of excavation.

KEY WORDS: safety, pit stabilization, excavation, constructional operations

1. INTRODUCTION

Excavation is presumed to be among high risk and damaging sites. Once in a while, there are reports about people injured or dead because of the collapse of the side walls of the excavation or relevant subsidiary activities. International experience has shown that the most appropriate strategies for avoiding such unpleasant accidents are decent standards and instructions on how to implement them exactly and staff training. In Iran, no specific standard has been until now developed to apply safety measures to excavation (Memarian, 2010). The growth and development of building industry and consideration to retaining working, effective, and respective human resource would lead us to move toward ensuring the security of the operation with a stricter look at various parts of constructional operations including excavation and drilling. Building industry is viewed as high risk industries due to the nature of constructional operations, particularly by the end of the implementation and completion of the building structure and frame. A glance at the statistics workshop events and the severity of occurred accidents will confirm this claim. In this regard, the recognition of available services, different practices of security and protection systems on the one hand and the awareness of duties and legal liabilities for implementation, on the other hand, can make excavation operation risks managed and relevant accidents considerably decline in number and severity through better and stricter planning (Tanbakozadeh, 2008).

Flows of public capital to construction sector can contribute greatly to the sector, but in the country a new crisis (known as construction-related accidents) has sadly arisen, the scope of which is broadening every day. Unprincipled excavation accidents resulted in the collapse of buildings in the vicinity of construction site, death and disability of installation personnel the number of whom is incessantly increasing, are quite known to every expert. Considering the weakness of monitoring systems, non-specialists have the audacity to step into specialized construction category with ease and a motivation for becoming rich. The consequence of this is the installation of a construction without regard to technical and engineering calculations, which in many cases the constructing process come to a halt due to technical defects or rise of accidents (Maleki et al., 2008). Drilling and excavation are one of construction activities which are conducted for different purposes such as: demolition and excavation of an old building for reconstruction, reaching a pristine level, protection from foundations against frost, installation of channels and underground tanks, parking spot, etc. To avoid the demolition of excavation wall, we have to implement structures strengthening the resistant force against wall demolition. Sadly, there are reports on irreparable damages inflicted by such operation, which in turn multiplies the importance of the subject matter (Zakariaei and Babazadeh, 2010).

Excavation operation is perceived to be among dangerous ground operations. According to available statistics, many individuals lose their lives or suffer serious injuries every year in excavation projects due to failure to comply with security principles. Today, in most countries, due to the importance of the issue, distinct standards and instructions are developed and utilized for excavation-related activities and security principle compliance. In Iran, for certain technical construction documents (standards, regulations, building regulations, technical specifications, etc.), a few rules and regulations have been enacted for excavation security, including work safety and protection during

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implementation (Iranian Ministry of Housing and Urban Development), regulations on workshop protection (Iranian Ministry of Labor and Social Affairs), and recommendations offered by Fire Agency (Ghiasian and Shargh, 2003). Excavation damages in recent years revealed that there is a need for further study on designing and building temporary flexible lateral restraint systems. As a consequence, one of the most important issues concerning Civil Engineering in urban areas is to stabilize braced wall using wale struts. Conducting accurate and appropriate studies are the origin of the most important and influential factors in selecting and designing pit stabilization system (Kariminia et al., 2013).

Excavation as one of the convoluted and dangerous works is required to be braced and stabilized by retaining structures in order to protect the lives of people inside and outside excavation, neighboring buildings, and provide safety conditions. Retaining structures consisted of various types which are selected with respect to type of soil, depth of excavation, and sensitivity of adjacent structures, operated by excavation project practitioners who has specific responsibilities and duties, and supervised by individuals and related agencies. Conducting excavation operation is required to take measures during, before and after the work, and employing them can avoid excavation accidents.

One of the major issues concerning urban construction is to ensure good stability during demolition, excavation, and retaining structure installation. In order to stabilize excavation walls in urban area, different forms of building elements composed of soil and rock compound are used to build walls and retaining system. As for demolition, excavation is presumed to be one of the most valuable advice for the safety of construction site. In the national building regulations, safety instructions are not stated clearly and appropriately with respect to demolition and excavation so that there is a need to bring in and issue regulations appropriate for this purpose. In view of a mismatch between urbanization conditions, technologies manufactured by other countries and the current situation in Iran, safety regulation in these countries cannot cover necessary safety instructions in such operations as good as it should be. Given the above discussion and the significance of the research on safety of excavation operation, in this paper, we decided to offer appropriate solutions with respect to optimization of workshops which are one of the important and necessary issues.

2. MATERIALS AND METHODS

2.1. Excavation

excavation means any removal of earth materials, road metal materials, stone, sand, and falling and sliding stone materials from the riverbeds, regardless of their type and quality, which are used to level, slope, and prepare the foundation of buildings, technical structures, communication roads, and supply soil from borrow sources. The entire excavation operation should be conducted in compliance with contour lines on operation maps and instructions of supervising agency. Excavation operation and uncoated surface regulation should be conducted simultaneously. Following procedures should be carried out immediately after excavation and it should not be, however, exposed to atmospheric agents and rainfall for more than 72 hours. In case following operation is failed to be performed as planned and scheduled immediately, controlling the previous layers and, if necessary, modifying, surface leveling and final regulation should be carried out prior to the implementation of following stages. If contractor attempts to remove surface and prepare the bed until the desired level for continued operation soil to ultimate level intentionally or unintentionally, it should be done according to supervising agency, and at the expense of the contractor. Throughout the earthworks, it is imperative to pay due attention to the process so that we can avoid additional excavation and loss of materials in the bed and walls, particularly at points that formwork is underway.

In case of additional excavation on the part of contractor, it is imperative to repair and regulate the site as per the intended level with materials and costs borne by contractor. Soil erosion compatible concrete, at least concrete 15, how machinery are deployed and operated at the site, and techniques of operation implementation should be verified by supervising agency depending on type and nature of construction site soil, considering the scheduled plan for operation implementation. The excavation of channel site intended for installing pipes and channels should comply with the plan and specifications and dimensions already determined. If needed, after verification of supervising agency, additional excavation can be conducted at pipeline site. In case digging procedure is performed by machine, it is essential to proceed with the operation up to the final depth of 15 cm, as the rest of operation should be proceeded in order to level and regulate channel floor by hand.

2.2. Foundation and excavation

Excavation is called ground operation when it is carried out below the ground surface in order to construct underground powerhouse, etc. however, digging the foundation refers to all operations conducted on the ground surface. By digging the foundation and excavating, we mean performing ground operation in an attempt to dig the foundation site out of a building and retaining walls, pipes, and bridge piers in the area of building and the like by hand or by appropriate equipment according to the levels required on the plans and instructions of supervising agency. Digging the foundation with vertical walls is limited to the outer surface of the foundation as digging it with horizontal walls is limited to the underside of the foundation bed and elevation of natural land, leveled land or embankment areas. Different forms of foundation digging should be conducted as per plan, specifications, and instructions of supervising agency in desired dimensions and sizes. Thus, digging foundations over horizontal and vertical dimensions is not allowed in any respect. If contractor mistakenly attempts to do excavation beyond specified size, it will be necessary to backfill and prepare the extra space for subsequent procedures with concrete or other appropriate materials according to supervising agency's view and the costs paid by contractor. The commencement of building foundation is not allowed before Pit site is approved and visited by supervising agency. Generally speaking, excavation operation should be performed for vertical wall unless soil type makes it inevitable to drill Pit wall in a slope fashion. If it is the case, drilling operation and slope of Pit wall is determined by prior approval of supervising agency, then it is dispatched to contractor to carry on the task. Digging the foundation and excavation where building foundation is predicted can be conducted if approved by supervising agency in such a way that there is no need for formwork as much as possible and one can use excavated front using plastic or other similar methods. In case we are unable to make use of excavated front for concrete pouring procedure as placing a formwork is inevitable, we can add the size of foundation as required up to 70 cm at the lowest point by the confirmation of supervising agency. Foundation digging and excavation should be proceeded until the bottom of the Pit is reached at a good state unless otherwise is specified in the technical specifications and operational plans or instructions of supervising agency. Overall, it is deemed necessary to replace loose materials with approved and good materials. If part of the bed excavated is accidentally made up of rock and other part is made up of sand, it is necessary to build appropriate bed for a structure to be established. In this case, contractor is hold responsible for reporting to supervising agency on what he has to pursue to handle it. If excavation operation is performed by a machinery, excavation should be up to 15 cm of ultimate levels and 15 cm of level taken out by hand and it should be regulated as per levels and slopes given in operation maps. To prevent ingress of water, it is essential to adopt common techniques such as construction of plastic water sealing wall, sheeting, siphoning water drainage, pumping, etc. the order and method of implementation should be approved by supervising agency prior to implementation (Sarmad Nahri, 2013).

2.3. Identifying land

Identifying the characteristics and capacities of the ground on which a structure is expected to be built and how to perform excavation and use struts or props, it is necessary to take account of observing safety requirements and the status of surrounding buildings during excavation.

By surveying ground, we mean the following details.

(1). General topography of study area, remolded soil, checking the status of cracks and possible instabilities in slopes, and checking soil swelling property.
(2). Determining the maximum and minimum level of groundwater that may be problematic in some cases or areas with respect to digging and building foundation.
(3). Soil strength (allowable bearing pressure in soil).
(4). Selecting depth of foundation and comparing different types of foundation and selecting the best ones
(5). Anticipating settlement
(6). Possible problems and difficulties of adjacent building in relation to excavation
(7). Checking the depth of glacier in the area
(8). Determining stability and impermeability of the bottom of Pit

2.3.1. Soil excavation of lands in sludge

Muddy and waterlogged grounds, water saturated soil contains organic materials, so it is unable to bear the weight of a building and will be crumbled due to the load it bears. Sludge at excavation site is seen as an obstacle to the implementation of work, causing equipment to tip into the Pit and fail, and eventually delaying timely operation implementation and reducing operation efficiency. As a consequence, contractor is required to take necessary measure to choose the type and number of machinery and their operation method before getting operation started. In muddy ground, small machinery with heavy reliance is preferable so that operation can be performed more easily and there will be no problem. In light of the difficulty and uneconomical aspect of excavation in sludge and carrying materials, contractor is first required to stabilize sludge through drying out the area with approved methods under supervising agency's command in case of high depth and volume of sludge, and subsequently attempt to carry out excavation work. The sludge coming from excavation and earthworks should bring into agricultural use in places where construction site is nearby as much as possible. However, the place of sludge discharge is recommended to be constructed as closely as possible and determined by supervising agency followed by an order sent to contractor (Sarmad Nahri, 2013).

2.3.2. Soil excavation in rocky lands

Excavation in rocky areas should be performed as per operation maps and instructions of supervising agency as well as desired levels and sizes. Contractor is thus required to take necessary measure and consideration to make excavated levels and sizes comply with the contents of map and work instructions, if additional stone removing operation becomes unavoidable, extra work should be separately stated in a meeting and confirmed by employer. Excavation work in rocky areas should be conducted in such a way that stone texture is determined below specified level lines as it should remain intact in the most favorable condition ever. As a means of breaking stones, we can refer to expansion materials than can be operable with the approval of supervising agency. The use of explosive materials in rocky area excavation should be pursued with prior approval of supervising agency. Transport and storage of explosives should be conducted in accordance with laws and regulations. Maintenance and storage of the materials require the knowledge of respective authorities and the use of such materials requires their prior knowledge. Demolition using explosives at a distance of less than a hundred meters from completed or incomplete buildings, and residential buildings is not allowed in any respect. Thus, contractor is required to inform supervising agency about the site and extent of explosion at least one hour prior to implementation. In case of the wide range of explosion and operation site, contractor is hold responsible for making sure a reliable informing system is deployed in the area for informing all personnel in advance.

2.4. Safety in excavation

Part of accidents that causes death or injuries of construction workers occur during excavation and after it, thus safety issues should be observed in the following three steps:

i. Safety issues before excavation
ii. Safety issues during excavation
iii. Safety issues after excavation

2.4.1. Safety issues before excavation

Before excavating, we should check various cases in the construction site, which are as follows:

- Before the demolition of building, the site of construction project, how adjacent buildings are connected to the structure of the construction, and share boundary walls, the place of boundary walls and how they are linked together, shared posts or ceilings of two adjacent buildings, openings, and horseshoe port and chimney pipes, or ducts installed in the boundary walls, type of materials, depreciation of the walls of adjacent buildings are required to be examined.
- By building safe ceilings using metal scaffolds top of which is covered by suitable net, it is necessary to provide adequate safety against the possible falling of objects and materials on ceiling, wall, courtyard and passages in the vicinity of construction site.
- Before beginning with demolition work in the construction site, existing drainage wells are required to be located, and filled by appropriate materials. If the depth of the wells is greater than that of excavation in the construction site, it is necessary to fill the wells with concrete materials at least up to 50 cm above the bottom level of excavation.
- The place of the well should be taken into consideration in the final maps for retaining structures as well as part of terms in the design of safety conditions.
- The selection of demolition method should be pursued carefully and demolition operation of construction structure should be performed under an engineer's supervision. Thus, it is recommended to choose demolition tools and equipment with care so that vertical or lateral dynamic or static forces can be hindered from imposing on adjacent building during demolition. Particularly, it should be noted that walls bordered by adjacent building are required to be demolished and removed by impact free equipment and methods.
- Before demolition operation in the construction site, it is necessary to cut off available mechanical and electrical split installations with the approval of the competent authorities and the relevant technical expert supervision. It is also advisable to inform technicians in charge in the project, especially supervising engineer and administrator, about different stages of excavation and how prefabricated and in situ elements, and provide necessary coordination between administrating engineers, supervisors, and designers to cope with predicted and unforeseen problems.

2.4.2. Safety issues during excavation

- Demolition and excavation should be conducted under the supervision of supervising engineer or supervising agency by respective administrator
- On a daily basis the statistics of construction workers be registered in specific notebooks exactly as per the specification of his identity card, address, and contact number.
- In all personal states, in order to check the current safety status and take permanent care of excavation walls and warn workers to run away at danger time, seek shelter or any form of necessary reaction. A suitable alarm system be installed as much as possible in construction site in order to signal danger and alarm workers and residents of adjacent buildings.
- Stage wise excavation as specified in operation map using special equipment or carrying out by hand.
- During excavation, stage wise methods should be designed and implemented exactly. Excavation and construction of retaining structure should not be abandoned for a long time at any stage, as sequential pace of work is required to be maintained.
- During excavation and installation of structure and after it, it is recommended to visit adjacent buildings and surrounding streets, any type of crack or increase in its dimensions in the wall, ceiling, floor of adjacent buildings and surrounding and under pressure streets, exposing to or getting away from pressures of doors and frames, breakage or crack of glasses, settlement or swelling of soil, mosaics or tiles on the floor, cracking sounds of structural and non-structural elements of buildings in the vicinity of excavation may be sprung from ground movement. In such circumstances, the issue must be investigated immediately. Weakness in an element of retaining structure may be the cause of such problem and is required to be diagnosed and strengthened by adding new element.
- If soil color of excavation wall turns darker in some parts than that of other parts in the construction site, it can be an indication of holes or drainage wells near the boundary of excavation, so the likelihood of instability will grow. Consequently, according to what was observed, it is necessary to take account of strategies for complementary stabilization in the area.

2.4.3. Safety issues after excavation

- After rainfall, storm, floods, earthquake, it is advisable to visit the site of excavation so that the points where the risk of wall falling or sliding exist can be stabilized and strengthened by pile, sheet pile or scaffold.
- To prevent the fall of people, animals, building materials, and equipment, and the clash of individuals with vehicles, it is imperative to fence off all around excavation. It is also recommended to use flashing lights or warning signs at night if necessary.
- Use of retaining structures: in many construction projects, it is necessary that ground be excavated with vertical or near-vertical walls. This may be conducted in order to construct underground, channel, and water supply. Lateral pressure exerted on the walls from soil movement due to its weight as well as possible overloads on the soil next to the Pit. These overloads can consist of soil above the horizontal level of edge of Pit, adjacent building, and loads from operation in adjacent streets, etc. In order to avoid Pit collapse and its negative consequences resulting from the excavation, temporary structures are used to brace Pit, which are called retaining structures. The main objectives of excavation wall safety using retaining structures include: protecting people inside and outside the excavation, property inside and outside the excavation, and providing safe conditions for operation. The excavation subject and design and implementation of retaining structures in civil engineering is a wide ranging scope, requiring studies, investigation, and geotechnical and structural, materials, technological, and administrative, and economical and social consideration. As a consequence, it can be said that selecting an appropriate method depends on all contributing circumstances, so we can act differently according to different circumstances. On the other hand, theories of excavation operation practices and retaining structures also depend on theoretical principles as they are influenced by administrative and experimental consideration simultaneously. Stabilization of excavation walls is performed in different ways and methods, namely the use of anchorage, tie back, diaphragm wall, Truss-Raker, Sheet pile method, bored pile walls, and soil nailing. Irrespective of its walls whether they remain stable after excavation, all construction excavations are required to be braced by retaining structures. (Ashrafi, 2012).

2.5. LITERATURE REVIEW

Excavation is one of the most important and complex principles of engineering, and should be designed, performed, and supervised by competent and experienced individuals considering the importance of research-based excavation operation in this context.

Banki (2003) conducted a research on constructional operations. Workshop and construction operation are perceived to be a dangerous work with respect to type of activity and a variety of risks it may involves as we are witnessing many accidents every year in this respect. Type of accident that occurs in workshops is invariably severe, causing death in some cases. In 2010, Zakariaei and Babazadeh conducted a research on safety in excavation operation in construction site in Iran. Drilling and excavation as construction activities are invariably performed for different purposes such as demolition, and excavation of a worn-out building to reconstruct, reach a pristine level, and protect foundation against frost as well as installing channels and underground storage, car parking, etc. In this research, safety regulations on drilling and excavation and installation of retaining structure are described. Salkhorde and Shabanzadeh (2013) conducted a study on reducing the risk of instability in excavations in Iran. The achievements of the research indicate the significance of the issue and interesting facts that as building construction in Iran quantitatively increases, interest in qualitative matter does not grow with the same speed and acceleration as building construction picks up. In this work, an attempt was made to take an influential step to minimize the risk of excavation instability, which brings an increase in safety in construction site, by reviewing different methods of excavation stability, and giving technical points. Guang-Dian (2004) introduced a method of stability analysis against upheaval of deep excavation by an upper limit method of plastic mechanics. The wreck model was founded according to Prandtl-Reissener revolving around ultimate capacity of foundation, in which Moher-Coulomb criterion was introduced. Reviewing excavation practices with regard to its significance in health and safety, Mckinley and Roberts (1993) provided a summary of physical and chemical practices to analyze having come up with some recommendations for excavation practice. Yang-qing (2005) asserted that according to the knowledge and experience in deep excavation engineering the characteristics of design system for deep excavation includes three dimensions-time, logic, and method of analysis. In this regard, designing a project is a key cycle. In this paper, out of the four aspects (safety, economy, environmental protection, and speed of construction), an index system for project design evaluation was proposed, as decision-making and evaluation of a desirable model from multiple objectives were inferred. Making decision according to a fuzzy theory was utilized for deep excavation project design, and its application was adopted in engineering to obtain the result of a better decision. In a study done by Nan (2011), safety index system based on risk assessment in the construction of deep excavation project was proposed with respect to the limitation of traditional risk assessment, which includes some contributing factors in safety in deep excavation engineering namely construction, geology, climate, and relevant environment. In this paper, influential index constitutes safety index as well as other five influential indices calculated, and safety conditions of deep excavation engineering were elaborated.

2.6. RESEARCH METHOD

The present research is an applied research in terms of purpose, and an descriptive and analytical research in terms of implementation. The research was conducted near Haghani Pit, one of the most dangerous pits in Tehran, District 2.

Participants of the present study consisted of 10 civil engineers and construction work experts working in the construction site located in District 2 in Tehran. The data collection method of the research is based on a field study, and the research instrument was a five-choice Likert-type questionnaire, which had 20 items; the first six items were related to the demographic characteristics of the sample, and the rest about safety assessment of excavation operations and workshop optimizations. In this paper, in order to estimate the reliability of the questionnaire, Cronbach's alpha was used with a value greater than 0.7. As a result, its reliability was confirmed. Questionnaires were distributed among participants and were taken back after completion. At the end, raw scores were converted to significant numbers using the SPSS software. Given the fact that the research data had normal distribution, researcher used a parametric t-test and examined the effect of independent variables on dependent variable. The results will be presented in the next section. According to obtained survey data, it found out factors such as: "the wall of building site and coupling to adjacent buildings", "the proper use of scaffolding and netting before demolition", "place of drainage wells, and blocking it before demolition", "choosing the right devices used in excavation operation", "detecting electrical and split installations before excavation", and "identifying the type of soil and land" were effective in pit stabilization. Based on these results, we defined research hypotheses:

H1. Walls of building site and coupling to adjacent buildings play a positive role in stabilizing Pit;
H2. Proper use of scaffolding and netting before demolition has a positive role in stabilizing pit;
H3. Place of drainage wells, and blocking it before demolition have a positive role in pit stabilization;
H4. Choosing the right devices used in excavation operation has a positive role in pit stabilization;
H5. Identifying electrical and split installation before excavation has a positive role in stabilizing pit;
H6. Identifying type of soil and land for excavation has a positive role in stabilizing pit.

Using Gantt chart, we show four stages of the research: before excavation (Fig.1), during excavation (Fig. 2), after excavation (Fig. 3), and finally, the overall project scheduling (Fig. 4).

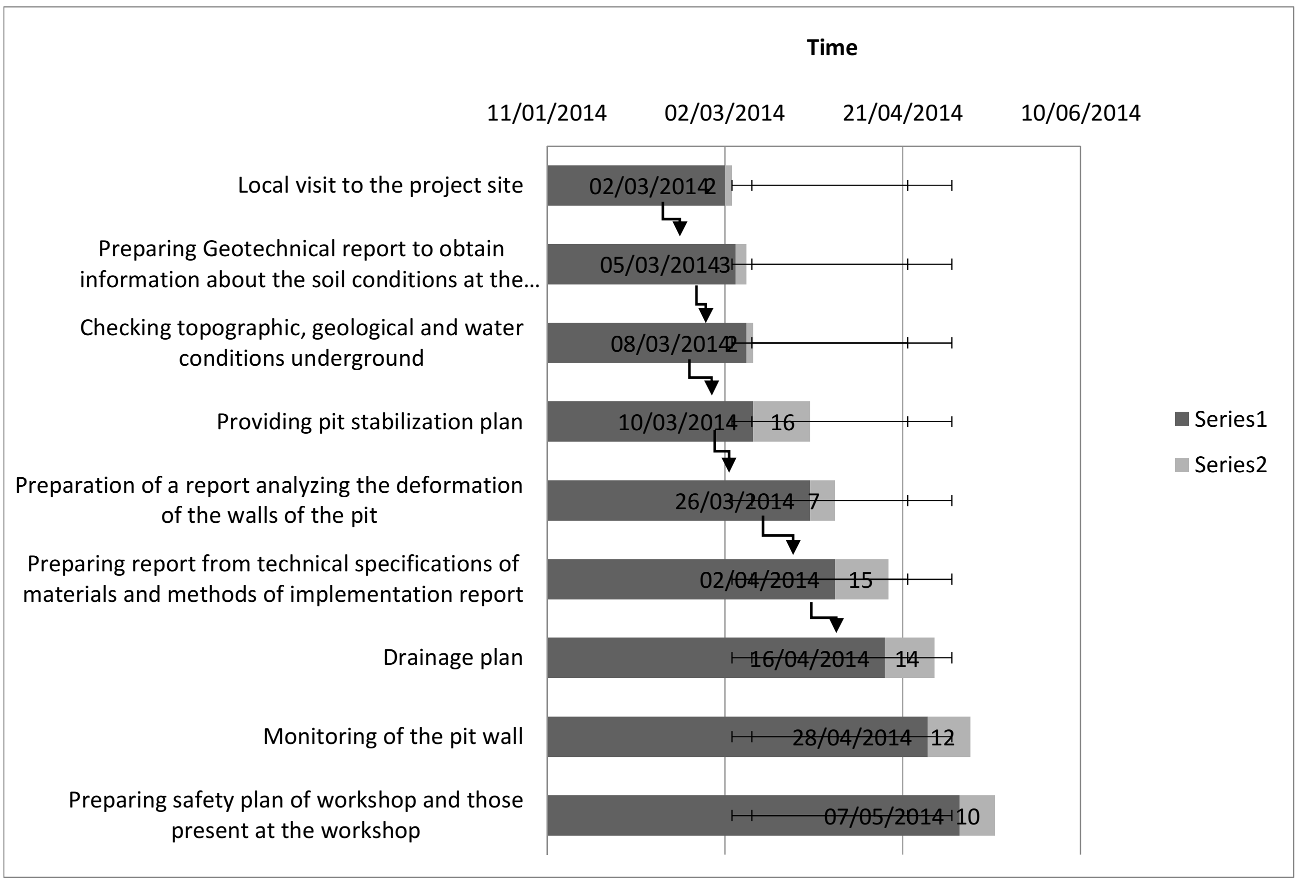

Figure 1. Gantt chart for the stage before excavation

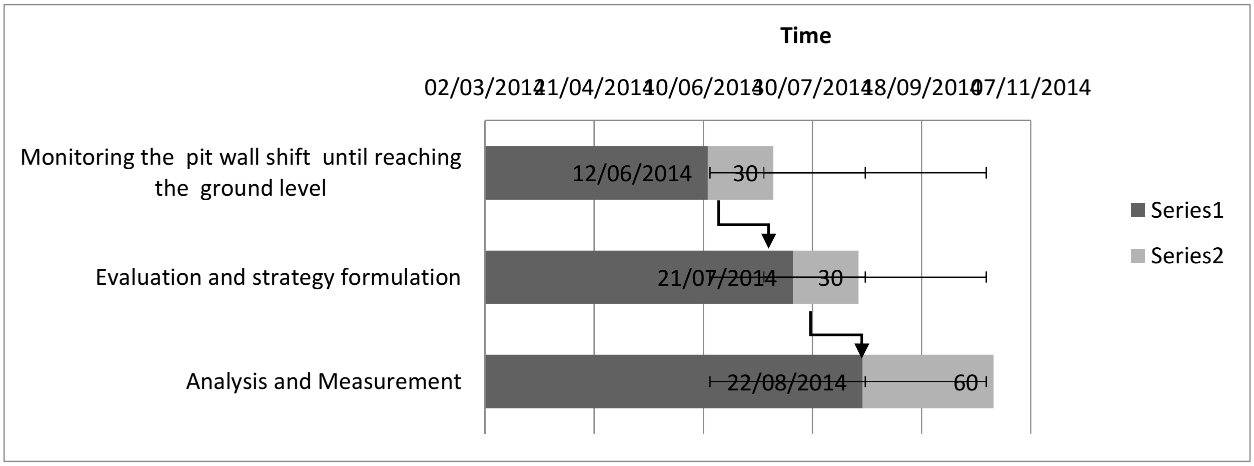

Figure 2. Gantt chart for the stage during excavation

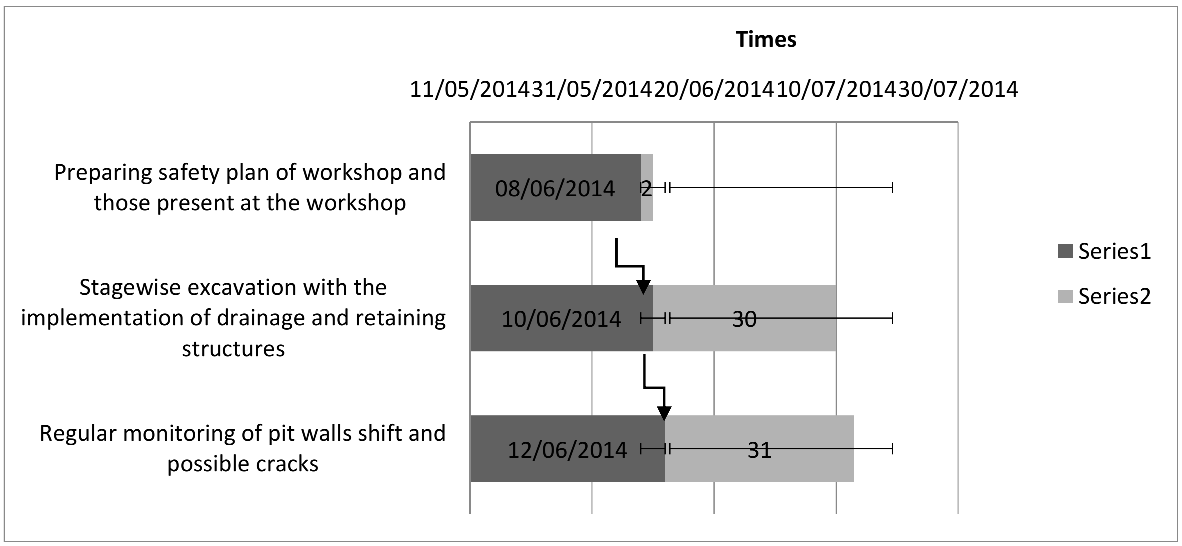

Figure 3. Gantt chart for the stage after excavation

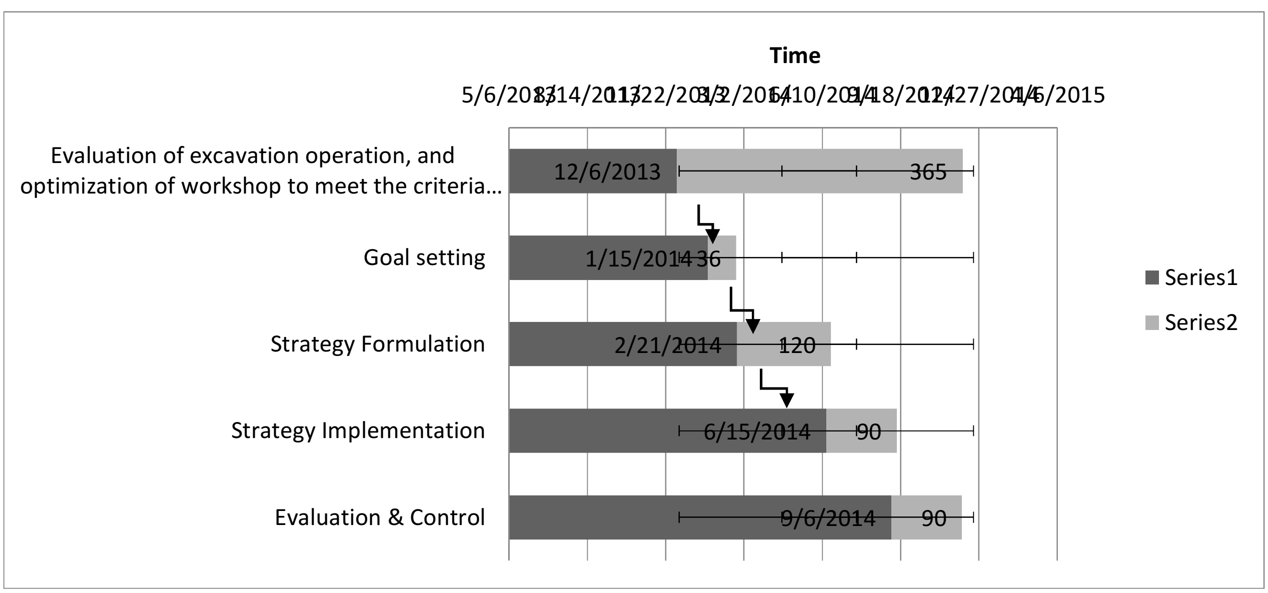

Figure 4. Gantt chart for the overall project

3. RESULTS AND DISCUSSION

In this section, first we review information obtained from study sample, and then analyze the defined hypotheses using SPSS statistical software.

3.1. Descriptive statistics

In this section, we present descriptive statistics of obtained data from the respondents about effective factors in pit stabilization. Tables 1-6 show the results.

Table 1. Frequency distribution related to the effect of the walls of building site and coupling to adjacent buildings

Factor		N	%
Walls of building site and coupling to adjacent buildings	Very low	0	0
	Low	0	0
	Average	0	0
	High	4	40
	Very high	6	60
	Total	**10**	**100**

Table 2. Frequency distribution related to the effect of proper use of scaffolding and netting before demolition

Factor		N	%
Proper use of scaffolding and netting before demolition	Very low	0	0
	Low	0	0
	Average	3	30
	High	3	30
	Very high	4	40
	Total	**10**	**100**

Table 3. Frequency distribution related to the effect of drainage wells place, and blocking it before demolition

Factor		N	%
Drainage wells place, and blocking it before demolition	Very low	0	0
	Low	0	0
	Average	0	0
	High	5	50
	Very high	5	50
	Total	**10**	**100**

Table 4. Frequency distribution related to the effect of the right selection of devices used in excavation operations

Factor		N	%
Right selection of devices used in excavation operations	Very low	0	0
	Low	0	0
	Average	4	40
	High	4	40
	Very high	2	20
	Total	10	100

Table 5. Frequency distribution related to the effect of identifying electrical and split installations before excavation

Factor		N	%
Identifying electrical and split installations before excavation	Very low	0	0
	Low	0	0
	Average	0	0
	High	4	%40
	Very high	6	%60
	Total	10	%100

Table 6. Frequency distribution related to the effect of identifying type of soil and land

Factor		N	%
Identifying type of soil and land	Very low	0	0
	Low	0	0
	Average	0	0
	High	3	%30
	Very high	7	%70
	Total	10	%100

3.2. Inferential statistics—Testing hypotheses

In order to examine research hypotheses, one-sample t-test was used. It is clear if mean value be more than 3, and t statistic and P-value less than 0.05, hypothesis is confirmed.

Hypothesis 1: Relationship between walls of building site & coupling to adjacent buildings, and pit stabilization

Table 7. Descriptive statistics of the factor Walls of building site & coupling to adjacent buildings

	Mean	SD
Walls of building site and coupling to adjacent buildings	4.60	0.516

According to table 7, the mean value and standard deviation of the positive role of building site walls and coupling to adjacent buildings in pit stabilization are 4.60, and 0.516, respectively.

Table 8. One-sample t- test result of H1

Test value=3				
Variable	**t**	**df**	**P-Value**	**Mean difference**
Building site walls and & coupling to adjacent buildings	9.798	9	0.000	1.60

Based on table 8, according to t statistic value (9.798) and the error level of less than 0.05 (P-value<0.05), we can say that the relationship between the above variables are significant at a confidence level of 99 %.

Hypothesis 2: Relationship between proper use of scaffolding and netting before demolition and pit stabilization

Table 9. Descriptive statistics of the factor proper use of scaffolding and netting before demolition

	Mean	SD
Proper use of scaffolding and netting before demolition	4.10	0.875

According to table 9, the mean value and standard deviation of the positive role of proper use of scaffolding and netting before demolition in pit stabilization are 4.10, and 0.875, respectively.

Table 10. One-simple t- test result of H2

Test value=3				
Variable	**t**	**df**	**P-Value**	**Mean difference**
Proper use of scaffolding and netting before demolition	3.973	9	0.003	1.10

As can be seen in table 10, since t static=3.973, and P-Value<0.05, it can be said that the relationship between the above variables is significant at a confidence level of 99 %. Therefore, Proper use of scaffolding and netting before demolition have positive role in stabilizing pits.

Hypothesis 3: Relationship between Place of drainage wells, and blocking it before demolition, and pit stabilization

Table 11. Descriptive statistics of the factor place of drainage wells, and blocking it before demolition

	Mean	SD
Place of drainage wells, and blocking it before demolition	4.50	0.527

According to table 11, the mean value and standard deviation of the positive role of place of drainage wells, and blocking it before demolition in pit stabilization are 4.50, and 0.527, respectively.

Table 12. One-simple t- test result of H3

Test value=3				
Variable	**t**	**df**	**P-Value**	**Mean difference**
Place of drainage wells, and blocking it before demolition	9.000	9	0.000	1.50

As can be seen in table 12, since t static=9.000, and P-Value<0.05, it can be said that the relationship between the above variables is significant at a confidence level of 99 %. Therefore, Place of drainage wells, and blocking it before demolition have positive role in stabilizing pits.

Hypothesis 4. Relationship between choosing the right devices used in excavation operation, and pit stabilization

Table 13. Descriptive statistics of the factor choosing the right devices used in excavation operation

	Mean	SD
choosing the right devices used in excavation operation	3.80	0.788

According to table 13, the mean value and standard deviation of the positive role of choosing the right devices used in excavation operation in pit stabilization are 3.80, and 0.788, respectively.

Table 14. One-sample t- test result of H4

Test value=3				
Variable	**t**	**df**	**P-Value**	**Mean difference**
Choosing the right devices used in excavation operation	3.207	9	0.011	0.800

As can be seen in table 14, since t static=3.207, and P-Value<0.05, it can be said that the relationship between the above variables is significant at a confidence level of 99 %. Therefore, choosing the right devices used in excavation operation have positive role in stabilizing pits.

Hypothesis 5. Relationship between Identifying electrical and split installation before excavation, and pit stabilization

Table 15. Descriptive statistics of the factor identifying electrical and split installation before excavation

	Mean	SD
Identifying electrical and split installation before excavation	4.60	0.516

According to table 15, the mean value and standard deviation of the positive role of Identifying electrical and split installation before excavation in pit stabilization are 4.60, and 0.516, respectively.

Table 16. One-sample t- test result of H5

Test value=3				
Variable	**t**	**df**	**P-Value**	**Mean difference**
Identifying electrical and split installation before excavation	9.798	9	0.000	1.60

As can be seen in table 16, since t static=9.798, and P-Value<0.05, it can be said that the relationship between the above variables is significant at a confidence level of 99 %. Therefore, Identifying electrical and split installation before excavation have positive role in stabilizing pits.

Hypothesis 6. Relationship between identifying type of soil and land for excavation, and pit stabilization

Table 17. Descriptive statistics of the factor identifying type of soil and land for excavation

	Mean	SD
Identifying type of soil and land for excavation	4.70	0.483

According to table 17, the mean value and standard deviation of the positive role of identifying type of soil and land for excavation in pit stabilization are 4.70, and 0.483, respectively.

Table 18. One-sample t- test result of H6

Test value=3				
Variable	**t**	**df**	**P-Value**	**Mean difference**
Identifying type of soil and land for excavation	11.129	9	0.000	1.70

As can be seen in table 18, since t static=11.129, and P-Value<0.05, it can be said that the relationship between the above variables is significant at a confidence level of 99 %. Therefore, identifying type of soil and land for excavation have positive role in stabilizing pits.

4. Conclusion

During recent years, we are often witnessing failure to comply with primary principles of excavation as well as the safety principles of the work can lead to devastating consequences, causing financial losses and claiming many lives. Thus, matter of excavation should be taken into due consideration during design, implementation and operation. Hence without adequate support, almost certainly new excavation would cause bearing capacity to fall and settle and lateral movement of available buildings. In demolition, excavation, and implementation of retaining structures, one of the most important points is to maintain the safety of construction site. In national building regulation, safety guidelines are not explicitly stated in order to perform demolition, excavation and implement retaining structure, so there is a need to prepare and develop regulations appropriate for the purpose. In the present study, we presented safety evaluation of excavation operation and investigated its relationship with pit stabilization. The research was conducted on Haghani Pit in Tehran, district 2. The study process was undergone in four stages: before excavation, during excavation, after excavation, and overall project scheduling which lasted for one year. Contributing factors in excavation safety in the study include: the wall of building site and coupling to adjacent buildings, the proper use of scaffolding and netting before demolition, place of drainage wells, and blocking it before demolition, choosing the right devices used in excavation operation, detecting electrical and split installations before excavation, and identifying type of soil and land for excavation. The results of analyzing research hypotheses indicated the significance relationship between these factors and pit stabilization. The main goal of a safe building excavation is to protect lives and property of individuals inside and outside an excavation and avoid any accidence. Therefore, this cannot be achieved unless all building excavation project administrators become aware of their duties and responsibilities in this respect and fulfil them.

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