Proceedings of 12th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2022 Month: October Volume: 12

Identifying and Evaluating the Criteria in Planning the Excavation Support System in Basement Construction using Analytical Hierarchy Process

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Abstract
With increase in urbanization and parking issues in the Pokhara Metropolitan City, the basement construction practice has been popular among builders and house owner in this city. Basement building involves the deep excavation during construction of foundation. Proper planning are required during the selection of support system which helps in successful completion of project within the budget and time. The objective of this paper is to identify the criteria in planning the excavation support system in basement construction in Pokhara Metropolitan City. Direct field investigation with questionnaire for key informants of the under construction basement building permitted by Pokhara Metropolitan City was done to know existing scenario of temporary protection measure and identify the criteria in the selection of excavation support system. Through field survey and expert consultation, five main criteria and twelve sub criteria along with seven protection measures during excavation were identified. The pairwise comparison of the criteria was carried. The total of 16 experts from academic, consultant, contractor and government officer were formed to administer comparison between the criteria. The result of this research is weightage for each criteria and sub criteria using AHP analysis through super decision software. Safety criterion is regarded as the main criteria in this issues followed by soil condition, constructability, environment impacts and cost. The protection of adjacent buildings is most important factor to be considered before excavation work. Based on the rank scale questionnaire, providing setback from all side of the building is the best performing option for excavation support followed by shoring, slope cutting and diaphragm wall during basement construction in the context Pokhara Metropolitan City.

Keywords
Basement construction,Excavation support system, Analytical Hierarchy Process, Rank Scale Questionnaire

1. Introduction

Infrastructures are key for the economic development of the country[1]. Basically, infrastructures are categories as economic infrastructure and social infrastructure.Building construction can be taken as part of work for infrastructure development.With increasing urbanization and parking problem in Pokhara Metropolitan City, building with basement facilities has become boon for infrastructure management as it provides additional space as well as parking facilities[2]. Basement construction has been mandatory in the main road of core city of Pokhara Metropolitan City for the proper management of traffic system as per Sixth Municipal Committee Decision. Construction of basement involves deep excavation which can bring hazards to neighborhood properties and life during foundation excavation[3].

Though NBC 114: 1994 has mentioned the construction safety regarding construction of foundation but it could not address how can we achieved that safety. It is unable to describe basement construction's protection measure and temporary protection work[4].Extensive digging for basement construction of Hilton Hotel in Naxal, Kathmandu owned by Shanker group has damaged the road along the sustained cracks in nearby buildings in January-9, 2017. The road department has taken Rs.6.3 million in security deposit from Shanker group [5]. The office of Pokhara Metropolitan City cannot guide the construction of basement due to lack of standard guidelines and code of practice. There is dilemma on contractors and engineers to plan for the appropriate

excavation protection measure in basement construction in Pokhara Metropolitan City. Economical and safe excavation protection measures for basement construction has been the major challenges for the engineers ,contractors and builders.

The decision to plan for excavation work with appropriate support system in basement construction is complex and involves various criteria. These criteria can be determined after understanding existing scenario of basement construction and opinions of client, contractor and consultant.This research opted to use Analytical Hierarchy Process to determine the weightage for identified criteria and specify the most important criteria in planning the excavation support system in basement construction in Pokhara Metropolitan City. Different excavation support system were suggested and ranked on the basis of rank scale interview questionnaire with experts.

Therefore, this paper deals with decision-making process to help the decision maker to plan for support system for deep excavation during basement construction in Pokhara Metropolitan City. This research identified five main criteria and twelve sub-criteria along with seven alternatives.These decision criteria are used to make a decision for planning the most appropriates measures that can be adopted during basement foundation construction. Those five main criteria are soil condition, safety, cost, environment impacts and constructability.

2. Research Objective

The objective of the study is to identify and evaluate the criteria in planning the excavation support system in basement construction in Pokhara Metropolitan City using Analytical Hierarchy Process.

3. Methodology

A descriptive research study was carried out, which used both quantitative and qualitative methods to identify the criteria and evaluate those criteria in decision making. A direct field investigation of twenty under construction basement buildings permitted by Pokhara Metropolitan City was done. A questionnaire survey of the key informants of the underconstruction sites was done to understand the existing practice of temporary protection measures during excavation in the basement construction. The criteria and protection measures that were involved during the planning of excavation were identified through the questionnaire survey. Through the expert consultation process and literature reviews, main criteria and sub-criteria which affect the main criteria were determined. The AHP questionnaire was distributed to 16 experts from different sectors for the comparison of the identified criteria. The judgement of experts was based on their knowledge and experience in the field of study. The expert groups are comprised of academics, consultants, contractors, and government officers. Protection measures during excavation work in the basement were identified. Seven alternatives that can be implemented on the site were determined. Finally, the hierarchy of the goal, criteria, and alternatives was developed. Through expert consultation, a rank-scale questionnaire survey was preformed to determine the best performing option for the planning of safe and efficient basement excavation work. Thus, methodology and approaches carried out for execution of this work consists primary data collection through questionnaire survey and expert consultation.The published article, reports and the literature were used to collect secondary data. After that analysis were done using excel sheet and Super-Decision software and determined the weighatge of identified criteria.

4. Literature Reviews

4.1 Basement

Basement are the storey of building that are constructed either completely below the ground level or extending up to 1.2 meter above the average ground level as per NBC 206:2015.Basement provides the additional space without increasing the ground coverage.Basement construction has lots of difficulties such as landslides of loose soil, damages to adjacent structure like building, roads etc[3].Proper selection of excavation support in basement construction involves various criteria to be addressed. In basement construction, project owners were liable to pay the compensation for neighborhood property damages and also neighbors were not satisfied with protection measures applied by contractors in basement excavation [2].Association of Specialist Underpinning Contractors, London had conducted survey for understanding the basement construction to develop the guidelines for safe and efficient basement construction considering health and safety as most important criteria[6].

4.2 Deep Excavation Support System

An excavation in land typically more than 4.5 m deep is termed as deep excavation[7].These excavation works require careful planning and design when constructed in urban area. Deep excavation supporting systems are an engineering solutions developed to retain excavation sides during construction.During excavation, different factors need to be considered like nature of soil, size, scale, ground water table,angle of repose and surrounding structure depending upon the project and construction site condition[8].Proper planning for selection of deep excavation support system is considered as multi-criteria decision making problem. In such a decision-making problem, the decision makers need to determine decision criteria and calculate the relative importance of the selected criteria using different Multi-criteria Decision Making techniques[9]. Diaphragm wall, micro piles, steel sheet piling are gaining their popularity in the basement construction.

4.3 Analytical Hierarchy Process

The AHP method, which was developed by Thomas Saaty in 1970, allows decision makers to solve the complex problem by developing multilevel hierarchy structure[10]. It allows decision makers to perform pairwise comparisons among different criteria and evaluate the most importance criteria for decision making process. The international scientific community that deals with complex decision problems has also declared the AHP method a robust and flexible method[11]. Saaty's nine-level standardized comparison scale which is illustrated in table below was used to assign the judgements in the pairwise comparisons[10].

Table 1: Saaty's nine-point scale for pairwise comparison

Rating	Verbal Judgments of Preferences between Alternatives i and Alternatives j
1	i is equally important to j
2	i is slightly more important than j
3	i is strongly more important than j
5	i is very strongly more important than j
9	i is extremely more important than j
2,4,6,8	Intermediate values

A-Rahbi et al. used AHP method to overcome soil erosion problem in Oman by proposing the best soil erosion protection methods considering three important criteria i.e. soil characteristic, climate and cost [12]. Usama Issa et al. applied Hybrid AHP-Fussy TOPSIS approaches to evaluate the deep excavation support system and found secant pile wall as appropriate support system in the investigated project over sheet pile wall and H-system [9]. The difference of perspective on socio-economic factor between planner and local people was identified and evaluated using AHP [13].Zuraidi et al. evaluated the criteria and attribute of defects in heritage building using AHP method to develop a strategic heritage building performance procedure in Malaysia[14].

5. Study Area

Pokhara Metropolitan city, consisting 33 wards, occupying area of 464.24 Km2 and has population of 5,18,452 lies on Kaski district in Gandaki province in western part of Nepal. There are 1,01,669 households in the city as per Nepal Census, 2021. It is one of largest metropolitan city in area and have huge potential of infrastructure development.Different area of Pokhara Metropolitan City like New road, Mustang Chowk, Nayabazar line etc. are restricted to give building permission without basement construction in order to manage the traffic parking problem. Therefore, large number of basement building are in construction. Basement construction projects undergoing in Pokhara Metropolitan City were taken as the study area. As the population size was small, the samples were chosen using non- probability sampling technique. Convenience and purposive sampling was used for questionnaire survey to undergoing basement construction project. The twenty buildings projects located on main road of core city area of Pokhara Metropolitan City and having the plinth area greater than 1500 square feet were taken as study area for pilot survey. The plinth area greater than 1500 sq. feet is subjected to expert technical team for structural and geotechnical study by the metropolitan city during building permit.

6. Finding and Discussion

6.1 Involvement of Technical experts during Construction

The results of questionnaire survey showed that all the project had hired the consultant for design purpose.

Only 60% of projects had hired the engineer for supervision work and 60% of project had contractor who had involved the engineers in the construction site. None of project had consulted with geotechnical engineer during the basement excavation work. None of the project had hired temporary work engineer during excavation work for excavation support system.

6.2 Importance of Deep Excavation Support System

Through the study of soil report of study area, it is found that there is great variation of soil type and its bearing capacity among the borehole log report of same project.The study showed that 85% of the project with basement facilities had excavation depth between 10 feet to 15 feet in the context Pokhara metropolitan City. The result of questionnaire survey showed that 55% of project had favored for support system in the basement construction while 35% of the project had discouraged for the excavation support system. The study showed that in 80% of project in charge suggested that it is good idea to invest in the deep excavation support system. The 10% of the project in charge were strongly agreed for the investment while 10% of the project in charge were undecided and remained neutral. The study showed that the contractor of the 55% projects were liable to bear the loss of damage caused to the adjacent structure during excavation while 20% of the projects, the owner were liable to bear the loss of damage caused to the adjacent structure. The 90% project did not insured the neighborhood properties. This showed that owner were unknown about risk of damages that can be occurred during excavation and were not willing to bear the extra cost for the insurance of adjacent property.The study showed that the 65% of the project did not provided any support system during excavation work while only 35% of the project had provided support system during excavation work for the safety of adjacent building.

6.3 Factor Affecting Selection of Deep Excavation Support System

Different factors that affect the performance of the different support system are type and mechanical behaviours of the soil, construction methods, excavation size, workmanship,installation process, type of support system and ground water table [15]. Respondents were interviewed to identify the important criteria in selecting an appropriated excavation support system. In 80% of projects, the project in charge suggested to address the soil characteristic, underground water table, depth of excavation, existing structure nearby and construction cost of support system. In 20% of projects, project managers recommended to address the environment impacts during installation of support system, effect on public properties and labour employed and time and efficiency of the support system.

6.4 Hierarchy Structure in Planning the Excavation Support System

After direct field investigation and questionnaire survey, the researcher team identified five distinct criteria, namely soil condition, safety, cost, environmental impacts, and constructability, as well as 12 sub-criteria that influence the main criteria.The hierarchy is arranged in three levels. The top level consists of goal which is to suggest the excavation support system in the Pokhara Metropolitan City. The middle level is comprised of the five main criteria that involved in the planning of excavation support system. The bottom level consists of seven different techniques and methods involved in protection of excavation side during the basement construction in the context of Pokhara Metropolitan City. The multi-level hierarchy structure for planning the basement excavation in Pokhara Metropolitan City is illustrated below.Through the AHP questionnaire, the pairwise comparison of the all criteria was done by the expert panel. All together 16 respondents had responded to the questionnaire. Out of 16, one questionnaire failed the consistency test and was removed from the study, while 15 questionnaire were valid and useful as most of the judgement that were given by the experts have consistency ratio less than 10%.

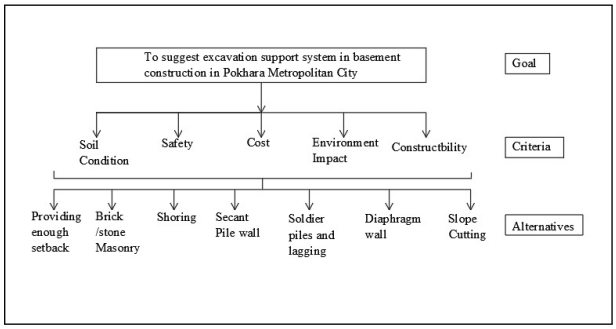

Figure 1: Hierarchy structure

General description of identified criteria is explained below.

6.4.1 Soil condition

The soil condition had included three important sub-criteria that need to be consider during planning i.e soil type and its properties, excavation depth and underground water table . Soil type and its properties represents the nature of soil like hard, soft, loose, sandy, clayey, silty etc. It comprises the different soil parameters like shear strength, cohesion, permeability, bearing capacity etc.Excavation depth refers to the excavation depth for basement foundation from ground level. Underground water table represents natural water table encounter during excavation.

6.4.2 Safety

The safety criterion answered how much safer the implementation of one alternatives with others in terms of adjacent building, worker and public properties. The successful completion of project is possible after safeguarding the adjacent building,public properties and workers.

6.4.3 Cost

The cost criterion was comprised of the construction cost of the support system and insurance claim cost. Insurance claim cost includes the cost that incurred for the insurance of the properties adjacent to the excavation.

6.4.4 Environment Impacts

The criteria is concerned with the effect on environment due to implementation of one alternatives with others. It is related with noise and dust produced during the installation of support system.

6.4.5 Constructability

This criteria is comprised of efficiency and time. Efficiency represents the performance of temporary protection works to retain the soil and time represents the duration taken by contractor for installation of support system.

6.5 Weightage of the Identified Criteria

On the basis of AHP questionnaire and expert consultation, the pairwise comparison of five main criteria and 12 sub-criteria were done and matrix had been generated by the geometric mean of multiple respondents. The weightage of the each criteria were determined using Super Decision softwares V 3.2 which is illustrated below.

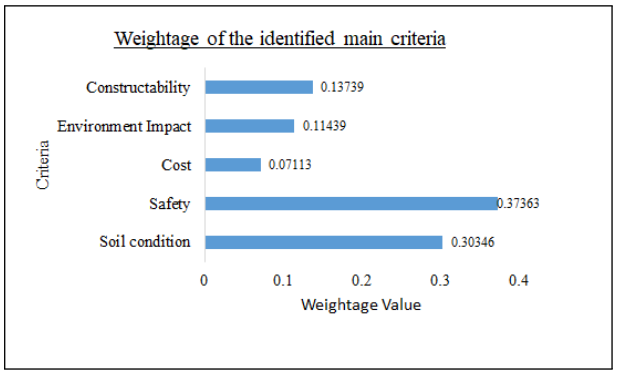

Figure 2: Weightage of main criteria

Safety (0.37363) is most important criteria to be addressed followed by soil condition (0.30346), constructability (0.13739), environment impact (0.11439) and cost (0.07113).The rules and regulations for basement construction are to be formulated considering the safety as the important factor.

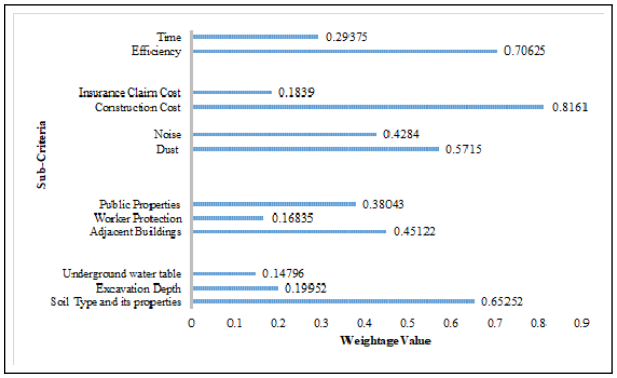

Figure 3: Weightage of sub-criteria

In the soil condition criteria, soil type and its properties had highest priority as compared with underground water table and excavation depth.The soil exploration of the construction site need to done prior to excavation work. The optimization of support system can be achieved through the proper study of soil. Similarly, adjacent building had governing role in planning support system.Public properties also needed to safeguarded from possible risks. The construction cost of the support system had more priority than insurance claim cost. Dust had significant influence in environmental aspects than the

noise. Efficiency of the support system had more priority than the construction time of support system.

6.6 Alternatives for excavation Protection Measures in Basement Construction

On the basis of field observation of various basement construction site within the Pokhara Metropolitan city and literature reviews, seven different alternatives were determined. The alternatives were ranked from 1 to 7 on the basis of their priorities. For the ranking of the alternatives, interview with experts and questionnaire was prepared and distributed with academician, contractors, consultant and government officer.The ranking of alternatives were done the basis of the respondent's experience and knowledge. The alternatives were ranked as per the existing practice of basement construction in Pokhara Metropolitan city. Generally, it is found that depth of excavation for basement construction is about 10 to 15 feet in Pokhara Metropolitan City. The result of analysis of ranking scale questionnaire is illustrated below.

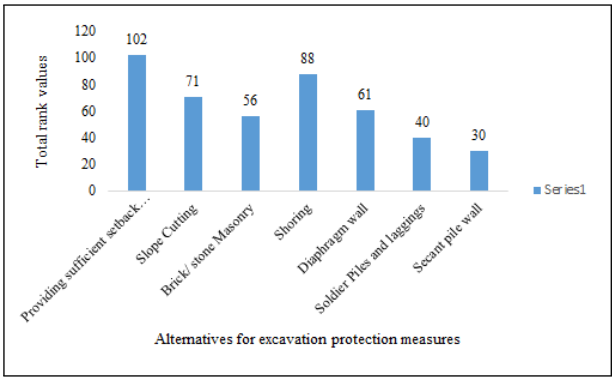

Figure 4: Weightage of sub-criteria

The result showed that providing setback from all side of the building has highest preference from the expert panel in planning for excavation work in basement construction followed by shoring, slope cutting, diaphragm wall, masonry support, soldier piles and lagging and secant pile wall.

7. Conclusion and Recommendation

Proper planning on deciding the excavation support system before excavation work during basement construction has great impact on the quality,cost, and duration of the construction project. Therefore, this study assessed different criteria and sub-criteria identified in planning the excavation support system in the hierarchical structure. Based on AHP analysis, safety criterion is regarded as the main factor in this issues followed by soil condition, constructability, environment impacts and cost.The protection of adjacent buildings was most important factor to be considered before excavation work. As the AHP method involved experts for the decision making process, it is a good guiding framework for planning. Different alternatives that can be adopted in basement construction for excavation support within the Pokhara Metropolitan City were evaluated.Based on the rank scale questionnaire, providing setback from all side of the building is the best performing option followed by shoring, slope cutting and diaphragm wall in the context Pokhara Metropolitan City.

Overall,the proposed study is to support for development of strategic planning for improvement of basement construction practice in the Pokhara Metropolitan City. It is found that owners and contractors were overlooked the government rules and regulations during basement construction.Government monitoring in the basement construction site was not found effective.In 90% of projects, the insurance to adjacent building was not done and in 65% of projects, support system was not provided. None of the project had hired temporary work engineer during excavation work for excavation support system.Temporary work engineer have great future scope for design and implementation of support system for safe and efficient basement construction in Pokhara Metropolitan City.

Acknowledgments

The authors are thankful to all the experts for their valuable cooperation and suggestion. The authors are grateful to all the building owner, neighbours, consultant and contractor who were interviewed during the study.

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