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Study of the Groundwater Flow During Excavation Work at Construction Site

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Abstract: The construction industry often experiences a variety of problems, especially regarding groundwater flow during excavation work at construction sites. Construction structures built on sites with rising groundwater surface have many challenges in the field of geo-technics. The increase in water surface in Malaysia is due to the infiltration of heavy rainfall and precipitation into the soil. The high-water tables induce negative effects on the construction buildings. This study focuses on adding more knowledge about extreme groundwater levels to avoid structural damage or building environment due to very high groundwater flow. Typically, the spread of extreme groundwater levels is due to interpolation between results obtained from the analysis of local extreme values in groundwater observation wells. Among other factors that affect groundwater during excavation work, is because the flow of water is not controlled according to appropriate methods. In addition, during construction activities, uncontrolled groundwater flow can cause damage to building infrastructure, even the maintenance cost for this problem is very high. Therefore, the purpose of this research is to improve the management techniques that form and solve the problem of rising groundwater flow at the construction site during excavation works. The objective of this research was to study the current practices, to identify the challenges, and to determine the improvement ways to controlling groundwater flow during excavation work at construction sites. This research uses a qualitative method through semi -structured interview questions for the data collection process. The respondents of this research are among the contractors registered with the Construction Industry Development Board (CIDB) Grade G7 in Johor and Selangor because these two states have the same type of soil, namely clay soil. Furthermore, the respondents are very important for this qualitative approach to ensure that all data obtained from the respondent is accurate and to answer the question on the basis of the respondent's work experience. Based on the respondents' experience, this study is

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very helpful for researchers to get more information about groundwater flow that often occurs at construction sites.

Keywords: Construction Site, Controlling, Groundwater Flow, Excavation

1. Introduction

Groundwater is the natural water that immerse in the soil and lies in position of tiny voids within the soil particles. Generally, groundwater come from the rain and melting of ice and snow. Malaysia is one of the countries with richest water resource and has highest rainfall (Department of Statistics Malaysia, DOSM). Even though the annual rainfall is high, the rainfall distribution in Malaysia is unequal. Rainfall distribution of Malaysia are unequal throughout the year, resulting in annual rainfall is high hence Malaysia ranked above global average about 2,600 millimeters (Azizan *et al.,* 2018). A large amount of groundwater comes from precipitation. In addition, groundwater handling encompasses a variety of techniques used to enable construction projects such as tunnels or underground excavations to be carried out in dry and stable conditions (Marios, 2002). According to the Malaysian Construction Industry Development Board (CIDB) Act 2004, the construction industry is one of the industries that contributes a lot development and economic growth of the country including Malaysia. The success of a country viewed from the aspect of infrastructure construction and other physical facilities. Construction development has contributed around 8% to 10% on the promote growth of difference countries.

In year 2020, the construction industry has many issues especially about groundwater flow during excavation work. Brassington *et al.* (2003) stated civil engineering construction works often have a significant impact on groundwater conditions. In addition, the groundwater provides almost half of all drinking water worldwide, about 40% of water for irrigated agriculture and about 1/3 of water supply required for industry. Almost every construction site has groundwater related problems and groundwater is a major cause of delays during the construction phase. Therefore, the research will focus on groundwater flow during excavation work on construction site. Most of the construction industry that occurred in Malaysia from last decade has influenced the quality of groundwater as mentioned by Asharuddin (2015). In construction site, there are several issues about groundwater flow during excavations work for basement construction usually considered an inconvenience. During excavation work, if groundwater control not properly emphasized, the following problems such as increased flooding of the construction area due to water seepage, inflow from the surrounding soil, and water-bearing rocks encountered.

Common groundwater issues during construction are unstable subgrade, unstable excavation and water seepage and construction delays and cost overrun. Groundwater policy has many challenges while managing it and the challenges that are often faced are due to climate change. Climate change can cause problems at construction sites, especially during excavation work, climate change can also increase the water level in the land surface, and groundwater problems will cause a building to collapse if not handled properly. Therefore, based on the above of problems, this research has been identified such as to study the current practices, challenges, and improvement ways to control groundwater during excavation work at construction site.

2. Literature Review

This section will explain more about groundwater as it will be the source of research in this chapter. The explanation will cover the current practices of groundwater, challenges to control the groundwater and improvement ways to control groundwater flow during excavation work at construction site. The purpose of the research is to gather a specific topic from various information sources that relate to the

research. This research is also assisted from previous sources so that the research can be conducted more easily to achieve the objectives of the research

2.1 Groundwater Flow at Construction Site

In construction site there are many problems because of groundwater flow during excavation work. The flow of groundwater below the surface is a fundamental property that controls the strength and compressibility of soil affecting soil's ability hold up on structural loads and groundwater affects the project by impacting the function and design of the facility, and the cost of its construction. Groundwater is a frequent cause of disputes between owners and contractors in construction projects. Besides, Davis (2020) stated groundwater is parts of the natural water cycle refer Figure 1. Some part of the precipitation that lands on the ground surface infiltrates into the subsurface. The part that continues downward through the soil until it reaches rock material that is saturated is groundwater recharge. The ground above the water table (the pink area) may be wet to a certain degree, but it does not stay saturated. That means that water on the surface will try to seep into the ground below it. Next, according Northeast Regional Climate Centre (2018) underground, water does not move much, but rather acts like a sponge, taking up spaces in between cracks in rocks and breaks in the soil. Water that moves into a natural storage area (called an aquifer) refers Figure 2 beneath the surface of the earth are referred to as groundwater. Unconfined aquifers are areas made up of soil or rocks that water can easily move. Besides, groundwater levels change for many reasons. Some changes are due to natural phenomena, and others are caused by man's activities. All these factors can influence how water levels in the aquifers change over time. There are short-term changes that can only be seen when water-level measurements are made many times a day. There are long-term changes that can only be seen after data are collected for many years. There are minor changes of only a few hundredths of a foot, and changes that are hundreds of feet (Shivakoti *et al.,* 2016).

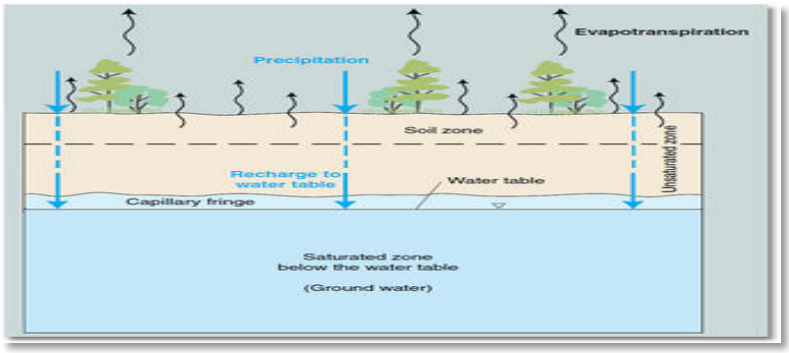

Figure 1: The natural water cycle (Davis, 2020)

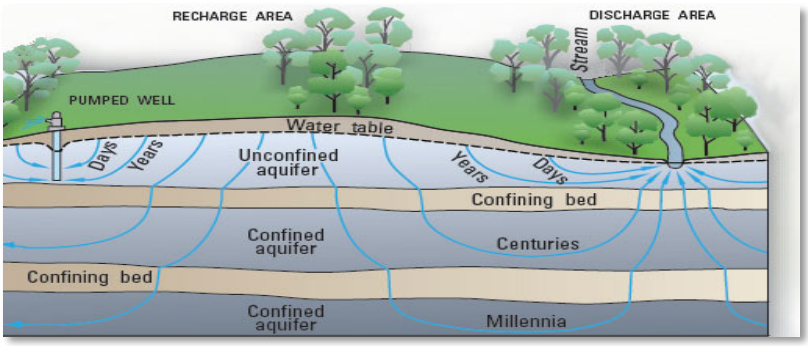

Figure 2: Water can take anywhere from days to millennia to resurface once it is below ground (Davis, 2020)

2.2 Groundwater Method

According Patricks (2019) the many methods that have been developed for the control of groundwater fall into four basic categories is:

(a) Open Pumping

Open pumping is the process in which as the excavation is advanced the water is allowed to flow in and is collected in ditches and sumps, then pumped away. The open pumping method is lowest in direct dewatering cost, and is viable under certain conditions (Patricks, 2019).

(b) Pre- Drainage

According Patricks (2019) pre-drainage is the process of lowering the water table prior to excavation, using one of several methods available.

(c) Deep Well

According Arjun (2020), deep well systems are groundwater methods used to remove the water from pervious sand or rocks formations beneath the excavations. This method can also be employed to remove the artesian pressure of the ground area under consideration. The method of deep well systems is more suitable in areas where deep excavations are performed. This is mainly employed for the ground preparation for the construction of tunnels, dams, powerhouses, shafts, and locks. The excavations and the shaft made can be 300 feet in depth.

(d) Well – Point System

According Arjun (2020) a series of well points connected to a header and used to drain an area or to control ground water seepage into an excavation. The well-point consists of a slotted or perforated pipe which is covered with a screen mesh. At the foot of this pipe is an orifice which permits jetting of the pipe into the ground during installation. A well-point system consists of a series of closely placed small diameter wells installed to shallow depths. These wells are connected to a pipe or header that surrounds the excavation and is attached to a vacuum pump. The well- point system has three type, first type is single stage system, second is multiple stage system and third is vacuum system.

2.3 Challenges of Groundwater Flow

2.3.1 Weather and Environment

According Australia Mining (2019) each site's groundwater flow requirements vary with environmental and geological considerations, as well as local climatic variations. Differences in weather conditions and environmental changes can have a significant effect on an operation. Mine sites need to assess the permeability and porosity of the ground, the amount of surface water and geological features such as seasonal rainfall before starting the process. The groundwater flow put in place must be able to cope with this to provide a safe solution and minimize production delays.

2.3.2 The Economic Challenges of Groundwater Flow

Atkinson *et al.* (2009) stated the challenges of mining economically have never been greater than under current global financial conditions. The costs and efficiency of groundwater flow are particularly important. During the planning and design the cost groundwater usually is captured as capital cost of the investment, nevertheless during the production the groundwater cost can be found as operating cost (Zeqiri *et al.,* 2007).

2.3.3 The Technology Challenges of Groundwater Flow

According Dahmas *et al.* (2019) groundwater is extracted for lengthy periods and in large quantities for drinking or industrial use, it can potentially lower groundwater levels and decrease yields. This depletion results in a reduction of valuable water resources for others. The challenge of the issues is contractors must use effective technology in groundwater flow. If the contractor does not use effective technology, the groundwater table in the basement area cannot control. So, this impact cannot be reduced. The most common problem of applying the groundwater flow is how to use the advanced technology. This method usually leads to inefficiency technology, which is caused by increased project complexity, increased project cost, an inability to control the project period, etc., during excavation work.

2.4 Improvement Ways of Groundwater Flow

2.4.1 Improvement of Equipment and Method

Specific selection of the groundwater flow technique or techniques at a particular site will depend on many factors. Besides, other methods of groundwater control that have been developed and used such as ground freezing, slurry trenches, cast in situ diaphragm walls, etc. have had some degree of success in the specific job conditions to which they are suited. The selection of the groundwater system should hinge on the experience and professional judgment of the engineer based on the soil materials, the source of water, and the demands of the project (Quinion *et al.,* 2014).

2.4.2 Improvement of the Technology Using in Groundwater Flow

According Gernant (2020) groundwater also known as construction groundwater, is the process of removing groundwater or surface water from a construction site. It is usually done before excavation for footings, which helps to lower the water table and provide a dry and stable working environment. Nevertheless, this is just one part of the construction planning equation for projects with high groundwater flow or poor soil conditions. Next, in areas with shallow groundwater flow, water levels can be expected between three and five feet from the surface. However, there may also be the potential for high-water levels or perched water conditions during seasonal fluctuations or abnormally heavy rains.

3. Research Methodology

The research methodology section describes all the necessary information that is required to obtain the results of the study. The research methodology consists of detailed information regarding workflow, strategy, and approach. The methodology adopted in carrying out the study should be well explained.

3.1 Research Design

This research will be using a qualitative method to collect data. The findings of the research can be analyzed analytically or descriptively based on data and the approach implemented in the research. According to Yin (2002) stated that the main purposes of the research design are to avoid a situation in which the evidence does not address the initial research questions. The research design will use an interview as a data collection method to achieve the research objectives. Qualitative research is a type of scientific research, which consists of associate investigation that seeks answers to an issue, consistently uses a predefined set of procedures to answer the question, collects evidence, produces findings that were not determined before and produces findings that are applicable beyond the immediate boundaries of the study (Nkwi *et al.,* 2001). In this research, the interview will act as an information collection and the result obtained from the interviewee, together with the literature review will be analyzed to achieve the objectives of this research (refer Table 1).

Table 1: Research objective and method

No.	Research Objective	Method
1	• To study the current practices of groundwater flow during excavation work at construction site.	• Literature Review • Qualitative (Interviews)
2	• To identify the challenges at control groundwater flow during excavation work on construction site	
3	• To determine the improvement ways to control groundwater flow during excavation work at construction site	

3.2 Research Process

This research was consisting of 5 phases, which describes the whole procedure and activities from the start of the research until the end of the research. The methodology to obtain information in this research is shown in Figure 3.

Phase 1 include the study and discusses the title from the problem statement. This phase includes the research background, problem statement, research questions, research objectives, the scope of research, the significant of research and research methodology.

In phase 2, the research explains about the process of literature review with the research title which is the study of the groundwater flow during excavation work on construction site. The literature review which includes the investigates of the tutorial articles, books and different resources associated with specific analysis areas. The research objectives can achieve by obtained information from literature review through a various resource such as reference books, journals, thesis, and internet articles.

Phase 3 is explained about data collection. There have two categories in data collection which are primary data and secondary data will be used in this research. The primary data will be collected through the contractor G7 conducting to control the groundwater flow on construction site. However, the secondary data will collect the data via books, journals, internet articles and newspaper articles. The data collected will lead us further understanding about the current practices of groundwater flow, the challenges to control groundwater and the improvements ways to control groundwater during excavation work.

Phase 4 was to express and analysis the data that collected through the qualitative method. It explains the data analysis technique and the results in the previous data collected from the interviewee. The collected data will be analysis to get the results. After collected the data, the thematic analysis method will be used to analysis the data collected from the qualitative research.

The final phase of this research is phase 5 which is conclusion and recommendation. In this phase, the results from the data analysis will be summaries and concluded. The recommendation and suggestions for further studies will be also included.

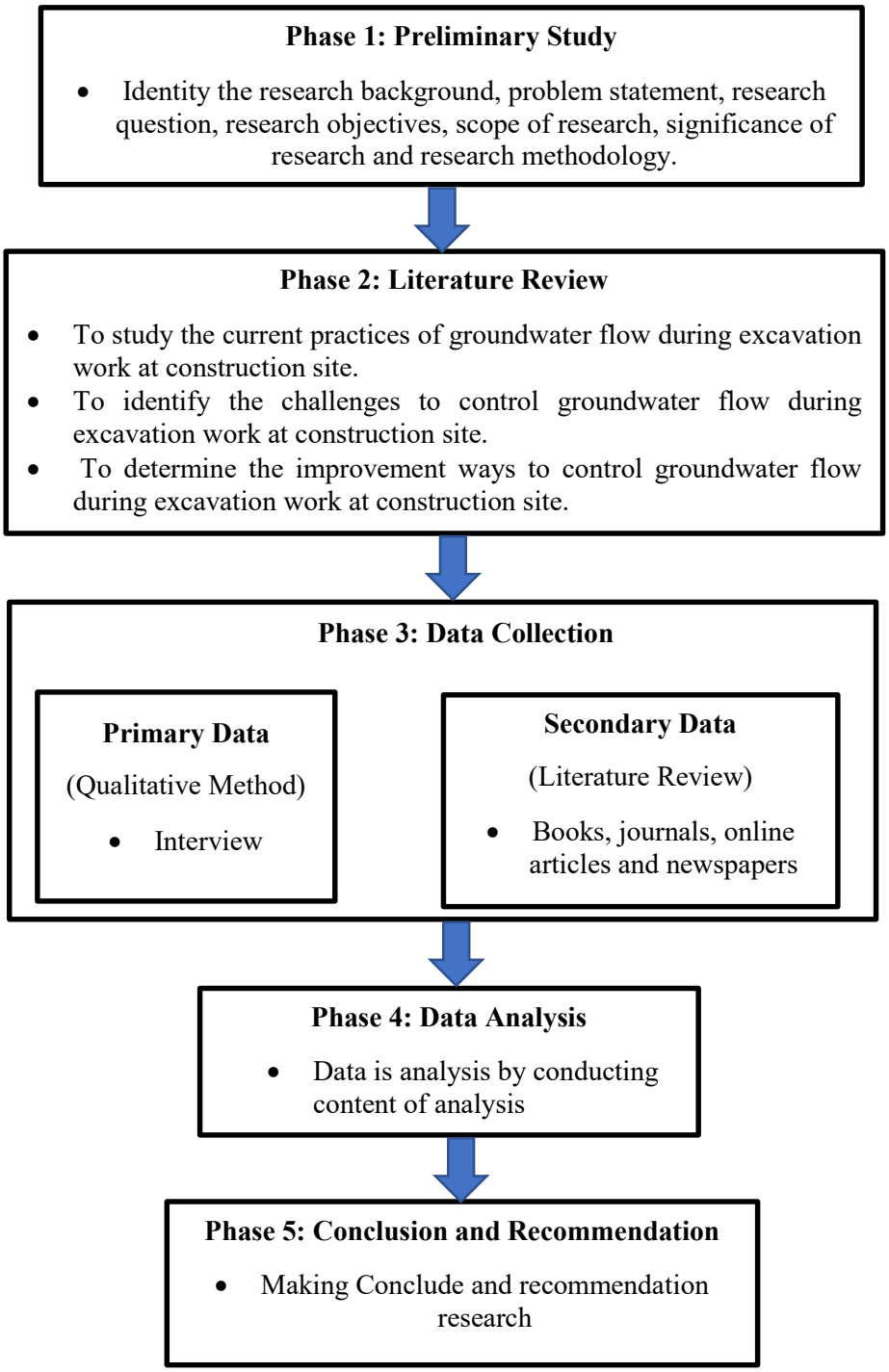

Figure 3: Research methodology flow chart

3.3 Data Collection

3.3.1 Primary Data

It is known as primary data that has been collected from first-hand experience. Primary data have not yet been published, and are more reliable, authentic and objective (Ajayi, 2017). Humans have not changed or altered primary data so their validity is greater than secondary data. Primary data were

collected through field studies to obtain direct feedback from respondents using questionnaire distribution methods, face-to-face interviews, observations and other methods (Curtis, 2008). The primary data collection in this study covers the research questions of the problem groundwater flow, the challenges and the improvement ways to control the groundwater flow during excavation work. The data collected will be reviewed and then analyzed as a result of the study.

3.3.2 Secondary Data

Secondary data is a type of data collected from a source that has already been published in any form is called secondary data. The review of literature in any research is based on secondary data (Kabir, 2016). Secondary data can be useful in identify problems, helps in preparation for effective research design and answer certain questions. The secondary data is collected by gathered the existing sources via books, journals, internet articles and newspaper articles and is presented in the form of a literature review in this research. It provides the initial framework for the research by analyzing the earlier works in the research topic.

3.4 Population and Sampling

For a research study, the population is important because it will help to define the concerns and issues to be examined and how much data and information must be collected. In order to achieve the outcome efficiently, the population must also be well established. As for this research, the selected population is contractor G7 that are registered and certified by CIDB. Sampling is a process of selecting a unit, group of people or organization from the research population so, the respondents of this research which is representative of one population are known as a sample of the research. As for this research, the representatives are Contractor G7 who work in Selangor and Johor. Researchers choose these 2 states because these two states have the same type of soil which is clay soil. This qualitative study was chosen because the researchers realized that groundwater flow problems often occur at construction sites. Therefore, the results of the analysis data obtained will be more detailed due to the collection of data from the respondents.

3.5 Pilot Study

The pilot study was significantly assisted the researcher to learn the skills when conducting the interview and the flow of conversation (Majid *et al.,* 2017). The interview will begin the social conversation for the specific respondent who feels not difficulties in answering the interview questions. It will be deeply discussed about the general issues about the groundwater flow during excavation work on construction site and the aim to collect the data for the research.

From the research, the researchers obtain five respondents from two different state which is two from Johor and three from Selangor that want to cooperate to gain the data collection. The aim of target respondent is project manager, site engineering and site supervisor. Before researchers distribute the interview questions to the respondents. The question was reviewed by several lecturers from the Faculty of Technology Management and Business (Department of Construction) in UTHM. The question was agreed upon by the lecturer and the researcher distributed the question to the respondents.

3.6 Data Analysis

The main strategy in this research will be using the survey method. The survey method can be carrying out in three different methods which is the questionnaire, interview and observation. The survey method is simpler to use rather than other methods. The interview method will be chosen among the three methods as stated above for collect the data in this research.

All the primary data collected through the specific respondent will be collected and doing analysis on the data. The data will be collected from the specific respondent in Selangor and Johor. The

feedback of the specific respondent will be recorded for further analysis. The thematic analysis will be use as a data analysis method to analysis the data collected in this research.

4. Results and Discussion

This research will explain the analysis of the data made on the basis of the research method used to achieve the research objectives. The objective of the research is to study current practices, identify the challenges, and determine the groundwater flow during excavation work on construction site. The method used to collect the data is the qualitative method used to conduct the interview session with the selected respondent. Any interview question answered by the respondent presented as data collection and analyzed using the content analysis method using Microsoft Word. Respondent for this research is the contractor G7 in Johor and Selangor and the contractor that has experience to control the groundwater flow.

4.1 Respondent Background

Respondents are important for this qualitative approach to ensure that all data obtained from the respondent is accurate and to answer the question on the basis of the respondent's work experience. The respondent background comprising of position, year of experience, company name, experience in groundwater flow and scope of work as presented in Table 2.

Table 2: Research background

Respondent (R)	Organization	Position	Experience in Construction Industry	Experience in Groundwater Flow	Scope of Work
Respondent 1 (R1)	Company A	Project Manager	6 Years	5 Years	Leading project planning sessions
Respondent 2 (R2)	Company B	Site Supervisor	3 Years	2 Years	Directs and supervises the activities of staff
Respondent 3 (R3)	Company C	Project Manager	6 Years	6 Years	Leading project planning sessions
Respondent 4 (R4)	Company D	Site Supervisor	3 Years	2 Years	Directs and supervises the activities of staff
Respondent 5 (R5)	Company E	Site Engineering	4 Years	6 Years	Managing parts of construction projects

4.2 Result

(a) Results Objective 1: Current Practices of Groundwater Flow During Excavation Work at Construction Site

Table 3 present the current practices to control groundwater flow during excavation work at construction sites is that the company provides a lot of good understanding of groundwater flow

conditions required. The contractor also explains the need for effective information in managing issues related to groundwater flow control is with its time management. Time management is very important in the construction industry especially when handling groundwater flow. According Lyn (2021) the successful project management guarantees project completion in time, according to estimates, and according to project specifications. Time management is one way to ensure that all these people use their time as efficiently as possible. In the opinion of all respondents, groundwater flows need to be identified before excavation work is carried out so that planning and construction can be done as efficiently as possible without hindrance. According to all respondents, the contractor needs to make a resistivity test because it is very important to know the groundwater content whether high or low. According to Asry *et al.* (2012), the resistivity method is the most popular of all the geophysical methods as far as groundwater explorations are concerned.

Table 3: Result of current practices to control groundwater flow during excavation work at construction site

Current Practices of Groundwater Flow	R1	R2	R3	R4	R5
Groundwater Management	✓	✓	✓	✓	✓
Method of groundwater flow	✓	✓	✓	✓	✓
Groundwater identified and evaluated during construction	✓	✓	✓	✓	✓
Data requirements for a groundwater flow	✓	✓	✓	✓	✓
Others	✓	✓	✓	✓	✓

(b) Results Objective 2: Challenges of Groundwater Flow During Excavation Work at Construction Site

Table 4 shows the challenges to control groundwater flow during excavation work at construction site. Based on the contractor's explanation it is clear that appropriate efforts should be made thought of finding a way how to address issues related to groundwater flow. This issue is often taken seriously, especially when excavations are carried out there is water coming out of the soil surface is something that should not be taken lightly. What has been stated clearly shows that groundwater control factors in the construction sector need to be addressed with a more strategic approach. What is worrying is that this groundwater flow does not seem to be taken seriously.

The attitude of most contractors who do not give priority to this issue has widened many problems or risks on the construction site. This situation if allowed to continue will have a negative impact on the contractor by suffering losses in terms of existing financial resources. This matter should be taken seriously by the company to appoint a project manager who is really experienced in this groundwater flow. Because, if not handled properly, the construction project will be delayed and cannot be completed according to the schedule or date that has been set. The main challenge that needs to be faced with this groundwater flow, the company needs to plan in advance or not to make excavations during the climate season. Because the challenge often faced by contractors is in dealing with environmental changes that can have an insignificant impact on operations is bad weather.

According Yuvan *et al.* (2020) Climate plays an important role in the construction industry, especially those involving excavation work. The climate also changes over time a scientifically proven and interesting phenomenon that is a major problem facing the construction industry. The construction industry is affected by climate change such as the physical effects of weather such as rain, heat and cold. Increasing climate change is affecting construction workers. It carries risks to workers at the construction site because in the event of extreme heavy rain it will cause the construction site to become slippery and the groundwater content will increase.

Table 4: Result of challenges to control groundwater flow during excavation work at construction site

Challenges of Groundwater Flow	R1	R2	R3	R4	R5
The frequent challenges of addressing environmental changes that can have a significant impact on operations	✓	✓	✓	✓	✓
The challenges that need to be considered to ensure that groundwater flow does not damage building structures in the future	✓	✓	✓	✓	✓
The best technology that is often used to solve groundwater problems	✓	✓	✓	✓	✓
Manage the challenges about technology to control the groundwater flow during excavation work that you often face	✓	✓	✓	✓	✓
Others	✓	✓	✓	✓	✓

(c) Results Objective 3: Improvement Ways of Groundwater Flow During Excavation Work at Construction Site

Table 5 present the result and analysis on improvement ways to control groundwater flow during excavation work at construction site is in this era of globalization that Malaysia has been involved in the use of technology in the field of construction which is considered still new for developing countries. The advanced technology used will further improve the quality and productivity of construction projects to enable infrastructure development in Malaysia to be standing with developed countries. The development of technology has enabled the building construction system to be more effective and systematic by constantly making technological improvements from time to time, especially those involving works to control the flow of groundwater. In addition, the problem of groundwater flow has been considered trivial where it shows a lack of awareness about the problem of groundwater flow among the construction industry. In fact, there are those who doubt that the strength in technological improvement will suffer from the lack of experience and technical knowledge possessed by contractors on this issue of groundwater flow. Therefore, it is important for local construction industries such as contractors to be ready and start taking initiatives in generating alternative methods of improving construction technology in order to compete in the growing construction industry due to globalization. Construction companies play an important role in modifying and developing such methods to adapt existing methods in other industries or other countries in order to compete in the highly competitive international market. So, awareness of current technological improvements and innovations in groundwater flow is very much needed nowadays.

Table 5: Result of improvement ways to control groundwater flow during excavation work at construction site

Improvement Ways of Groundwater Flow	R1	R2	R3	R4	R5
The improvement ways often used if the construction site has a very high quantity groundwater flow	✓	✓	✓	✓	✓
The technology used as the improvement ways to control the flow of groundwater during excavation work at construction site	✓	✓	✓	✓	✓
Control the flow of groundwater to ensure the stability of the excavation and the stability of the slope can lower the water level before the excavation work is done	✓	✓	✓	✓	✓
The improvement ways in term of equipment and methods that are often used to control the flow of groundwater during the handling work is being carried out	✓	✓	✓	✓	✓
The improvement ways that can contribute to groundwater management to achieve a suitable level of success in certain working conditions	✓	✓	✓	✓	✓
Others	✓	✓	✓	✓	✓

5. Conclusion and Recommendation

In conclusion, the objectives of this research is to investigate the current practices, challenges, and improved ways of groundwater flow during excavation work at construction site. The research objectives have been accomplished as concluded. Based on the data that has been analyzed, it can be concluded that the contractor adopts the current practice of groundwater flow during excavation work on construction site. This aims to increase the level of productivity of a construction project carried out. In addition, each tool used in construction activities involving groundwater flow must be maintained in accordance with a predetermined period. In addition, the contractor explained the various challenges faced when controlling the flow of groundwater so that construction does not experience delays and does not affect the cost of construction. Based on the data analysis, it can be concluded that in order to control groundwater flow, the company needs to further improve methods or improve skills in controlling groundwater flow while excavation work is being carried out. This is because, there are some companies ignoring about the matter. As a result, groundwater flow affects the structure of the building in the future and can cause the building to collapse because the quantity of water is not controlled as well as possible. Furthermore, the main issue that they need to make improvements is in terms of equipment because the equipment does not make these improvements can affect the contractor from successfully regulating the flow of water. Not only that, the company also made improvements in terms of experience and skills. There have been some limitations and difficulties in completing this study, the data collected is adequate in order to achieve the research objectives. Hopefully, the data

collected will bring awareness to the contractor on groundwater flow during excavation work on construction site.

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