

Standard Penetration Test in Malaysia: Safety Issues and Improvement Opportunities

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ABSTRACT - Standard Penetration Test (SPT) is the most frequently used field test for site investigation where drilling work is performed in-situ to determine properties of geomaterials for a project. The SPT results can be affected by the 'SPT System,' which includes the operator of the drill rig, the specific model of the drill rig itself, the SPT equipment used to perform the test, and the procedures used in performing the overall test. The safety hazards associated with the system affect the SPT results. Although several countries are embracing innovative technologies in the SPT drilling works to enhance safety performance, the adoption of these technologies in Malaysia remains relatively sluggish. This study aims to analyse the current SPT practice in Malaysia from the lens of 'the SPT System,' technologies used in the SPT drilling works, and identify the best practice adopted locally in ensuring safety. This study collected 102 responses using a questionnaire survey validated by four construction professionals experienced in the SPT drilling works. The study revealed that the British Standards are the most used standards in Malaysia. The traditional methods are still being practiced as the "SPT System" in Malaysia due to the difficulties in obtaining skilled operators for new technology adoption. Advanced technologies have not been adopted because construction professionals are complacent with the current technologies. Amongst innovative safety gear, smart equipment tags and smart wrist wearables are the most favourable. This study presents new findings and sheds light into the local practice of the construction professionals in Malaysia in the SPT drilling works. This study provides an insight for Malaysian construction industry to develop a strategy in improving the efficiency and safety of SPT drilling works through adoption of innovative technologies. Technology driven safety hazard mitigation may boost Malaysian Technical and Vocational Education and Training (TVET) industry and in doing so will increase TVET operators to be trained and certified.

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1.0 INTRODUCTION

The Standard Penetration Test (SPT) is an in-situ field test performed prior to the construction of any engineering project to determine the suitability of the site for its intended purposes. The test results provide engineering properties of the earth materials and groundwater conditions of the site. The test is used widespread because it is simple, inexpensive and can be carried out by the drilling crew [1]. The preparation prior to carrying out the SPT is important and has significant effect on the SPT results [2]. The results are also affected by the energy delivered by the 'SPT system' which includes the operator of the drill rig, the specific model of the drill rig itself, the SPT equipment used to perform the test, and the procedures used in performing the overall test including drilling the hole and sampling. All these four factors within the 'SPT System' contribute to differences in delivered energy [3]. Although the testing procedure is straight forward, the four factors within the 'SPT system' can be affected by the safety aspect. Warnberg, et al., [4] revealed that poor safety affects the quality performance of a project.

In Malaysia, the cable percussion drilling rig and its accessories made up of split-spoon sampler, hammer, and drill rods are commonly used. The SPT is performed by driving the split spoon sampler into the ground by a dropping a 64 kg mass hammer falling from a predetermined height. The main safety concern over this SPT drilling works involves the transferring the drilling rig to the ground manually, rotating and moving parts, cable and links performance, tools and task that requires manual handling, dust, noise, exposure to extreme weather condition, remoteness of the exploration site, working near the road or construction sites, housekeeping, and adequate personal safety gear [5][6]. The safety concern raised in this study came from the actual experience observing a near-missed accident when one part of the SPT equipment become detached and landed near drill operators. The labour-intensive manual transferring of SPT drill rigs, equipment, and accessories onto the ground from a lorry using pipes as in the traditional method raised another safety concern. These concerns are valid as falling object is ranked as top three most common types of construction accident in Malaysia, Thailand and in the US [7][8]. Conventional work processes including those very labour-intensive with few technological advances, involving unsafe behaviours, use of heavy machinery, and dangerous working conditions are also attributes to high rate of construction accidents [9][10]. The adoption of innovative technologies can handle these deficiencies by mitigating occupational safety and health (OSH) risks and improve the overall safety performance.

However, the adoption of innovative technologies is relatively low in the Malaysian construction industry, especially those pertaining to the SPT drilling works. There is very little research in this area, especially in developing countries such as Malaysia [11]. Adopting innovative technologies unlock opportunities for stakeholders to improving safety performance as well as reducing accident in the construction site. Thus, it becomes crucial to investigate the current practice and technology used in the SPT drilling works in the Malaysian construction industry and identify the best practice adopted locally to ensure the overall safety.

To address the gap in relation to SPT drilling works, this study aims to analyse the current practice of the SPT drilling works in Malaysia from the lens of ‘SPT System,’ identify technologies used in the SPT drilling works, and identify the best practice adopted locally in ensuring safety and quality of works. This study is one of a few studies focusing on the SPT drilling works in Malaysia. Therefore, the findings of this study can help Malaysian construction professionals involved in the SPT drilling works consider the adoption of innovative technologies that can ensure quality results and the safety of site operators. Furthermore, the findings shed light into weakness areas faced by construction professionals that require further attention. Scholars can use the findings by developing frameworks for improving safety performance, especially for the SPT drilling works.

2.0 RELATED WORK

The construction site, including the exploration site for the SPT field works, is known for its hazardous working conditions and being one of the world’s most dangerous working environments in the world [12]. In Malaysia, the Occupational Safety and Health Department (DOSH) statistics recorded 169 deaths and 3,911 accidents in 2018, with a fatality rate of 13.44 per 100,000 workers [13]. This is ten times worse than that of the United Kingdom [11][14]. In Malaysia, safety hazards are related to human, environment, materials, equipment and safety technologies [15]. ‘Unsafe Method,’ including incorrect work procedure, the low level of knowledge, the lack of training, and attitude, and failed to obey the work procedure, is one of the contributing factors to safety hazards [7]. Consequently, safety at the construction site directly affects the quality performance of a project [4]. In the SPT drilling works, the quality of the SPT results is affected by the ‘SPT system,’ which include the operator of the drill rig, the specific model of the drill rig, the SPT equipment hardware used to perform the test, and the procedures used in performing the overall test [3]. These four factors overlap with the factors listed in the safety hazards in Malaysia. Therefore, quality of SPT results depend on the ‘SPT System’ and are also affected by the safety aspect related to the four factors.

2.1 OPERATOR OF THE DRILL RIG

In a well-planned drilling works, the most prevalent drilling problems include pipe sticking, lost circulation, hole deviation, pipe failures, borehole instability and contamination and equipment and personnel-related problems [9]. When such problems arise, the experience and competency of the operators is necessary to resolve the problem on site. Operators of the drill rig must be competent in handling the equipment and ensuring safety. In many advanced countries, operators of the drill rig are certified and licenced [10][16]. The certification and licencing are important in maintaining the reputation of the companies in delivering quality services and ensuring safety of their employees under hard working conditions. Uncertified operators can easily contribute to safety hazards by mishandling manual tools and tasks, repairing/modifying broken or problematic tools on site, and forgetting the number of blow count as a result of working under hot, dusty and noisy work environment. The certification of drill operators in Malaysia is not yet a culture. However, the need for certification is obvious as Hamid et. al. [7] showed that competency is one of the main contributing factors to construction accidents in Malaysia. Workers are inadequately trained for safety, orientation, and poor inspection program. The certification of drill operators is in agreement with the Malaysian national policy of Technical and Vocational Education Training (TVET).

2.2 SPT drill rig and equipment

Drill rigs are large and heavy and consist of slow-moving units. Hazards associated with drill rigs include noise, rig stability, rotating and moving machinery, manual handling of drill rods, bits, and other heavy equipment, falling objects, exposure to dust, mud, aerosols, and gases, working at height, intersecting a drillhole containing an unexploded charge and exposure to extreme weather condition [17]. In Malaysia, cable percussion drilling, and its accessories are commonly used (Figure 1). A drilling rig with machine power driven by gasoline or diesel, compressed air, or electric is used to drill borehole to up to a depth of 50 m. Other than this percussion drilling, there are four other common types of drilling technologies used worldwide, including rotary drilling, hand-auger drilling, jetting, and sludging. The choice of drilling technology used is based on the site geology, the anticipated depths of the boreholes, and their expected diameters. This conventional technology has been used since the 1980s and is still widely used in Malaysia and many developing countries due to cheaper cost of operation. In 1998, the Promotion of Appropriate Technology (PAT) company and its partner Action Contre La Faim (ACF) cooperated to improve drilling machines. They produced three models of improved drilling machine which can be purchased, including ACF/PAT 201, ACF/PAT 301 and ACF/PAT 401 (Figure 2). Improvements in the drill technology include additional pulley, bigger drill pipes, higher mud pressure, improved tool sets, and improved borehole compressor [18].

Advanced technologies in drilling rig come with better safety features, ease of operation and truck mounted (Figure 3). The various models of advanced rigs depend on the type of project, the purpose of test, geological site conditions, and the accessibility to the exploration site. The added safety features on all these rigs include automatic SPT hammer, drill rigs fitted with a rotation cage around drill rods equipped with emergency stop buttons and many more. Large drilling companies have the capability to offer customised rigs with special kit and advanced technologies to ensure maximum productivity and safety at the construction site [19]. Due to advanced technological components and handling of the drill rig, every member of their drilling team in such company holds nationally recognised certifications and licences from their country.

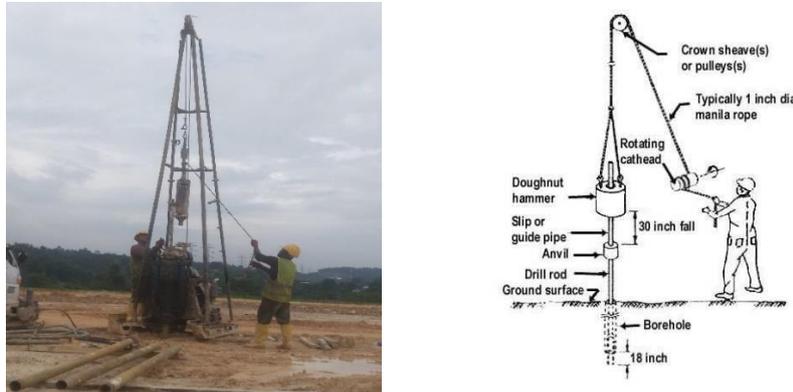


Figure 1. The SPT equipment commonly used in Malaysia



Figure 2. Improved low-cost drill rig technology [18]



Figure 3. Advanced drill rig technology – truck mounted with automatic SPT hammer [16][19]

2.3 Standard Operating Procedures (SOP)

There are various standards available for the SPT drilling works to be conducted. The commonly used standards in Malaysia are the Malaysian, British and American standards. These standards are MS 1056:2005 Soils for civil engineering purposes-test method, BS 1377: Method of test for soils, BS 5930:1999 Part 1: Code of Practice for Site Investigation, BS EN ISO 22476-3, BS EN 1997-2, and ASTM D1586-08a (100). In general, all construction work must be conducted in compliance with a particular standard to ensure quality and safety. While standard used is normally clearly identified, the adherence to the standard can be a problem and still needs to be regulated [7].

2.4 Personal Protective Equipment (PPE) and safety practices

Standard Personal Protective Equipment (PPE) is normally worn on the construction site, comprising of safety helmet, eye protection, high visibility clothing, protective gloves, and footwear. In the drilling work, since the safety hazards may involve harmful gases, noise, extreme weather conditions, and dangerous natural habitat at the exploration site, the suitability of the basic PPE worn can be argued in terms of adequate safety. The use of innovative smart PPE and wearables may enhance and provide better safety protection for drill operators. PPE has witnessed great improvements due to the advancement of technologies in this digitalisation era. Safe constructions involving user-friendly and powerful wearable technology, such as smart watches, boots, helmets, glasses, and body wear, are the main focus nowadays. Each of these technologies provides different tools in an arsenal designed to keep workers safe, healthy, and productive [20].

The smart watch technologies are capable of monitoring health and activity data, detecting falls, and enable smart communication. Safety boots have been improved to smart boots that come with pressure, enabling the detection of falling objects or small shocks. Injury sustained by construction workers is informed automatically with the built-in communication system. The smart boots also come with location detector and self-charging feature. The new safety helmet has upgraded hard hat into smart hat enabling the detection of fatigue, microsleep, and distance which can prevent workers from collision with machinery, equipment, or existing structure. The highly visible clothing is now capable of detecting body temperature and harmful gasses and reduces muscle fatigue.

2.5 Research Gap

The adoption of innovative technologies in the SPT drilling works can reduce OSH risks and improve safety performance. However, the adoption of innovative technologies is relatively low in the Malaysian construction industry, especially those pertaining to the SPT drilling works. To leverage the benefits of innovative technologies in improving safety performance, the current practice regarding the SPT drilling work must be investigated. This study fills this gap by analysing the current practice of the SPT drilling works in Malaysia from the lens of the 'SPT System', identify technologies used in the SPT drilling works, and identify the best practice adopted locally to ensure safety and quality of work

3.0 RESEARCH METHOD

3.1 Survey Development

This study employed a quantitative methodology using a questionnaire survey to address the three main objectives mentioned. A questionnaire survey is an effective and economical approach to collect information from a large sample and is widely used technique in the construction safety management studies [21][22][23]. After developing the survey, this study conducted semi-structured interviews with four construction professionals involved in the SPT drilling works. The main purpose of the semi-structured interview was to revise the survey in terms of completeness, technicality, and language. The construction professionals were also requested to add any additional input to improve the survey. Finally, the survey was finalized based on the given recommendations and suggestions.

The survey consists of four main sections. Section 1 asked about the respondent's profile, including job position held, years of work experience and familiarity with the SPT drilling work. Section 1 was developed to ensure the respondents have relevant experience and familiarity with the SPT drilling works which can enhance the validity of the analysis. Section 2 includes questions on SOP and method statements. Section 3 includes questions about the drilling technologies. Finally, section 4 includes questions on best practice in ensuring safety and quality of work. Appendix 1 shows an example of the developed questionnaire survey in this study.

3.2 Data Collection

The target population consisted of construction professionals with sufficient knowledge and understanding of the SPT drilling works. As the sampling frame was not known, this study used the non-probability sampling. The non-probability sampling technique can be used to select participants when a random sharing is difficult to justify. This technique allows to control the respondent quality while achieving representative samples [22]. As a result, the convenient and snowball sampling techniques were adopted for to obtain a sufficient sample size. Initially, eligible construction professionals who could answer the survey were identified through the authors' referral network and communication. Then, they requested to share the survey with other construction professionals involving in SPT drilling works to increase the response rate. Finally, 102 valid responses were collected. Although the sample size may seem small, it is still appropriate for the study's statistical analyses because the central limit theorem holds when the sample size is greater than 30 [19]. Table 1 summarizes the participants' demographic profile. Among the sample, 42.16% are engineers, followed by operators at 20.59%. Regarding working experience, 30.39% of the respondents have 1 to 3 years of working experience. Construction professionals with 6 to 10 years of working experience and more than 10 years of working experience contributed to the survey by 20.59% and 25.49%. Construction professionals with less than 1 year working experience have the smallest contribution to the survey with 7.84%. Regarding familiarity with the SPT drilling works, the majority of the sample (86.27%) is familiar to very familiar with the SPT drilling works. Given the working experience and familiarity of the respondents with the SPT drilling works, the data was considered reliable for the analysis.

3.3 Data Analysis

Reliability test was conducted using Cronbach’s alpha to test the internal consistency. The Cronbach’s alpha is the most popular index for reliability testing of Likert scales. Its value ranges between 0 and 1. A value closer to 1 indicates higher reliability of the developed instrument. Furthermore, the data was analysed using frequencies and percentages for each question. This allows identifying common practice used by construction professionals and compare between different categories.

Table 1. Respondent profile

Description	Demography	Nature of business			Total	% Response
		Civil engineering	Geotechnics	Geology		
Job position	Project Manager	19	0	1	20	19.61
	Engineer (Project/Site/Resident)	33	3	7	43	42.16
	Safety Officer	5	0	0	5	4.90
	Technician/ Clerk of Work	7	2	4	13	12.74
	Operator	2	4	15	21	20.59
	Total	66	9	27	102	100.00
Working experience in the engineering works	Less than 1 year	7	0	1	8	7.84
	1-3 years	22	3	6	31	30.39
	4-5 years	13	1	2	16	15.69
	6-10 years	13	3	5	21	20.59
	More than 10 years	11	2	13	26	25.49
	Total	66	9	27	102	100.00
familiarity with SPT drilling works	Familiar to very familiar	53	9	26	88	86.27
	Unfamiliar to somewhat familiar	13	0	1	14	13.73
	Total	66	9	27	102	100.00

4.0 RESULTS AND DISCUSSION

The results show that the Cronbach’s alpha value was 0.529, which is less than 0.70. Nevertheless, Nunally [24] suggests that reliability scores in the 0.50 to 0.60 range are acceptable when the research is exploratory research, suggesting that the data are reliable. To discuss the safety issues related to the SPT drilling works and how it can be improved through the adoption of innovative technologies, the next subsection discusses the status of SOP and method statement being used by construction professionals. The second subsection discusses the current SPT drilling technologies employed locally, followed by their level of awareness and readiness for new technology adoption. In the final section, overall safety measures are discussed which include the safety issue regarding the drill rig transferring method used and innovative PPE and wearables.

4.1 Standard Operating Procedure (SOP)

Survey results show that SOPs and method statements are in place when SPT drilling works are performed. The British Standards, BS 1377: BS 5930:1999 Part 1, BS EN ISO 22476-3, and BS EN 1997-2, are the most commonly used standards with approximately 81%, followed by the Malaysian Standard with 30% and the American Standard (9%). When asking about the reason of using the current standards, the results showed that these standards comply with specification (71%) and match with site conditions (55%). Although the SOP is in place where safety issues and quality of work at the exploration site can be assumed to be good, there can be doubt as to whether the SOP and method statement are fully understood and adhered to. Hamid et. al. [7] show that incorrect procedure used at the construction site is one of the ‘unsafe method’ leading to construction accident in Malaysia. Laporan Operasi Tapak Pembinaan (OTP) 2020 [25] also reported that the conformance level at the construction site varies from 3% to 27% which can be considered as low. These unsafe methods and the low level of SOP adherence could be due to the lack of training and poor inspection [7]. The ways forward to develop professionalism within the TVET players in Malaysia include proper training program leading to certification of drill operators and checkers is highly needed. The certification program not only enhances the competency of Malaysian TVET professionals, but also ensures the safety of the TVET operators.

4.2 SPT Drilling Technology

The SPT drilling technologies include but not limited to cable percussion drilling, rotary drilling, hand-auger drilling, jetting and sludging are drilling. In Malaysia, rotary drilling (92%) and percussion drilling (75%) are the two-drilling technologies used. When asking about the reasons drilling technologies being used, the results showed that the availability of skilled operator (70%) and good performance of the drilling machinery (66%) are the two main reasons for drilling technologies being used. Hand auger drilling and other drilling methods such as jetting, sludging, plasma deep drilling,

etc. are seldom used based on their unreliable performance. Furthermore, the most common problems encountered during the drilling process include drill pipe failure (42%) and pipe sticking (36%). Other drilling technologies, such as down-the-hole hammer drilling (43%) and electric impulse drilling (28%), are known by local operators. However, they are seldom used due to lack of skilled operators (84%) to perform the task. The improved PAT drilling machine and advanced truck mounted drill rig are technologies local construction professionals are not familiar with because technologies are not available in Malaysia (44%). Regarding the type of SPT hammers, the automatic hammer is the most common hammer used by construction professionals (40%), followed by the safety hammer (34%). When asked about the reasons for SPT hammers being used, ensuring safety (60%) and being economical and effective were the dominant reasons (47%).

The findings show that the availability of skilled operators and equipment performance are the two main reasons for the type of drilling technologies being used in Malaysia. Construction professionals are aware and ready to adopt innovative technology as the survey results indicated that the cost of the equipment and its accessories is not their primary concern. Rohana [27] also found that financial resources influence the intention to adopt innovative technologies amongst Malaysian construction industry. On the other hand, immature technologies and complex implementation of new technologies are major technical challenges behind their uncertain adoption [28]. Although the adoption of innovative technologies in the SPT drilling works is significantly low, there is a positive sign of its possible adoption, e from the push by the government through the Industrial Revolution 4.0 (IR4.0) and digitalization policies. It is timely for Malaysia to replace the existing labor-intensive practice towards automation and robotics. This technology-driven change can reduce manpower with the possibility of eliminating some construction worker [29][30]. Through adoption innovative technologies, the issue of relying on foreign labor in the construction industry can be resolved and at the same time the new technology can attract local TVET players to join the industry with clear skill pathways towards certification. As any certification and innovative technology adoption require extensive training, local operators are also raised another concern about the training program if new technology is adopted. This concern can be considered as not critical because COVID-19 experience has prepared Malaysian for training to be done online. One can argued whether online training is effective for technical competency, however future of training in technical competency has transform from physical training to the online training program assisted with virtual reality (VR) and augmented reality (AR) in which many engineering industries nowadays have use it with success.

4.3 Safety and Best Practices

One of the most concerned safety hazards in the SPT drilling works in Malaysia is the traditional labor-intensive transfer method of drill rigs to the ground. The use of a small basic lorry and pipe railing in the transfer process is dominantly practiced (93%). Safety hazards associated with this handling method can be falling heavy objects as equipment may derail, a hand caught between the object that can cause direct injury to operators and heavy manual lifting leading to musculoskeletal disorders which is highly reported among Malaysian construction workers [31]. Local operators are aware of safety hazards related to this method, and therefore, they are emphasizing on operators wearing full PPE, following the SOP, checking the ground condition and environment, including the weather, make sure good pipes are used and checked work in teams and fully focused on the job and wear gloves. They also recognized that using platform and mechanical lifting aid are means to improve the transferring method of the drill rig to the ground. Using a bigger truck with a lower tailgate platform has also been suggested. Although awareness level on how to mitigate safety hazards is high, only 7% of local professionals are using mechanical lifting aid. The advanced truck mounted SPT drill rig, including its equipment, is a technology that has not been used in Malaysia. This advanced technology has not been adopted locally because construction professionals are complacent with current technology (16%). The strong push for using advanced technologies by the government is being offset by the need to keep the construction cost low as requested by the client and the tendering practice that prioritizes 'lowest price,' limiting embracing innovation in Malaysia [21][32].

Safety measures taken by Malaysian construction professionals include site preparation system checklist, appropriate tools usage, appropriate PPE and adequate safety management plan. The PPE used when performing the SPT drilling works according to the operators is adequate, and they believe that their PPE is fully adequate in protecting them against any accident. While safety helmets (79%) and safety boots (78%) are the most important PPE items ranked by the construction professionals, gloves on the other hand is the least important PPE item ranked from the survey. Local operators may overlook the importance of gloves as a protective item, and the use of simple PPE for safety purposes still generally receives some resistance [33]. In the drilling works, many accidents are related to hand injury, such as crushed fingers while breaking out rods, laceration to fingers and hand when grabbing fallen equipment or object, jammed hand between water swivel and head, crushing thumb and finger [34]. Although only small numbers of respondents emphasize the importance of wearing glove, local operators should pay more attention to the degree of safety hazards involving gloves and hand injury. Despite resistance to wearing simple PPE, 99% of construction professionals are extremely interested in the new innovative smart PPE and wearables. Among innovative safety gear highly interested by the local construction professionals are smart equipment tags (33%), smart wrist wearable (25%), and smart atmospheric sensor (20%). Smart boots are the least favorable (10%). The fact that they are eager to recommend smart PPEs to be purchased by their companies. It was hoped that this innovative technology may boost their motivation to use them, and consequently improve safety at the construction site.

5.0 CONCLUSION AND RECOMMENDATIONS

Safety issues in the SPT drilling works strongly affect the quality of the SPT results. To improve the overall quality and safety of SPT drilling works, the adoption of new technologies, such as using improved PAT drill rigs, advanced truck mounted SPT drill rig with equipment and its accessory need to be considered in replacement to cable percussion or rotary drilling rig. The use of an advanced truck mounted drill rig with automatic safety hammer may resolve the challenges associated with the labour-intensive manual drill rig transfer methods. This study revealed that local operators are aware and ready for the adoption of new technology and are concerned about safety hazard. However, the deterrent factor in new technology adoption is the availability of skill operators and the 'low cost' demand from the client and the 'low price' tender system. The findings of this study revealed a positive indication on innovative technology adoption to address safety in the SPT drilling works that can be used by the construction industry, the local authority, and the government to develop a strategy on how the local industry should employ a technology-driven method to mitigate safety hazards. The strategy should include the use of automation and robotic for the SPT machinery and the use of online assisted by AR/VR training program for upskilling drill operators towards certification. The certification should consist of both technical and safety aspects to ensure that quality TVET professionals are developed in Malaysia. The findings are of great importance in synthesizing the current SPT work practice that construction professionals should be aware of to improve the current situation. This study also provides the best practices that construction professionals should embrace to reduce accidents on site and improve overall safety performance. Although the objectives of this study were achieved, there are some limitations worth stating. The sample size was small. Future works can target a larger sample size to generalize the findings. SPT drilling works, and practises are shaped by the industry context within a country. Therefore, the findings of this study should be interpreted in the context of Malaysia. Future works can compare the SPT drilling works practises and technologies used in ensuring safety in different contexts. Nevertheless, the findings of this study provide greater insights into the SPT drilling works and best practice in Malaysia to ensure overall all safety.

6.0 AUTHOR CONTRIBUTIONS

Aishah Abu Bakar.: Writing- Original draft to final preparation, and data analysis

Nur Afifah Fatinnisa' Rizal Imran.: Data curation

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8.0 DATA AVAILABILITY

The data used to support the findings of this study are included within the article.

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10.0 CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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APPENDIX 1

Questionnaire Survey

Section 1: Respondent Background

1. Job position:
 - a. Project manager
 - b. Engineer (Project/Site/Resident)
 - c. Safety Officer
 - d. Technician/Clerk of Work
 - e. Operator

2. Yours of experience in the engineering works:
 - a. Less than 1 year
 - b. 1-3 years
 - c. 4-5 years
 - d. 6-10 years
 - e. More than 10 years

3. Familiarity with SPT drilling work
 - a. Unfamiliar to somewhat familiar
 - b. Familiar to very familiar

Section 2: Standard Operating Procedure (SOP) and Method Statement

4. I am using the following Standard Operating Procedure (SOP):
 - a. MS 2038:2006
 - b. MS 1056: 2005
 - c. BS 1377
 - d. BS 5930:1999 Part 1
 - e. BS EN ISO 22476-3
 - f. BS EN 1997-2
 - g. ASTM D 2113
 - h. ASTM. D1586-08a (100)
 - i. All above
 - j. Others (please specify):

5. I am using the following method statement for borehole drilling works:
 - a. MS 2038:2006
 - b. MS 1056: 2005
 - c. BS 1377
 - d. All of above
 - e. Others (please specify):

6. I am using the above method statement because:
 - a. To comply with specifications and design criteria
 - b. The method statement is fix since it has been standardized
 - c. It is company's tradition / standard practice
 - d. It matches with site conditions
 - e. It matches with available machinery and tools
 - f. Sampling method used
 - g. All above
 - h. Others (please specify):

Section 3: Drilling technology: Usage, problems, and awareness

7. I am using the following drilling technologies in borehole drilling work:
 - a. Percussion drilling
 - b. Rotary drilling

- c. Hand-auger drilling
 - d. Jetting
 - e. Sludging (reverse jetting)
 - f. Plasma deep drilling
 - g. Hydrothermal jet spallation drilling
 - h. Long hole directional drilling
 - i. Others (please specify):
8. I am current drilling technology is being used because:
- a. Low-Cost Operation
 - b. Fast Drilling
 - c. Ease of handling
 - d. Availability or maintenance / repair parts
 - e. Availability of skilled operator
 - f. Less Pollution
 - g. The Depth of the Borehole
 - h. The type of soil on site
 - i. All above
 - j. Others (please specify):
9. The most common problems of drilling technology that I have encountered are:
- a. Equipment and Personnel-Related Problems
 - b. Pipe Sticking
 - c. Loss of Circulation
 - d. Hole Deviation
 - e. Drill pipe Failures
 - f. Borehole Instability
 - g. Others (please specify):
10. Innovative technologies are not being used in the drilling works in Malaysia because:
- a. Expensive machineries/parts
 - b. Lack of skilled workers
 - c. Comfortable with the same technology
 - d. The technologies are not available in Malaysia
 - e. Training cost for the new technologies is too expensive
 - f. Others (please specify):
11. I am using the following types of SPT Hammers:
- a. Safety Hammer
 - b. Slip Rope Hammer
 - c. Donut Hammer
 - d. Automatic Hammer
 - e. Spooling Winch Hammer
 - f. Others (please specify):
12. I am using the types of hammers stated in the question 11 because:
- a. More economic
 - b. High Repeatability
 - c. More effective
 - d. Low risk of safety concerns
 - e. Low-cost equipment
 - f. Others (please specify):

Section 4: Safe equipment, handling, and safety gear

13. The machine is transferred from the lorry to the ground by:
 - a. Manually by workers
 - b. Machine attached to the lorry
 - c. Others (please specify):

14. Safety measures that being used while transferring and handling machine:
 - a. Checklist for site preparation
 - b. Tools
 - c. PPS
 - d. Safety management

15. The following are the safety equipment that I always wear while working:
 - a. Safety Helmet
 - b. Safety Boots
 - c. Gloves
 - d. Reflective Jacket
 - e. All above
 - f. Others (please specify):

16. The following are the latest innovation of safety equipment that I will wear while working in the future:
 - a. Wrist Wearables (To detect falls and warn other workers right away)
 - b. Smart Helmet (To indicate the need for a break by monitoring vital signs)
 - c. Smart Boots (To locate workers correctly)
 - d. Equipment Tags (Give out warning to nearby workers that a functional machine is operating)
 - e. Atmospheric Sensor (To generate alarms or send notifications straight to wearables, increasing worker awareness)
 - f. Others (please specify):

17. I am interested in wearing innovative smart PPE:
 - a. Yes
 - b. No

18. I would highly recommend the latest innovation on safety gear to my company
 - a. Yes
 - b. No