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# Correlating button bit reliabilty and rock resistivity in bore well construction

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**ABSTRACT**

Groundwater resources are essential to maintain a stable water supply to growing cities for the efficient farming region and for domestic purpose. Due to simplicity of the techniques, the Vertical Electrical Sounding (VES) has proved very popular with groundwater prospecting and engineering investigations. The main objective of the investigation is to delineate the subsurface lithology and to assess the groundwater resources of the study area. It also aims to focus on the identification of fracture zone and its thickness by using VES method. The life of a button bit in bore well drilling depends mainly on hardness of rock. As the hardness varies at different locations, the reliability of the button bit also varies accordingly. In order to arrive at the reliability, the life of the button bit in terms of depth of drilling has to be obtained. This can be converted in terms of time from the known velocity of drilling. It is proposed to arrive at the drill bit reliability from the obtained failure rate.



## Introduction

Groundwater resources are main sources for potable water supply, industrial, domestic and agricultural uses. Study of groundwater geology is much useful for all the activities of human life [1]. Sustainable water supply is essential to engage the inhabitants in dry season farming. Development of this resource requires rapid and cost effective techniques of locating sustainable water bearing units (aquiferous zones) in a region (location of study area) where abortive boreholes are prevalent. Among others, Geophysical approach has been used to locate these zones with great successes [2]. The Vertical Electrical Sounding (VES) techniques have been used in a wide range of geophysical investigations such as mineral exploration, engineering studies, geothermal exploration, archeological investigations permafrost mapping [3]. permafrost mapping [3]. This method as a low-cost technique and veritable tool in groundwater exploration is more suitable for hydro geological survey of sedimentary basin. This method is widely used to settle a wide variety of groundwater problems [4].eothermal exploration, archeological investigations, permafrost mapping [3]. This method as a low-cost and permafrost mapping [3]. This method as a low-cost technique and veritable tool in groundwater exploration is more suitable for hydro geological survey of sedimentary basin. This method is widely used to settle a wide variety of groundwater problems [4]. The main objective of the investigation is to delineate the subsurface lithology and to assess the groundwater resources of the sub watershed. It also tries to concentrate on the identification of fracture zone and its thickness by using VES method. The study area faces water scarcity problem both with respect to irrigation as well as drinking purposes and is covered by sedimentary and hard rock formations. Presence of groundwater in this type of area is limited to fractured and weathered horizons and upper unconsolidated materials. Fractured zone is the main target for identifying the groundwater potential in the hard rock terrain [5]. In most geological conditions, predominantly button bits are used which consist of a number of cemented carbide buttons inserted and/or soldered into holes of a steel body.

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**Nomenclature**

| | |
|---|---|
| VES | Vertical Electrical Sounding |
| CRM | Computerised Resistivity Meter |
| R | Resistance |
| L | Length |
| A | Area |
| P | Resistivity |
| S | Longitudinal Conductance |
| T | Transverse Resistance |
| h | Thickness |
| K | Geometrical Constant |
| R(t) | Reliability |
| λ | Failure rate |
| t | time |

Tool wear will occur under certain loads and temperatures just as one result of a complex tribological system. The removal of material is caused by microscopic and macroscopic processes such as abrasion, adhesion, material fatigue or brittle failure of tool materials [6]. The objective of the paper is to predict the tool bit wear. An accurate prediction of penetration rate from rock properties and drill operational parameters is of vital importance for the efficient planning of operation [7]. Most face designs for button bits are offered in multiple carbide configurations and typically differ in diameter, shape (i.e. profile) and quantity. There are some general guidelines to follow while selecting between multiple carbide configurations including resistance to penetration rate, specific rock conditions, vibration and wear [8]. The drillability is not only decisive for the wear of tools and equipment but is also with the drilling velocity that is a standard factor for the progress of excavation works. There are many parameters such as rock strength and hardness which affect the drillability of rock cutting tools [9]. The estimation of drillability in anticipated rock conditions might bear an extensive risk of costs. Various geological and mechanical parameters affect the drillability of a rock mass [10]. To determine drilling costs, knowledge of drillability of rocks in engineering projects is very important. In drilling operations, so many parameters such as the properties of rock and the drilling equipment affect the drilling performance. Various rock parameters have been used to predict the performance of drilling rigs [11]. Drillability indicates whether the penetration is easy or hard. Drillability cannot be measured by logging tools, but is an estimation based on other drilling parameters according to Cheniany, Khoshrou and Shahriar et al. (2010) [12]. Sticky and sandy shale, gravel, salt, plastic clay, hard and soft sand, sandstone, limestone, dolomite and granite common formations drilled. Its resistance to penetration is affected by characteristics of each formation [13].

**Methodology**

**Location of the study area**

Electrical resistivity investigation was carried out in various geographical locations, in order to study the subsurface geologic layer with a view of determining the depth to the bedrock and thickness of the geologic layers. VES using Schlumberger array was carried out at fourteen VES stations. CRM Aquameter was used for the data acquisition. The field data obtained has been analyzed using computer software (IPI2win) which gives an automatic interpretation of the apparent resistivity. The VES results revealed different type of the subsurface geological sequence.

Small patches of hydromorphic saline soil are encountered along the coastal areas. Based on nature of formation, the aquifer can be classified into hard rock aquifers and sedimentary aquifers. Groundwater occurs under phreatic conditions in the shallow weathered portions whereas it occurs under semi confined to confined condition in the deep-seated fractures of the crystalline formation. The hard rock formations in general lack primary porosity. The water is stored in the secondary pores developed as a consequence of weathering in fractures, fissures and joints etc. The movement of groundwater is controlled by the extent of the interconnection of the fractures. The sedimentary formations are confined to the coastal belt.

**Vertical Electrical Sounding**

Geophysical prospecting of groundwater comes under both surface and subsurface geographic expedition. Schlumberger array of electrical resistivity method is one of the electrical methods under geophysical prospecting. The schlumberger array was used to ensure deep penetration and for logistics of limited man power in the field. The investigation processes and VES have been carried out. Resistivity profiling with *AB/2* 10, 20, 30, 40 and 50 m have been carried out. VES has been conducted at 14 locations with *AB/2* as 50 m. The resistivity data have been qualitatively and quantitatively interpreted and analyzed by software packages.

**Drillability**

Drillability is the resistance of rock to penetration by a drilling technique and it is a term used to describe the influence of numbers of parameters on the drilling rate (drilling velocity) and the tools wear of the drilling rig. Drillability is a comprehensive index which reflects the capacity of anti-crushing in drilling process. The drillability is not only decisive for the wear of tools and equipment but is along with the drilling velocity. The estimation of drillability in calculated rock conditions might bear an extensive risk of costs. Thus, an improved prediction of drilling velocity and bit wear would be suitable. Various geological and mechanical parameters determine the drillability of a rock mass. Drillability of rock is one of the important parameters to decide the progress and economics of excavation. Tool wear will in any case influence the achieved drilling velocity of a button bit. The main reason is the wear affected change of the button's geometry. This is because the shape of a drill bit button is of crucial importance for the penetration into the rock.

**Drilling equipment and bit tool wear**

In most geological conditions, predominantly button bits are used which consist of a number of cemented carbide buttons inserted and/or soldered into holes of a steel body (Fig. 1). The properties of the button bit can be adjusted effectively to the local circumstances by variation of the amount of button composition, button geometry, inserted buttons, solding and steel quality or the bit's flushing system.

Tool wear in hard rock drilling can be defined as a process of continuous loss of material from the surface of the drill bit due to mechanical contact and relative movement of the bit over the rock surface. Tool wear will occur under certain loads and temperatures just as one result of a complex tribological system. The removal of material is influenced by microscopic and macroscopic processes such as abrasion, adhesion, material fatigue or brittle failure of tools. These processes are controlled by a vast variety of factors coming from the main fields of geology, tools and logistics. Rock properties, joint features, weathering / alteration of rock, water situation, composition of inhomogeneous rock masses and under- ground stress situation have been identified as major geological factors.

**Figure. 1. Main characteristics of a button bit**

Tool characteristics, rotating velocity, temperatures, flushing, feed, tool handling and rock supporting methods represent some main factors from the fields of tool and logistics.

**Predicting bit wear rates**

**Testing and prediction methods – an overview**

Prediction of tool wear rates will be based on a wide variety of testing procedures and standards. It will cover a big span of scale, ranging from model tests to on-site real-scale drilling test with simplified tools and further on to microscopic and chemical analysis of rocks and minerals. Based on their scale and parameters they are able to take different factors into account whilst disregarding others.

**On-site and block drilling tests**

Real-scale drilling tests, using the original drilling tools and machinery and being performed on representative outcrops or samples of the rock are a reliable testing method to obtain data for drilling performance and tool wear. Depending on the size and condition of the testing area or sample nearly all influencing factors are taken into account. But, the procedures are rather costly with respect to personnel and material costs and therefore carried out most seldomely.

**Model Development**

Mean Time To Failure (MTTF) is a basic measure of reliability for non-repairable systems. It is the mean time expected until the first failure of a piece of equipment. Failure rate is the reciprocal of MTTF.

Reliability is given by

$R(t) = e^{-\lambda/t}$

where

$\lambda = 1/MTTF$

MTTF can be obtained after the replacement of the button bit.

**Correlating Resistivity and reliability**

In general for measuring the resistivity of the sub surface formation four electrodes are required. The current of electrical intensity (I) is introduced between one pair of electrodes called current electrodes which can be identified as A and B. Another pair of electrodes called potential electrodes represented as M and N is used to measure the potential difference produced as a result of current flow. Let δ represent the potential difference. If K represents geometrical constant, then the apparent resistivity measure is K*D/I, which can be calculated if we know the electrode arrangements. The important requirements for the resistivity survey are the power source, electrodes, cables and meter to measure current and potential.

A series of measurements of resistivity are made by increasing the electrode spacing in successive steps about a fixed point. This method is also known as the Resistivity sounding, expanding electrode method or Depth probing or VES. The apparent resistivity values obtained with increasing values of electrode separation are used to estimate the thickness and resistivities of the subsurface formations. The different sections are shown in Fig. 2. The main application of VES is groundwater exploration to determine the disposition of the aquifers.

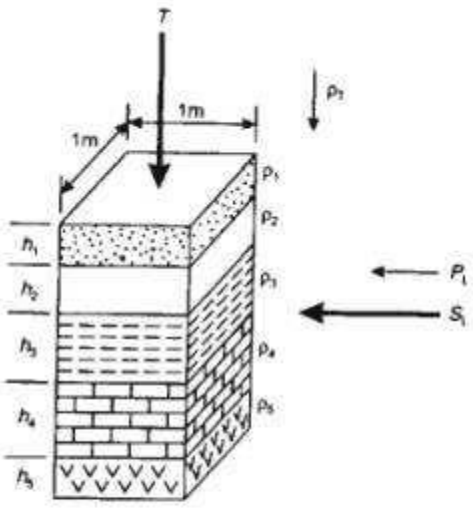



**Figure.2**

The interpretation of resistivity data is done in two stages, first stage being the processing of data to get the geoelectric parameters in terms of depth/thickness and apparent resistivities and second stage being the inference of the nature of surface lithology on the basis of the local geological knowledge and correlation studies based on the above parameters.

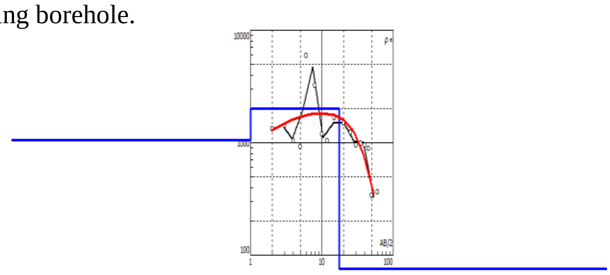
**Drilling Test**

After conducting VES at different stations, drilling tests were done on intact rock samples. The test is performed on different rock samples. The wear is measured after each drilling work in instrumentation lab. The bit life was determined on field by monitoring the total depth drilled before the bits were replaced.

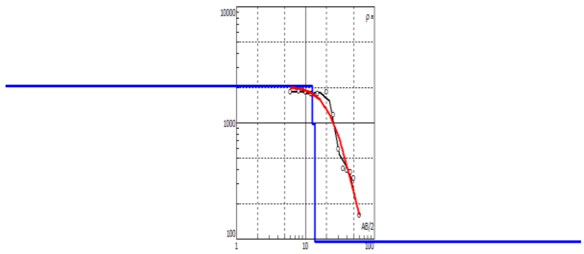
**Result and discussion**

The quantitative approach is to get the geoelectric parameters i.e., the layer thickness/depth, true resistivity, etc. The VES data of the study area (Table 1) have been qualitatively and quantitatively analyzed and interpreted using software MapInfo 8.5 and IPI2 WIN version 3.1.0. The IPI2 WIN software (8) is used to prepare the VES curves. The curves are shown in Fig. 3.

Electrical resistivity survey has been carried out at different stations and totally 14 VES were conducted. Isoresistivity maps were generated and both low and high resistivity anomalies have been demarcated. The field curves of the study generally suggest four geoelectric layers. Their equivalent geologic units are the top soil, weathered basement, and fractured basement rock. Based on the hydrogeological condition and geoelectrical resistivity survey findings, the aquifer can be classified into hard rock aquifers and sedimentary aquifers. Based on the qualitative interpretation of the VES data, it is deduced that these stations are viable positions for making boreholes with appreciable thickness of weathered and fractured basement (aquiferous zone). This geologic layer is characterized by structural features like fractures, fissures or pore spaces that groundwater permeability and storage hence suggesting these points for sitting borehole.



VES 1



VES 11

**Figure 3. Interpretations of Vertical Electrical Sounding Field curves**

The wear at each station was measured and the rate of wear is calculated at each station and the result is tabulated. (Table 2).

The variation of wear with depth and time taken for the wear is plotted as shown below.

Reliability of the button bit is calculated at each station and the results were tabulated. Reliability Vs Time graph is plotted for each station.

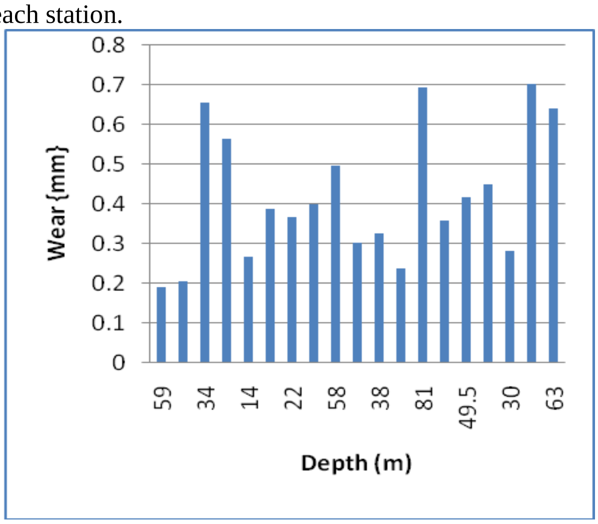



**Fig 4. Wear Vs Depth**

**Table 1. Summary of VES data interpretations with positions**

| VES No | 1st Layer Resistivity ρ1 (Ohm meter) | 2nd Layer Resistivity ρ2 (Ohm meter) | 3rd Layer Resistivity ρ3 (Ohm meter) | h1 (m) | h2 (m) |
|---|---|---|---|---|---|
| 1 | 1049 | 2010 | 3.28 | 1 | 16.6 |
| 2 | 291 | 614 | 13.5 | 3 | 37.8 |
| 3 | 547 | 163 | 5.18 | 5.81 | 54.2 |
| 4 | 228 | 47.4 | 244 | 4.24 | 3.36 |
| 5 | 478 | 297 | 61.9 | 3 | 37.8 |
| 6 | 941 | 37.9 | 140 | 5.01 | 3.35 |
| 7 | 609 | 613 | 6.91 | 3 | 27.3 |
| 8 | 452 | 181 | 234 | 4.28 | 12 |
| 9 | 2064 | 983 | 95.7 | 12.5 | 1.22 |
| 10 | 1108 | 65.4 | 202 | 7.96 | 6.66 |
| 11 | 311 | 820 | 19356 | 1.93 | 38.1 |
| 12 | 1360 | 39.5 | 55631 | 3 | 3.2 |
| 13 | 818 | 99 | 30664 | 20.2 | 12.9 |
| 14 | 625 | 1591 | 7.87 | 6.51 | 11.4 |

**Table 2. Rate of wear over depth and time**

| Sl.No | Time (h) | Depth(m) | Wear(mm) |
|---|---|---|---|
| 1 | 11.1 | 59 | 0.191 |
| 2 | 10.4 | 38 | 0.207 |
| 3 | 12 | 34 | 0.656 |
| 4 | 10.3 | 26 | 0.566 |
| 5 | 4.8 | 14 | 0.268 |
| 6 | 6.8 | 39 | 0.387 |
| 7 | 5.8 | 22 | 0.367 |
| 8 | 12.1 | 47 | 0.401 |
| 9 | 10.3 | 58 | 0.496 |
| 10 | 9.1 | 35 | 0.303 |
| 11 | 14.1 | 38 | 0.327 |
| 12 | 12 | 28 | 0.239 |
| 13 | 9.9 | 81 | 0.693 |
| 14 | 7 | 42 | 0.36 |
| 15 | 12.1 | 49.5 | 0.419 |
| 16 | 12.8 | 55 | 0.451 |
| 17 | 10.9 | 30 | 0.283 |
| 18 | 12.1 | 82 | 0.703 |
| 19 | 14 | 63 | 0.641 |

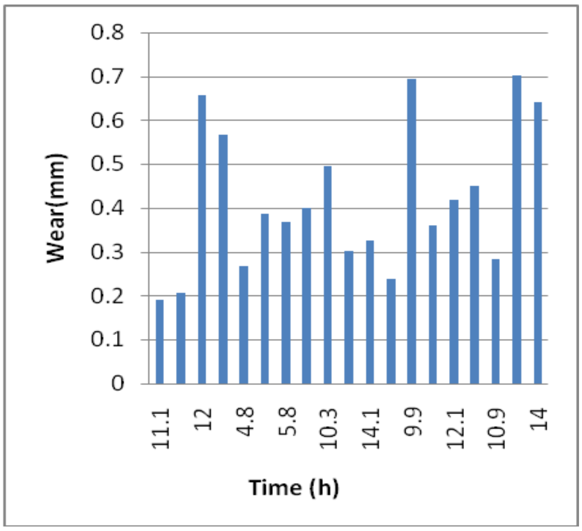



Fig.5. Wear Vs Time

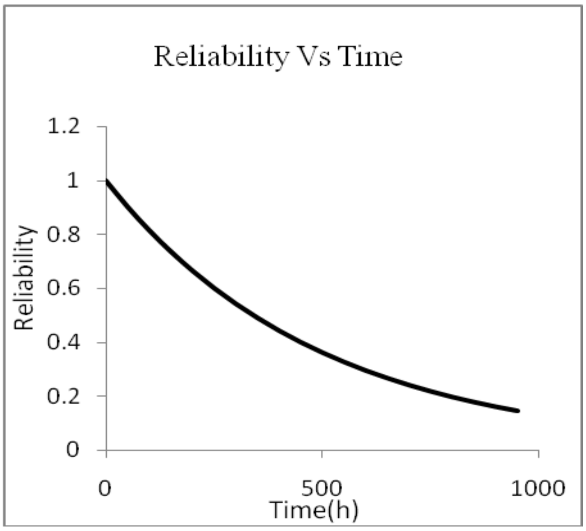



Figure. 6. Relaibility Vs Time

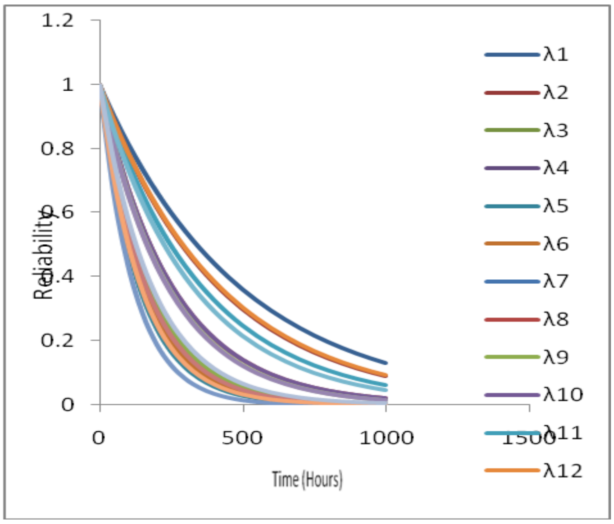



**Figure 7. Relaibility** Vs Time (for all stations)

On analysis, it is found that wear rate is comparatively less in Station 1, 2 and 12 and life of the button bit is more in these areas.

**Conclusion**

Numerous parameters such as the origin of rocks formation, Mohs hardness, texture of rock (shape and size of rock grains), porosity, density, abrasiveness, rigidity, P-wave velocity, elasticity and plasticity, tensile strength, affect the drilling rate and drillability of rocks.

The bit wear of pneumatic top hammer drills was correlated with rock hardness. Also a correlation between resistivity and reliability was presented. Considering the presented results, it is obvious that the correlations have been suggested according rock hardness and bit wear. It is suggested that in future studies the parameters of drilling equipment, rock parameters and effects of bit diameter be incorporated. This will help in estimation of button bit reliability at different geographical locations as resistance varies from location to location.

**References**

[1]. Ahilan J. and G.R.Senthil Kumar. Archives of Applied Science Research, 2011, 3(2): 414 – 421

[2]. J. Raimi, M. S. Abdulkarim, Hamidu I, A. S. Arabi. Application of Schlumberger Vertical Electrical Sounding for Determination of Suitable Sites for Construction of Boreholes for Irrigation Scheme within a Basement Complex, International Journal of Multi Disciplinary Sciences and Engineering, 2011, Vol 2, No.6, [ISSN: 2045-7057]

[3]. B.S. Jatau, N.O. Patrick, A. Baba, S.I, Fadele, The Use of Vertical Electrical Sounding (VES) for Subsurface Geophysical Investigation, IOSR Journal of Engineering (IOSRJEN), 2013, Vol. 3, Issue PP 10-15

[4]. H.T.Nejad, M.Mumipour, R.Kaboli, O.A.Najib Vertical Electrical Sounding (VES) Resistivity Survey Technique to Explore Groundwater in an Arid Region, Southeast Iran, 2011, Journal of Applied Sciences 11 [23]: 3765-3774

[5]. Ramanuja chary K. R., and T. Gangadhra Rao. A monograph on groundwater exploration by resistivity and well logging techniques, (IGIS**,** 2005**)** Hyderabad.

[6]. Ralf J. Plinninger, Georg Spaun, Kurosch Thuro, Technical Review- Predicting Tool wear in drill and blast, Tunnels & Tunnelling International Magazine 2002.

[7]. N. Bilgin, S. Kahraman. Drillability Prediction in Rotary Blast Hole Drilling, International Mining Congress and Exhibition of Turkey-IMCET 2003, ISBN 975-395-605-3

[8]. www.rockmore-intl.com

[9]. Edy Tonnizam Mohamad, Rosli Saad, Nor Nazrin Binti Hamzah, Siti Norsalkini Mohd. Akip Tan. Assessment on Abrasiveness of Rock Material on the Wear and Tear of Drilling Tool. 2012, EJGE Vol. 17 Bund. A

[10]. K. Thuro, Drillability prediction - geological influences in hard rock drill and blast tunneling 1997, Geol Rundsch 86: 426 – 438

[11]. Olgay Yarali, Eren Soyer, Assessment of relationships between drilling rate index and mechanical properties of rocks, Tunnelling and Underground Space Technology 33, 2013 46–53.

[12]. Performance prediction of hard rock TBM using Rock Mass Rating (RMR) system, Rostami, J. (2010), Tunnelling and Underground Space Technology, 25(4), 333-345.

[13]. Silje Marie Solberg, Improved drilling process through the determination of hardness and lithology boundaries, 2012, Earth Sciences and Petroleum Engineering, Norwegian University of Science and Technology

[14]. S. H. Hoseinie, M. Ataei, A. Aghababaie. A laboratory study of rock properties affecting the penetration rate of pneumatic top hammer drills, ***J****ournal of* ***M****ining &* ***E****nvironment, Vol.4, No.2, 2013, 133- 142.*