Application of a Laser Distance Sensor in the Measurement of Stemming Height

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Abstract

Surface mining blasting techniques may be viewed as the most inexpensive technology used for fragmenting rocks masses compared to underground mining blasting techniques. About 20-30% of the energy used is utilised for rock fragmentation and displacement, while the remainder is lost as ground vibrations, air blast, noise, and fly rocks of which are all dangerous as they pose hazard to the environment. To minimise these effects of blasting, there is the need to use an appropriate stemming height to achieve the purpose of minimising the effects of blasts. This project seeks to introduce the use of a laser distance meter in the measurement of stemming height which can be used as an alternative to the traditional method of measuring the stemming height with tape measures having counterweights tied at its end. The method used involved reviewing relevant literature, data collection from the Gold Fields Ghana Limited, Tarkwa mine with the use of both the proposed device and the tape measure and analysing of the data obtained from the field. Analysis of the data showed a difference which averaged at about 0.05m per the data collected. The use of the proposed device gave readings that were of higher accuracy with their three decimal point values as compared to the tape measure’s readings. The use of the device comes with coupled advantages of simplicity and ease of use as personnel do not need training to use the device. The results obtained showed that the device can be used as an alternative to the use of the tape measure. This device is proposed because of it reduces personnel contact with explosives, thereby reducing the cost of hang glove acquisition as these explosives tend to wear the hand gloves. The proposed device as an alternative to the use of tape measure is more advantageous due to the continuous wiping of explosives on the surface of the tape measure after taking the reading which defaces the tape measure’s readings making it impossible to read from it. This will replace the frequent purchasing of tape measures to replace defaced ones. This device is more expensive than a tape measure as the least price on the market was about GHc 300 but is worth the purchase due to the safety relief it brings to the personnel and the company’s budget on replacing wearing hand gloves and frequent defacing of tape measures’ surfaces. The frequent need to replace worn-out hand gloves and tape measures and their repercussive accumulative cost would be lower if a laser distance sensor is used instead with a relatively high initial purchase cost.

Keywords: Blasting, Stemming, Stemming Height, Tape Measure, Laser Distance Sensor.

1 Introduction

The measurement of the initial stemming height, before gassing of the explosives in the explosive column and the final stemming height, after gassing of the explosives in the explosive column was done initially at Gold Fields Ghana Limited with a calibrated stick or a charging stick, which advanced to the use of a tape measure with a counterweight tied at its tip. The use of the tape measure has some difficulties that comes along with it. The bulk emulsion soils the surface of the tape measure, making its reading difficult. Also, cleaning of the surface of the tape measure defaces it by rubbing off the markings or the writings on the tape measure.

The use of the tape measure is also associated with parallax and reading errors as the height of the drill cuttings at the collar of the drill hole is sometimes read in addition to the stemming height. The parallax error comes into play when reading from the tape measure at a height.

The personnel in use of the tape measure touches the tape measure with the explosives on it which contaminates the hand of the personnel with the explosives and for that matter they must wear gloves to protect themselves. The hand gloves will have to be replaced with time as a result of frequent contact with the emulsion, wearing out the hand gloves.

This project seeks to provide an alternative to the use of the tape measure with a distance sensor, which would be used to measure the stemming height of the drill hole. It will then tackle the challenges with the use of the tape measure because there would be no defacing of the device used in taking the measurement. Also, there would be no parallax errors associated with the reading as the user would have to take the measurement at the tip of the drill hole and not on the drill cuttings. This is a non-contact mode of measurement which implies that, there would be no contamination of the hands of the personnel in the use of the measurement device thereby reducing cost on the hand gloves provided for their use. The class of laser to be used in this project is a low power laser system, which is in the visible range 400 - 700 nm wavelength that may be viewed directly under carefully controlled exposure conditions with no hazard to the explosives and the user when wearing safety goggles.

1.1 Problem Formulation

This project is aimed at taking measurement of stemming height with the use of a laser distance sensor and comparing the results obtained to that of the classical approach of measuring the stemming height with the use of a tape measure. Recommendations will also be made per the observations and results obtained.

1.1.1 Blasting operation and its relationship with stemming height

1.1.1.1 Blasting and the effects of blasting

The mining sector considers blasting to be an essential part of their operations' success. Explosives are required in blasting rock, despite the associated hazards. An excavation process' primary goal is to remove rock material, either to make an opening or to collect material for its inherent worth. It is essential to cause further fracture and fragmentation of a rock mass in order to remove a portion of it. The first preliminary stage in the extraction process is rock fragmentation, which is essential to mining. Drilling blast holes, filling the borehole with explosives, and then detonating the explosive in each hole. All holes must be bored in line with the predetermined drilling pattern for the optimum blasting results. Blasting by design is the consequence of a variety of elements that must all be managed in order to get the desired outcome.

About 20-30% of the energy released during blasting is utilized for rock fragmentation and displacement, while the remainder is lost as ground vibrations, air blast, noise, and fly rocks of which are all dangerous to the environment as they pose hazard to the environment (Ghasemi, Sari and Ataei, 2012). They are a major source of concern because they will wreak havoc on the surface infrastructure, constructions and annoyances to the residents in the area and even the safety of both man and animals around these blasting areas. Mines are reaching inhabited areas at an alarming rate. The combined influence of various elements such as site features, surface propagation, ground body waves, and structural response should be considered while analysing vibration-related problems.

Ground Vibration

According to Yenzanya (2018) vibrations in the ground are generated by rock blasting, piling, excavation, vibration compaction, and other factors. When ground vibrations, which are a type of energy transfer through the ground, reach a particular threshold, they can cause damage to nearby structures. Some of the energy released by a blast travel in all directions from the hole as different-frequency seismic waves. Distance dampens the energy of these seismic waves, and the waves with the highest frequency are damped first. This indicates that the blast's main frequencies are higher at close range and lower at further ranges. To assess the possible damage, the ground vibration intensity was evaluated in terms of Peak Particle Velocity (PPV). Peak particle velocity, which is a structural damage indication, is mostly determined by the maximum charge, the distance between the blast and the measuring site, and the medium's characteristics. Ground vibrations produced from bench blasting may cause damage to pit slopes, infrastructures and even underground workings in close vicinity to an operational open pit mine. Ground vibration levels caused by blasting must therefore be monitored and predicted to take steps to mitigate their harmful consequences. Also, geological conditions of the mine, the blasting parameters including the stemming height and the material used for stemming and other environmental factors may influence the propagation of vibration through the ground.

Air blast

According to Aloui et al. (2016), air blast represents an undesirable and unavoidable output of blasting technique. The air blast damage and annoyance may be influenced by numerous factors such as blast design, weather, field characteristics, and human response. Air blast disturbances propagate as compression wave in air. Under specific weather conditions and poor blast designs, air blast can travel for long distances. The over pressure may be expressed in Pascal (Pa) or with decibels (dB). Air blast is an atmospheric pressure waves emanating from explosion in air. The audible part of the air blast (acoustic) is characterised by higher frequency from 20 to 20,000 Hz. The sub-audible part of the air blast (infrasound) having a low frequency content below 20 Hz. Unlike the audible air blast (Acoustic), which is classified as noise, the air blast at frequencies below 20 Hz is called concussion. According to Olofsson (1990), the immediate effect of blasting is not only to cause ground vibrations and throw, but also an air shock wave. In most routine blasting, in which the explosives are enclosed in blast holes, and which are designed for ground vibration velocities of 70 mm/sec or less, the blasting does not cause air shock waves of the magnitude that may cause damage to buildings. These are classified as an "over pressure" when air blast pressure exceeds atmospheric pressure. Air blast exerts a force on structures and in turn causes a secondary and audible rattle within a structure. It is very often confused with vibrations transmitted by the ground. High air blast over pressure could cause structural damage, while those produced by routine blasting operations under normal atmospheric conditions are not likely to do so. The air blast threshold recommended by the Environmental Protection Agency (EPA) of Ghana should not exceed 117 dB(L). This is the standard set for every mine in Ghana to adhere to.

Fly rocks

Fly rocks are defined as the rocks propelled beyond the blast area by the force of an explosion. Fly rocks come in different sizes and shapes, ranging in mass from few ounces to several tons. When an explosive charge is fired in a blast hole, a compression wave travels to the highwall face. Sandstone, shale, limestone, dolomite, and granite are all strong in compression and suffer little damage from the compression wave. However, when the compression wave arrives at the free face, it is reflected as a tensile wave. Because most of these rocks are brittle, the tensile wave causes cracks and fractures in them. The rocks are therefore weakened by tension. The gases produced by detonation enter the tensile-fractured areas and resume their expanding operation, causing fissures to propagate. After that, gas pressurization causes the fragmented mass of rock to erupt from the bench. When the pressurization is much more than the formation can contain, then there comes the outburst of the rock, causing fly rocks as defined (Bajpayee, Verakis and Lobb, 2007).

According to Bajpayee, Verakis and Lobb (2007), the listed effects of blasting can be reduced by designing a safe and efficient blast. The burden, spacing, depth, stemming, subdrill, initiation system and the type of explosives employed should match the characteristics of the rock formation. Loading an explosive charge close to the collar zone causes insufficient stemming, resulting in bench-top fly rock. High explosive concentration in the blast holes causes excessive localized energy density due to explosive charge migration into fissures, caverns, voids, and mud seams. Taking the use of appropriate stemming height into consideration

1.1.1.2 Stemming

According to Konya and Konya (2018), stemming is employed to help sustain this gas pressure over time to increase the performance of a blast. Stemming materials are nonexplosive materials that are placed on top of an explosive column. This can also be referred to as "Tampering". The goal is to maintain it in the blast hole for the duration of the detonation. Stemming has been found to improve explosive efficiency in a variety of explosive and blasting conditions. Proper stemming has been proven to boost explosive efficiency by more than 41%. Furthermore, stemming is critical in overbreak control, with good stemming resulting in a 200% percent boost in the performance of a stemmed presplit hole when compared to an unstemmed presplit hole. Proper stemming has also resulted in an 18.6% reduction in digging time for shovels and excavators (Konya and Konya 2018).

Stemming is one of the major components of a proper blast design, with proper stemming leading to up to a 98% decrease in air overpressure, (Konya and Konya 2018) and according to Konya (2015), the optimum stemming height results in a reduction of ground vibration and fly rock, and an increase in rock fragmentation. With all these advantages of the stemming height, one may be forced to use more of the stemming materials to combat the effects of blast as in preventing or reducing the cases of ground vibration, fly rocks and to increase fragmentation of the rock mass. The other side of the coin is that the use of too much stemming materials can lead to an increase in this same ground vibration and fly rocks one may try to prevent with a bonus effect of having a mixture of finely fragmented materials and boulders, which are undesirable in the act of blasting. Using too much of the stemming material can cause a reduction in the bench's stiffness ratio, causing it to act as a cratering mechanism, leading to the ground vibration and fly rocks (Konya 1968). There is the need then to use an appropriate stemming height to fight the effects of using more stemming materials and using low amount of the materials, which would result in excess cost and delay subsequent activities. This stemming height should then be measured properly for the optimum stemming height to be reached, to ensure efficient and effective fragmentation of the formation.

Measurement of stemming height

The measurement of the stemming height is done after the explosives have been placed in the drill hole or when the hole has been charged. This activity is done by the personnel using a measuring instrument or a measurement device to take the reading of the depth of the drill hole from the explosive column to the collar of the drill hole or the blast hole.

Since the use of less and using more of the stemming materials apart from the appropriate stemming causes adverse blast effect, there comes the need to measure the appropriate stemming height to correspond to the designed stemming height that has been designed with the blast pattern to achieve the desired fragmentation with minimal effects from the blast.

The devices used in the measurement of stemming height are as follows.

The charging stick

Gold Fields Ghana Limited, Tarkwa used to use a charging stick, which was placed inside the drill hole after charging to take the reading of the stemming height. This was cut at the exact height needed for the stemming height. The use of the charging stick although was efficient sometimes, could not reach a depth of more than 3 m. When there were drill holes with fractures or cracks in the formation, the emulsion seeped into these holes, making the drill holes empty with no emulsion as though have not been charged. These charging sticks would not be able to reach these depths to measure the volume of explosives needed to top up. There is also the disadvantage of the emulsion soiling the surface of the stick-rule, to the extent that when pulled up after the measurement, they drip onto the working gear of the person taking the measurement. Again, it could not be used to measure holes that were deeper than the length of the stick.

The tape measure

A tape measure of with a counterweight tied to its base was used to replace the charging stick. Both the charging stick and the tape measure are used side by side. The charging stick used only for charging to prevent overcharging and undercharging of the drill holes during charging and the tape measure as a quality control mechanism to double check the stemming height. The tape measure is reeled into the drill hole after the emulsion has been pumped into the holes. The counterweight hits the surface of the emulsion and then the reading is taken from the collar of the hole. The tape measure is then reeled back into its place. The personnel then move to another hole. The counterweight is tied at its base to indicate to the personnel taking the measurement that the tape has reached the bottom or has hit the surface of the emulsion placed in the drill hole. This process although simple has a lot of complications.

There is the case where the surface of the tape measure is soiled with the emulsion pumped in the hole as it is being reeled in and out of the hole guided by the hand of the personnel. The personnel in attempt to take the reading from the tape measure would then have to clean the surface of the tape measure in order to get the reading and then record this reading. Wiping the surface of the tape measure with time gets the surface of the tape measure defaced to the extent that there would be no way any reading can be taken from the tape measure. The tape measure must then be replaced as reading has become impossible. Again, as the personnel tries to clean the surface of the tape measure to take the reading with the hand glove, the hand gloves with time also gets worn out and then must be replaced, bringing in extra cost.

The laser distance sensor

This is a proposed device that can be used to measure the stemming height. This is an electronic battery-operated device having a wide range of distances that can be measured per the discretion of the user as to the distance, the depth, or the height he wants to measure. The user in his attempt to measure the distance must turn on the device, press a button to open the laser point, direct the laser to the point where the desired measurement is to be taken and then press that same button again to take the reading from the screen of the device. In the application of the device in the drill and blast activities, the device can be used to measure the depth of the hole and the stemming height.

The Operating Principles of the Laser Distance Sensor

Laser distance detectors are used to precisely measure the distance between an object that is being targeted by a laser path. This fundamental measurement operating principle is based on timing the transition of laser pulses between the laser distance meter and the item being measured. This is also called the Time-of-Flight Method. The time-of-flight method makes use of the pulse, amplitude or frequency modulation laser range methods. The flying time of the pulse reflected off the target is measured in the Pulse Modulation method with respect to the Time-of-Flight Method (Goldstein, 1967; Koechner 1968 and Määttä et al., 1993).

Pulsed methods are primarily employed across large distance methods and in situations that need quick measurement times. The laser range finder consists of a transmitter, a receiver channel and a time measuring unit. In simple terms, the device uses the time of flight of light to measure distance. The laser beam is projected from the housing's aperture and shines on a target surface, where it creates a small spot. From there the laser light is scattered in all directions. A collection lens is in the sensor to the side of the laser aperture. It collects a portion of the reflected light, which is focused on a photodetector and converted to an electrical signal. The signal is amplified and symbolises a shift in phase. This phase is compared to a reference signal to determine the amount of shift and hence a change in distance.

Measurement of distances with the use of a laser depends on the application of LiDAR (Light Detection of Laser Imaging and Ranging). A laser pulse is emitted to an item or surface by this LiDAR laser. The distance between emitting the diode and receiving the reflection is then calculated using the elapsed time between emitting the diode and receiving the reflection.

A precise wavelength of light is emitted by the LiDAR. After the receiver receives the signals transmitted by the device, a comparator determines the reception time. The distance measured is then calculated by determining the phase shift between the broadcast and received signals. By comparing the signal from the laser with the delayed signal returning from the target, the time delay is indirectly calculated.

Lasers must adhere to the same regulations as ordinary light. Speed, extreme precision, and a strong focus on microscopic surfaces are just a few of the benefits. Lasers can be used to measure size across extremely short distances as well as very long distances.

2 Materials, Methods Used

2.1 Materials

In order to take measurement of the stemming height, a tape measure and a laser distance sensor were used.

2.2 Methods Used

The methods used are:

i. Review of relevant literature;
ii. Field visit for data collection;
iii. Compare the collected data using the planned stemming height, the actual measurement taken by the tape measure and that of the laser distance sensor; and
iv. Analyse the averages of the planned stemming height, the actual measurement taken by the tape measure and that of the laser distance sensor.

Data Collection

Data related to the use of tape measure was collected from the Gold Fields Ghana Limited, Tarkwa Site, under the supervision of BCM. This data was taken from one of the Teberebie pits specifically the Teberebie Cut 4. The data collected includes the following:

i. The hole Identification number of the individual blast holes (Hole ID);
ii. The design depth of the individual blast holes;
iii. The actual depth of the individual blast holes;
iv. The initial stemming height of the blast holes using the tape measure;
v. The final stemming height of the blast holes using the tape measure;
vi. The initial stemming height of the blast holes using the device; and
vii. The final stemming height of the blast holes using the device.

These data were measurements taken in the pit by the Quality Assurance and Quality Control team of the BCM using the tape measure, whilst the distance sensor device was also used to check the stemming heights of the blast holes. The data obtained shows how the device is more accurate and helpful in terms of ease of work or simplicity.

In taking the data, the initial stemming height of the blast holes are measured first after the boosters and the emulsion (explosives) are pumped into the blast holes. Then the final stemming height was also measured after 45 minutes where the explosives have gassed up, thereby decreasing the stemming height by about 0.2 m.

Emulsion and blended ANFO-emulsion explosives constitute most explosives used in the mining industry. These types of explosives require sensitisation prior to detonation by the introduction of void spaces into the emulsion matrix. Void spaces create hotspots within the explosive sensitizing it to detonation. The density of a typical emulsion explosive is around 1 300 kg/m3 and this density needs to be reduced to around 1 000 kg/m3 for an efficient blast. As such, gas is introduced into the emulsion equivalent to around one third of the total emulsion density. This gas may be introduced, for example, by sparging air through the emulsion or blending in hollow glass micro balloons or porous material. A more effective means of sensitization is through chemical gassing, where a chemical reaction is used to generate gas bubbles within the emulsion. Chemical gassing usually involves the reaction of nitrite with ammonia or other amine substrate such as thiourea to produce nitrogen gas. However, such processes are typically slow, especially at low to ambient temperatures, which can cause significant mine-site delays.

3 Results and Discussions

3.1 Results and Discussions

A total number of 211 blast holes were on the blast pattern. These holes were charged with a booster and emulsion from the African Explosives Limited (AEL). In analysing the data, the designed, initial and the final stemming height measured by the tape measure and that measured by the laser sensor were plotted against the Hole I.D using excel spreadsheets. The average initial stemming height measured by the tape measure was 3.2625m and that of the laser distance meter being 3.1853m, which was 0.2625m and 0.1853m difference respectively as compared to the planned stemming height of 3.0m.

The formula used to calculate the average stemming heights for the tape measure and that of the laser distance sensor were:

$$\bar{X} = \frac{\sum(\text{Initial Stemming height measured by the tape measure})}{(\text{Total number of holes measured by the tape measure})}$$

$$\bar{X} = \frac{\sum(\text{Initial Stemming height measured by the laser distance sensor})}{(\text{Total number of holes measured by the laser distance sensor})}$$

The final stemming heights also averaged 2.8336m and 2.8673m for the reading of the tape measure and the laser distance sensors respectively. These were also calculated by using the formula:

$$\bar{X} = \frac{\sum(\text{Final Stemming height measured by the tape measure})}{(\text{Total number of holes measured by the tape measure})}$$

$$\bar{X} = \frac{\sum(\text{Final Stemming height measured by the laser distance sensor})}{(\text{Total number of holes measured by the laser distance sensor})}$$

Figure 4.1 shows a graph of design initial stemming height, initial stemming height measured by the tape measure and the initial stemming height measured by the laser sensor, plotted against the Hole I.D.

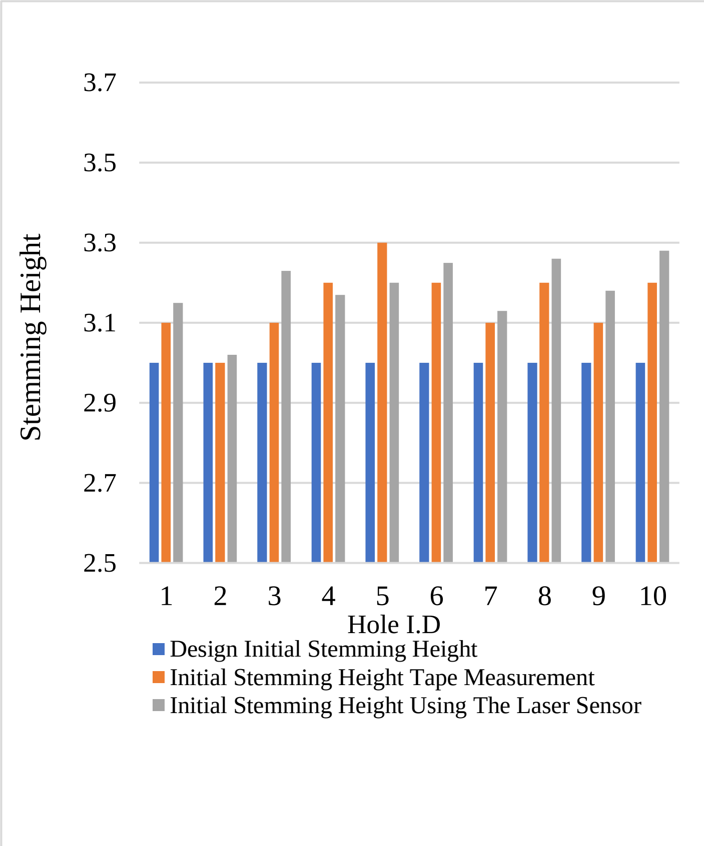

Figure 4.1 A Graph of Stemming Initial Heights Against the Hole ID's

Figure 4.2 shows a graph of design final stemming height, final stemming height measured by the tape measure and the final stemming height measured by the laser sensor, plotted against the Hole I.D.

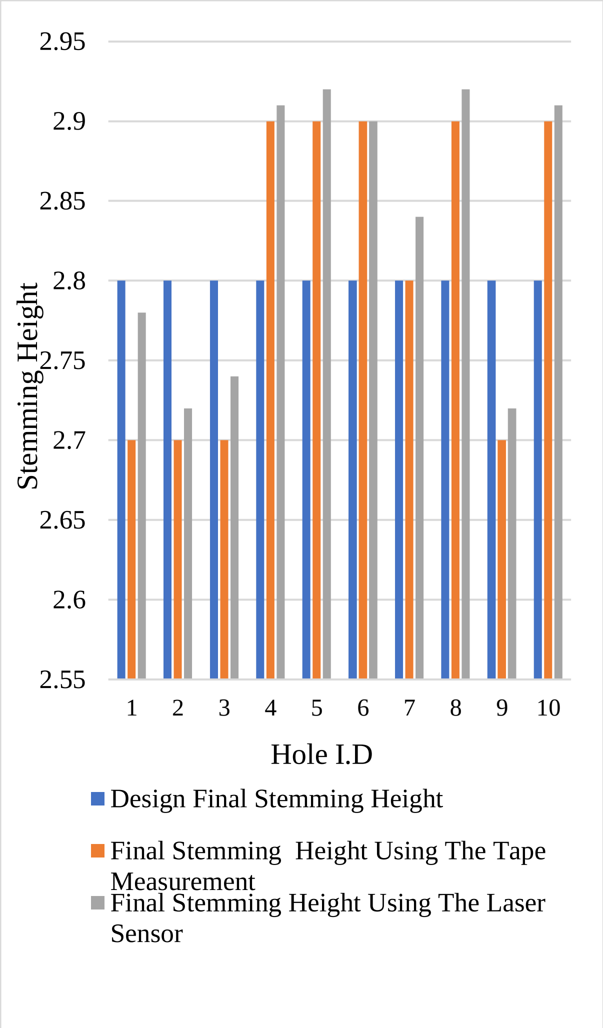

Figure 4.2 A Graph of Stemming Initial Heights Against the Hole ID's

The average stemming height of the initial stemming height measured by tape measure which is 3.2625m and that of the laser distance sensor being 3.1853m are almost the same with a difference of 0.0772m. The average final stemming height of 2.8336m and 2.8673m measured for the tape measure and the laser distance sensor respectively also have a difference of the final stemming height also being 0.0337m.

These average stemming heights are almost the same as the planned stemming height given as 3m and 2.8m for the initial stemming height and the final stemming height respectively. If the recorded values are close to the planned or designed measurements, then it means the device is also accurate just as the tape measure, which has been used over the years in the QA/QC of the drill and blast activity.

3.2 Advantages of the Laser Distance Sensor over the Tape Measure in Handling, Ease of Operation, Maintenance and Cost, of the Laser Distance Sensor to the Tape Measure

The Laser Distance Sensor has a wide range of advantages compared to the use of the traditional tape measures when it comes to handling and maintenance of the two devices.

For the handling aspect, the device is equipped with a band that is worn around the wrist, which holds the device around the wrist. Its portable nature gives the user the merit of ease in writing down the dips after taking the measurement instead of having to put down the measuring device and writing down the dip as it is in the case of the tape measure.

It makes work faster as it reduces the need for two or more personnel to be allocated to one pattern as one takes the measurement whilst the other records the measurements taken. With the use of the laser distance sensor, an individual can take the measurement and record at the same time or take the measurement and recall the measurements taken as these measurements are stored on the device. It makes the Quality Assurance/Quality Control's work more credible during rainy seasons as they can take the measurements and recall them for recording's sake than to be in the rain with their papers and pens to record the measurements they have taken.

Operating this device needs little or no training as it has few buttons clearly labelled by their functions for the layman to be able to operate.
First timers would be little or no training as the buttons are clearly marked indicating the button to turn on/off, changing units of measurements, recall last measurements and the button to take the reading when the laser hits the desired surface.

The laser distance sensor has a strong covering frame, which protects the entire device from rupturing when it hits a hard surface. Maintaining this device only requires regular change of the batteries. It uses the regular dry cell batteries to operate and they cost less as compared to buying new tape measures when they get defaced.

The laser distance sensor comes at a disadvantage of having a relatively high cost as compared to the tape measure. This cost suffices the need to replace hand gloves and tape measures as they deface easily from wiping off the surfaces clean from the emulsion after every measurement.

4 Conclusion and Recommendation

4.1 Conclusion

The following observations were made:

i. The laser can be pointed at the sides of the drill holes, giving a false reading of the stemming height;

ii. Since the laser distance sensor is a non-contact form of measurement, the personnel get no contact with the explosives, thereby reducing the risks of the effects of explosives (emulsion) on the skin of the personnel and reactivity of the explosives to the hand gloves of the personnel; and

iii. Personnel who are reactive to hand gloves can work without the use of hand gloves since there would be no contact with the explosives.

From the observations, conclusion can be drawn that the laser distance sensor can be used as an alternative to the tape measure in the measurement of the stemming height.

4.2 Recommendation

It is recommended that; the measurement of the stemming height should be done in manner that the laser will be pointed directly into the hole to get the correct reading of the stemming height.

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APPENDIX A

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) DATA

Table A1 Quality Assurance/Quality Control (QA/QC) Data

Hole ID	Design Depth	Actual Depth	Design Initial Stemming Height	Initial Stemming Height Tape Measurement	Initial Stemming Height Using The Laser Sensor	Design Final Stemming Height	Final Stemming Height Using The Tape Measurement	Final Stemming Height Using The Laser Sensor
1	10.2	11.2	3	3.1	3.15	2.8	2.7	2.78
2	10	11.1	3	3	3.02	2.8	2.7	2.72
3	9.7	10	3	3.1	3.23	2.8	2.7	2.74
4	9.9	9.9	3	3.2	3.17	2.8	2.9	2.91
5	10.1	10.4	3	3.3	3.2	2.8	2.9	2.92
6	10.1	10	3	3.2	3.25	2.8	2.9	2.9
7	10.2	10.2	3	3.1	3.13	2.8	2.8	2.84
8	10.2	10.5	3	3.2	3.26	2.8	2.9	2.92
9	10.1	10.2	3	3.1	3.18	2.8	2.7	2.72
10	10	10	3	3.2	3.28	2.8	2.9	2.91
11	9.8	9.2	3	3.6	3.68	2.8	3	3.13
12	10	9.5	3	2.9	2.96	2.8	2.9	2.78
13	10	9.6	3	3.1	3.17	2.8	2.9	2.93
14	9.9	9.8	3	3.2	3.25	2.8	2.9	2.97
15	9.8	10	3	3	3.07	2.8	2.7	2.7
16	9.8	10	3	3.1	3.16	2.8	2.8	2.83
17	9.7	10	3	3.3	3.35	2.8	3	2.94
18	9.8	9.8	3	3.2	3.14	2.8	2.9	2.88
19	10	10.1	3	3.1	3.03	2.8	2.8	2.76
20	10.2	10.1	3	3.2	3.24	2.8	2.8	2.91
21	10.3	10.4	3	3.1	3.22	2.8	2.8	2.85
22	10.1	9.1	3	3.2	3.24	2.8	2.9	2.95

23	10.1	9.8	3	3.1	3.17	2.8	2.8	2.84
24	9.9	10.1	3	3.2	3.24	2.8	2.9	2.87
25	9.7	10	3	3.1	3.14	2.8	2.7	2.76
26	9.8	10.1	3	3	3.06	2.8	2.7	2.73
27	10.2	10.4	3	3.2	3.24	2.8	2.8	2.91
28	10.2	10.5	3	3.1	3.14	2.8	2.8	2.87
29	10	10.2	3	3.2	3.25	2.8	2.9	2.88
30	9.6	9.7	3	3.1	3.17	2.8	2.8	2.79
31	9.6	9.6	3	3.1	3.13	2.8	2.8	2.85
32	9.9	10	3	3.2	3.22	2.8	2.9	2.97
33	9.9	10.1	3	3.1	3.18	2.8	2.9	2.87
34	10	10.3	3	3.1	3.15	2.8	2.8	2.85
35	10.1	10.3	3	3.2	3.26	2.8	2.9	2.82
36	10.2	10.2	3	3.2	3.27	2.8	2.9	2.94
37	10	10.1	3	3.1	3.15	2.8	2.7	2.72
38	10.1	10.2	3	3.2	3.23	2.8	2.8	2.81
39	9.9	10	3	3.1	3.14	2.8	2.9	2.95
40	9.7	9.6	3	3.2	3.23	2.8	2.9	2.99
41	9.9	10.2	3	3.2	3.24	2.8	2.8	2.75
42	9.9	10.2	3	3.2	3.25	2.8	2.9	2.87
43	9.9	10.1	3	3.1	3.2	2.8	2.8	2.77
44	10	10.2	3	3.2	3.29	2.8	2.9	2.84
45	9.9	9	3	3.1	3.15	2.8	2.9	2.95
46	9.8	10	3	3.2	3.25	2.8	2.9	2.97
47	9.8	10	3	3.2	3.3	2.8	2.8	2.88
48	9.8	10	3	3.1	3.3	2.8	2.8	2.74
49	9.8	10	3	3.2	3.25	2.8	2.9	2.91
50	10.1	10.4	3	3.1	3.15	2.8	2.8	2.73