Effectiveness of Banana Trunk as Protection Wall from High Velocity Shrapnel During Detonation of Unexploded Ordnance (UXO)

Abdul Rashid Othman¹, Ahmad Humaizi Hilmi¹, Asna Rasyidah Abdul Hamid¹,² and Wong Xian Jun²

¹Faculty of Mechanical Engineering Technology, University Malaysia Perlis, Kampus Tetap Pauh Putra, 02600 Arau, Perlis, Malaysia
²Center of Excellence Geopolymer and Green Technology (CEGeoGTECH), Universiti Malaysia Perlis, Arau, Perlis 02600, Malaysia

Email: rashidothman@studentmail.unimap.edu.my

Abstract. This paper is to investigate banana trunk fibre to be constructed alternatively for the sand bag and high energy absorption. The aim of this study also for enhancing method of absorption velocity shrapnel during detonated of Unexploded Ordnance (UXO), Explosive Remnants of War (ERW) and Improvise Explosive Device (IED). The study involved blast test which is providing high energy impact based on the amount of explosive used. Type of explosive were used are Emulex 180 with velocity of detonation 4500m/s to 5700m/s, Explosive energy 4.17 MJ/kg, density 1.13g/cc to 1.21g/cc and initiation were used are No. 8 Detonator. The structure of specimen is analysed using Stereo Microscope Image Analyser (35x zoom) which is an optical instrument that can observe the structure of the fragments (banana fibre) after blast test. Results shows that banana trunk can become a protection wall as it can absorb the impact of blast from explosion.

1. Introduction
Explosions may be caused by a number of occurrences, including industrial accidents or UXO explosions. The majority of explosive ordnance disposal (EOD) operators are unable to deal with fragments, splinters, or shrapnel, which are produced by an explosion, rendering them highly dangerous and potentially fatal. A bomb of total weight 20kg containing 2kg explosive remnant of World War II (WWII) was discovered at the water tank construction site of University Malaysia Perlis Sports Centre Zone in Ulu Pauh, Perlis, BH Online, April 11, 2017. A mortar bomb with total weight of 1350 grams and an explosive weight of 220 grams were discovered in a rubber tree plantation area in Felda Mata Ayer, Padang Besar, Hmetro online October 26, 2020. The EOD suit is one of the methods for shielding the EOD operator with wall protection. Sand bags are often used as wall protection. The disadvantage of a sand bag is that sand may be one of the splinter's enhancements. The aim of this study is to establish a new method of blast absorption and shrapnel defence. One of the methods for minimising harmful destruction is by blasting or high energy absorption. Banana trunk can potentially take place of the sand bag as a wall protection. Banana fibre prevents the trunk from becoming a splinter. The blast and explosion heat would be absorbed by the water density in the trunk. The splinter or shrapnel would be stopped by the trunk. Emulex 180 will be used to make the booster charge, which will be attached to a ball bearing as shrapnel and splinter. During the experiments, other safety precautions were introduced, such as the digging process, also known as the Underground Hole Technic. [1] In general, banana trunk...
is a cheap, abundant, and renewable resource for adsorbent synthesis. Banana fibre has a tensile strength of 600Mpa, making it one of the strongest natural fibres. [2] When banana fibre is combined with virgin fibre, the tensile strength rises to 891 MPa. Banana fibre has equivalent tensile strength, durability, and rot resistance to glass fibres.

2. Experimental Procedure

2.1 Material Selection
Banana trunk are being chosen as the material for blast test mitigation. The typical banana trunk was obtained from farming plantation. As mentioned earlier, banana trunk is being chosen for this research target as a blast mitigation material because banana plants could be easily found in most rural areas in Malaysia. [3] Besides, fibre in the banana trunk seems to have the potential possibility to weaken the fragment from UXO. The properties of banana trunk fibres are stated in table 1. After the blast test, banana trunk as parameters will be defined to quantify the effectiveness of blast load mitigation. Figure 1 shows the banana trunk fibre.

Table 1. Properties of banana trunk Fibre [4].

| Fibres         | Width or diameter (µm) | Density (kg/m³) | Cell L/D ratio | Microfibrillar angle (degree) | Initial modulus (GPa) | Tensile strength (MPa) | Elongation (%) |
|----------------|------------------------|-----------------|----------------|-------------------------------|-----------------------|------------------------|----------------|
| Banana pseudo-fibre | 80–250                 | 1350            | 150            | 10 ± 1                        | 7.7–20.0              | 54–754                 | 10.35          |

2.2 Preparing of Banana Trunk Fibre
Banana trunk is common in Malaysia. However, there are still many people who have not realized the advantages and benefits of this banana trunk. In fact, most of the people here prefer to throw it away and became a waste. Despite other benefits, this banana trunk can also be used for various purposes, including being an explosive blast absorption. These banana trunks were cut and weighed in figure 2 (a) and the dimension of each banana trunk was taken to determine the fibre content. Ball bearing are simulated as fragmentation will be attach at explosive charge toward to banana trunk. Banana trunk will be placed in three horizontal banana trunks in the explosion hole in the middle of the explosive charge as shown in figure 2 (b) each banana trunk will be monitored ball bearing will penetrate the trunk with each gram of explosion will be increased from 500g to 1kg Emulex.
Table 2. Specimen Data of Banana Trunk for protection wall.

| Explosive  | Banana Trunk  | Weight | Diameter | Height |
|------------|---------------|--------|----------|--------|
| 500 grams  | Banana Trunk 1| 5.1 kg | 14.2 cm  | 75 cm  |
|            | Banana Trunk 2| 4.9 kg | 13.8 cm  | 75 cm  |
|            | Banana Trunk 3| 4.8 kg | 12.2 cm  | 75 cm  |
| 600 grams  | Banana Trunk 4| 5.1 kg | 14.3 cm  | 75 cm  |
|            | Banana Trunk 5| 4.7 kg | 11.5 cm  | 75 cm  |
|            | Banana Trunk 6| 4.6 kg | 11.2 cm  | 75 cm  |
| 800 grams  | Banana Trunk 7| 5.1 kg | 14.3 cm  | 75 cm  |
|            | Banana Trunk 8| 4.7 kg | 11.6 cm  | 75 cm  |
|            | Banana Trunk 9| 4.6 kg | 11.3 cm  | 75 cm  |
| 1000 grams | Banana Trunk 10| 5.1 kg | 14.4 cm  | 75 cm  |
|            | Banana Trunk 11| 4.7 kg | 11.7 cm  | 75 cm  |
|            | Banana Trunk 12| 4.6 kg | 11.3 cm  | 75 cm  |

Figure 2. a) Preparing of Banana Trunk Fibre. b) Layout of Banana Trunk.

2.3 Preparing Explosive Charge

Figure 3 shows the commercial explosive which is Emulex. Based on the specification, the VOD of the Emulex is in the range of 4500 m/s to 5700 m/s. The explosive category in industrial explosives because of the range of (VOD) is 2000-7000 m/s. The composition of Emulex contains 74%-80% Nitrate salts (ammonium nitrate), 10%-20% water, 6%-10% fuel (diesel, white mineral oil, and emulsifier). It is wet and it needs to make shape before the detonation. The Emulex is normally used for blasting activity because the VOD of Emulex is moderate. The Emulex is moulded by hand into a ball shape, wrapped in a plastic sheet with an amount of ball bearings wrapped in paper and placed in front of Emulex ball inside the plastic sheet as shown in Fig 4a. Explosive will be placed directly to the banana to allow the blast to be more focus to the impact area (banana trunk).

Figure 3. Emulex®180 (Surface & Underground Blasting)
2.4 Steps and Preparation or Underground Explosion

The blast test is an important method for this research. Emulex is the type of explosive which is prepared before the experiment. The apparatus used in underground explosions are Emulex, a detonator, aluminum foil and ball bearings. The procedure for the underground explosion for blast test is explained as follows. A backhoe is used to dig a hole in the ground at a depth of 1m. A smaller hole is dug at the bottom side of the main Underground Hole Technic as shown in figure 5. Then several banana trunks would be stacked horizontally to cover the Emulex ball in the small hole. An aluminum foil sheet would be inserted at the back of the banana trunk, to check the ability of the banana trunk to mitigate the blasting after the test. The blast test is finalized and ready to be run.

Figure 5. a) Schematic Method. b) Layout Method Underground Explosion.
2.5 Numerical Calculation

Energy Absorption calculation. The total energy absorbed (EA) or Work Total is represented by the area under the load-displacement curve (WT). Equation 1 below can be used to compute it:

\[ WT = \int_{S_i}^{S_f} Pds \]  

(1)

The maximum crushing load is \( P \), and the crushing distance is \( ds \). Meanwhile, \( S_i \) means the starting distance before deformation, while \( S_f \) means the final distance after deformation. The work done is measured in kJ.

The specific energy absorption (SEA) is the energy absorbed per mass of the banana trunk and the SI units of the SEA is kJ/kg. Energy absorbed per unit mass (that is, specific energy absorption) can be calculated from the equation

\[ SAE = \frac{WT}{m} \]  

(2)

Where:
- \( SAE \) = Specific energy absorption
- WT = Work total/ Energy Absorption (EA)
- \( m \) = Weight of specimen

The crash load/energy absorption characteristics of the banana trunk, namely total energy (J/m³), total work done in compression (J) and specific Energy Absorption (kJ/kg) are presented. After the blast test, the banana fibre will be collected and tested to compare its energy absorption ability with the banana fibre before being used as blast protection. The blasted banana trunk will be coiled with aluminium foil to see whether it would break down. Since banana trunk before and after blasting test would be tested, specific energy absorption (SEA) was found to be the suitable parameter to compare between the before-after-test banana trunks.

3. Results and Discussions

3.1 Stereo Microscope Image Analyzer (x35)

Stereo Microscope Image Analyzer (x35) are optical instruments that can see the structure of the fragments (banana fibre) after blast test. The banana specimen was investigated at structure level for appearance of crack, porosity, and micro defect. The findings of this study will aid in understanding the proposed connectors between mechanism and energy absorption behaviour, as well as encourage possible uses for these connectors in terms of dispersing blast or impact energy. This revealed that a more desirable shape is a stronger banana trunk container filled with steam fibre. The banana steam fibre structure showed promising application potential in linear energy absorption. Blast test findings of banana trunk cores compaction were used to confirm the numerical technique, and the dynamic responses of layered-gradient core banana trunk were briefly described in terms of deflection response and energy absorption. The results of the simulations for dynamic failure behaviour and damage evolution features match with the experimental data. For a greater degree of blast force, the maximum deflection at banana pseudo-stem fibre was less than the standard. The blast impact at banana trunk were related if explosive charge was more higher and stand-off distance still maintain, the degree of ball bearing penetrate to the banana are increases, while the energy absorbed by the deformation and parameter banana trunk both rose. No ball bearing is observed to penetrate aluminium foil sheet. This indicates the ball bearing does not penetrate banana trunk No 3. This is also a prove that banana trunk can absorb blast.
Table 3: Results of compression tests for various banana trunk weight fractions and ball bearing penetration.

| Properties                              | 500grams | 600grams | 800grams | 1000grams |
|-----------------------------------------|----------|----------|----------|-----------|
| Mass (kg)                               | 5.1      | 4.9      | 4.8      | 5.1       |
|                                          | 4.7      | 4.6      | 5.1      | 4.7       |
|                                          | 4.6      | 5        | 4.7      | 4.6       |
| Specific Energy Absorption (kJ/Kg)       | 150      | 160      | 170      | 190       |
| Ball Bearing Penetration (cm)            | 4.3      | 8.2      | 8.8      | 18.2      |

The average specific energy absorption for banana trunk is 167.5 kJ/kg and increase to 190 kJ/kg when 1000 grams of explosive is added. However, the value SEA increased as the explosive is increased from 500 grams to 1000 grams. The energy absorption for 150 kJ/Kg shows the penetration of ball bearing to 4.3 cm from 15 cm diameter of banana trunk. However, the result show banana trunk is potentially to absorb ball bearing. The value of energy absorption for front is higher than middle and rear banana trunk. The highest value of specific energy absorption is 190 kJ/Kg that obtained by 1% fibre loading, whereas the lowest is 150 kJ/kg for 2% fibre loading. For specific energy absorption results, the value for pure banana trunk which is clearly higher than the sand bag. For 4.3 cm penetration of ball bearing, the value of specific energy absorption increases from 1% to 3%. Figure 6 show the illustration of ball bearing penetrate banana trunk and specific energy absorption were absorb by banana trunk.

![Figure 6. Illustration of Ball Bearing Penetrate Banana Trunk.](image-url)
Figure 7. (a) Stereo Microscope (b) The structure of the fragments using Stereo Microscope Image Analyzer (x35).

4. Conclusion
In a nutshell, all the procedures and steps involved in this experiment have been clarified. The Specific Energy Absorption (SEA) is crucial for the parts design that require weight reduction, such as banana trunk. SEA is the energy absorbed per the mass of the specimen, and its unit is kJ/kg. Brief explanations about the process start with the preparation of the specimen, then preparation of the Emulex, before further explanation about the blast test is done. Furthermore, discussion on the process after blast test which is the cutting process of the banana trunk is done. The analytical analysis is based on the suitable formula that are related to the mass and volume to find the force applied on the banana trunk. Banana trunk can potentially become protection wall against UXO, ERW and IED as it can protect from explosive size of 1 kg. Further research will be done to explore the effectiveness of banana trunk against explosion beyond 1 kg.
References

[1] Sanjay M R and Siengchin S 2018 *Int. J. Appl. Sci. Technol.* **11** p 233
[2] Rahman M, Das S and Hasan M 2018 *Adv. Mater. Process. Technol.* pp 527-537
[3] Kumar P S and Suganya S 2017 *Sustainable Fibres and Textiles* pp 1-18
[4] Subagyo A and Chafidz A 2018 *Banana nutrition-function and processing kinetics*
[5] Fan M and Weclawski B 2017 *Advanced High Strength Natural Fibre Composites in Construction*
[6] A. Subagyo and A. Chafidz 2018 *Banana Nutrition - Function and Processing Kinetics*
[7] Xu S, Wu P, Li Q, Zhou F and Chen, B. 2021 *Cem. Concr. Compos.* **119** p 103989
[8] Munjal P, Sharma B, Sethi J R, Dalal A and Gholap S L 2021 *J. Hazard. Mater.* **403** p 124003
[9] Qi R, Langdon G S, Cloete T J and Yuen S C K 2020 *Int. J. Impact Eng.* **146** p 103698
[10] Mouritz A P 2019 *Compos. -A: Appl. Sci. Manuf.* **125** p 105502
[11] Gargano A, Das R and Mouritz A P 2019 *Compos. B. Eng.* **177** p 107412
[12] Curry R J and Langdon G S 2021 *Int. J. Impact Eng.* **151** p 103822
[13] Black C, D'Souza T, Smith J C and Hearns N G 2019 *Forensic Chem.* **16** p 100185
[14] Kerber A, Gargano A, Pingkarawat K and Mouritz A P 2017 *Compos. -A: Appl. Sci. Manuf.* **100** pp 170-82

Acknowledgments

The authors hugely thanks to the Ministry of Education that gives research grant of the Fundamental Research Grant Scheme (FRGS) under a grant number of FRGS/1/2018/TK03/UNIMAP/02/21 and also from grant number of FRGS/1/2015/TK03/UNIMAP/03/6. The authors also acknowledge the Faculty of Mechanical Engineering Technology, University Malaysia Perlis for the lab facilities. This project was done with help from Idrus Dato’ Wan Bain Shooting Captain, Rifle Range Sungai Batu Pahat Perlis, Squadron Ke-6 Regiment Askar Jurutera Diraja and Unit Pemusnah Bom (UPB), Perlis to assist during the Field Blast Test.