Abstract. The development of the palm oil industry today is increasing rapidly. The result of the palm oil industry is often a waste of Oil Palm Empty Fruit Bunches (OPEFB). OPEFB can be processed into fibres that can ultimately be used as an engineering material. Concrete foam is one kind of lightweight concrete that uses foam as light aggregate. Concrete foam is made by stirring a mixture of cement, sand and water and the foam that has been created by using a foam generator to create the foam separately. Once the foam is formed and then incorporated into the concrete mixture into the mould. OPEFB fibres are used as reinforcement of lightweight concrete that participated in the mixed grout. The purpose of this study is to obtain the maximum tensile stress in the concrete foam to high-speed impact loads. The mechanical strength of the material is to impact loads obtained by 2 gage testing method by using an air gun compressor machine. High-speed impact the test results obtained by the average tensile stress is 4.54MPa at a distance of 50mm impact and pressure 0.3MPa. This indicates that the concrete foam reinforced OPEFB fibres is more effective to absorb the impact loads lighter than the brick found in the market.

1. Introduction

Concrete resemble stone obtained by making a mixture that has a certain proportion of cement, sand and coral or other aggregates, and water to make the mixture becomes hard in the mould according to the shape and dimensions of the desired structure[1][2]. The methods are often used in the manufacture of lightweight concrete is to include a blowing agent into a mixture of water, sand and cement [3][4]. The formation of pores in the concrete makes the concrete to be light due to the reduced amount of material used without reducing its strength. In addition to adding the foam agent into the concrete mixture, the addition of lightweight aggregate such as fly ash [5], sawdust [6][7], rice husk ash [8], Styrofoam [9], and pumice [10][11][12] can also reduce the weight of the concrete type.

OPEFB sewage treatment today has begun to examine its usefulness so that the economic value of the waste material can be increased and at the same time can provide a solution to the handling of waste products that were previously wasted. For example, the use of such technology in the field of OPEFB is the manufacture of particle board [13], parking bumpers [14], a bike helmet [15], and the raw material...
of paper [16] so it is still possible OPEFB fibre is processed to shape material/other structures that have a high economic value. One form of the structure is a concrete structure.

This study investigated the mechanical behaviour of concrete foam mixed OPEFB fibre to impact loads at high speed.

2. Methodology

The materials used in this study are: (1) Sand, (2) Cement, (3) Water, (4) Foaming agent, and (5) Fibre OPEFB. Mixing all of these materials will produce concrete foam material for test specimens with a size of $\varnothing 19 \times 300$ as in Figure 1.

![Figure 1. Specimen](image)

(a) Concrete specimen, (b) Dimension of specimen

Measurement of lightweight concrete strength is done indirectly by using 2 strain gage which attaches to the input bar (location A and B) as in Figure 2. In principle, the voltage waveform through the input bar captured by strain gage a and b. Furthermore, DAQ will process the data and send to the PC.

![Figure 2. Technique two gauges on the test setup](image)

This study will also develop a calculation of impact loads on the specimen (location c) that the two rods which collide interface. By using the theory of propagation of voltage in the one-dimensional rod will be calculated the magnitude of the impact on the location c.

The impact of the trunks collinear can be analysed simply by using Lagrange diagram or diagram space of time. Representation or depiction of space-time of longitudinal wave propagation is useful for examining issues collinear impact of multiple trunks. This diagram is made by knowing the dimensions and mechanical properties of each of these rods. Lagrange diagram can be used to:

1. Describe the method of measurement (Lagrange diagram comparing the graphs obtained from the measurement results).
2. Plan impact rod length, the input rod, specimen, and the rod incident.
3. Predicting the location of the occurrence of cracks in the specimen.
The horizontal axis is the length of the rod arrangement to be analysed, while the vertical axis shows the travel time of the waves along the stem, as shown in Figure 3.

Figure 3 shows a diagram for the Lagrange case without specimens. Point d and e are great and the location where the voltage shape is known. Figure 3 (a) is a depiction of the propagation of the voltage in the second rod. The dotted lines indicate compressive stress and a full line as tensile stress. While Figure 3 (b) is the elastic stress conditions in locations d and e. Here we can see that if the specimen is not installed then the transmission factor ($\alpha$) = 0 and the reflection factor ($\beta$) = 1, it means that the overall voltage as tensile stress is reflected back into the trunk successor (input bar) [17].

**Figure 3.** Diagram Lagrange without the specimen.

After reaching the free end (a), waves propagate back toward the trunk interface successor and impact stem (b). If the mechanical properties and cross-sectional surface area which suffered the same impact loads, then the whole wave voltage is passed to the successor rod at a time $T_{2S} = T_{1s}$.

After reaching the trunk interface successor and specimens, most of the waves passed to the specimen and partially returned to the stem successor. The time needed is $T_{2b} = T_{1ib}$. Similarly, the waves emanating from the impact rod also propagate along the rod successor and forwarded to the specimen.

Lagrange diagram that comes with the specimen is shown in Figure 4. The wave began to spread after $t_{ib}$. After reaching the free end(f), wave back and toward the trunk interface successor and specimen (c) the time $t_{2wp} = t_{1sp}$.
Impact loads, the incident voltage which is transmitted to the specimen foam concrete composite fibre blended TKKS, can be calculated if the price impact stress ($\sigma$) has been known. In Figure 3 (b) has demonstrated the magnitude of the incident voltage which is transmitted to the specimen, which shows that the incident voltage is determined by the transmission factor ($\alpha$) whose price can be calculated if the geometry and mechanical properties of both rods are known.

Price impact stress ($\sigma$) and incident voltage ($\sigma\alpha$) can be obtained by measuring the strain that occurs on the trunk successor. Incident voltage can also be measured directly on the specimen by using a strain gage (direct measurement).

3. Results and Discussions

3.1. Results

This part of study discusses the high-speed impact of the dynamic test result on the specimen concrete foam reinforced by fibre TKKS. The specimen concrete foam, as the object of this study, has a dimension Ø19x300 mm, density 1281 kg/m$^3$, and the elasticity 43.8 MPa.

High-speed impact test by using test equipment Compressor Air Gun contained on Impact and Fracture Laboratory Department of Mechanical Engineering USU. Cylindrical test specimen with a size Ø19x300 mm. The specimen size is based on the calculation diagram Lagrange. It is known that the striker and the rod material is steel VCN150 successor to the value of Modulus of Elasticity 200 GPa with wave velocity $C_0 = 5000$ m/s. Striker length is 300 mm and the input bar length is 2000 mm. Prior to testing the impact of the specimens need to know in advance the value impact on a successor to the rod without the specimen. Impact test on the trunk successor without specimen was conducted to determine the successor stem response to impact loads. Schematically shown in Figure 3 and 4.

Testing successor stem response without specimen (empty impact test) performed at a pressure of 0.3 MPa with a variation of impact distance of 30 mm up to 300 mm. The test results are shown in
Figure 5 and Figure 6 show that the increase in distance of impact will increase the amplitude of the voltage but does not change the value of the time of impact, time reaching the peak of the wave, the time for one full wave, the time between half-wave, and the time to half-wave. The amount of time can be obtained longer or shorter by increasing or reducing the length of the stem or trunk of its successor’s impact and can also change the type of material impact rod or rods successor. This is caused by the amount of time is a function of the length of the rod and the velocity of propagation, where \( t = \frac{l}{C_0} \).

### Table 1. The response of input bar on Channel 1 and 2 for various distances

| ID (mm) | Channel 1 | Channel 2 | Difference |
|---------|-----------|-----------|------------|
| 30      | 13.11256  | 12.11411  | 0.99845    |
| 40      | 16.5507   | 14.58233  | 1.968372   |
| 50      | 19.7445   | 17.18574  | 2.55876    |
| 60      | 23.77302  | 20.62388  | 3.149147   |
| 70      | 25.84806  | 22.57736  | 3.270698   |
| 80      | 28.16496  | 26.25736  | 1.907597   |
| 90      | 28.98233  | 26.56     | 2.42236    |
| 100     | 31.29922  | 28.77023  | 2.528992   |
| 110     | 34.29705  | 31.48155  | 2.815504   |
| 120     | 38.46202  | 34.96434  | 3.497674   |
| 130     | 39.70357  | 36.23566  | 3.467907   |
| 140     | 41.70295  | 37.56775  | 4.135194   |
| 150     | 43.86729  | 40.52093  | 3.346357   |
| 160     | 45.9612   | 42.4893   | 4.006822   |
| 180     | 46.89426  | 46.03287  | 2.861395   |
| 200     | 50.68155  | 47.84992  | 2.831628   |
| 220     | 53.96713  | 50.71132  | 3.255814   |
| 240     | 55.67876  | 52.19597  | 3.482791   |
| 260     | 59.17643  | 54.46698  | 4.709457   |
| 280     | 60.08434  | 55.2744   | 4.556899   |

Figure 7 explains that the difference between the voltages received by the Channel 1 and Channel 2 increase in size with increasing distance of impact. It is hinted that the impact distance that allows for use in testing the impact strength of concrete foam with stem successor is <100 mm with a pressure of 0.3 MPa.
The magnitude of impact stress on stem response testing successor without specimens for each range impact is shown in Table 1.

This test is used to compare the impact on stem successor voltage and the voltage incident that resulted in a broken foam concrete before paired strain gage on the specimen. The test set-up is shown in Figure 8.

![Stress Vs Impact distances](image)

**Figure 7.** Display of the voltage on the trunk successor

![Structure of rod and specimen](image)

**Figure 8.** Structure of rod and specimen

It is known that the measurement of impact stress ($\sigma_2$) = 60.2 MPa, and incident stress ($\sigma_1$) = 5.9 MPa. To get the impact stress 60.2 MPa requires a distance (ID) impact of 300 mm with a pressure of 0.3 MPa.

Table 2 shows that the voltage is higher with the increased distance given impact. The magnitude of the impact voltage between the results of stem response without the specimen and the specimen attached is relatively equal. The voltage transmitted by the successor rod is absorbed by the specimen and then reflected back to the so-called stem-voltage transmission factor. From the data processing amount of the average transmission, the factor is 17.08% for a range of distance variation impact.

**Table 2.** Data voltage measurement impact and incidents

| ID (mm) | Average $\sigma$ (MPa) | Transmission factor $\alpha$ (%) |
|---------|------------------------|---------------------------------|
|         | Impact                 | Incident                        |
| 30      | 14.2028                | 1.8264                          | 12.8596                        |
| 40      | 16.4750                | 2.8340                          | 17.2020                        |
| 50      | 21.4392                | 4.5413                          | 21.1823                        |
| Avrg    |                        | 17.0813                         |                                |
| Std. Dev|                        | 4.1627                          |                                |

At a distance of impact 50 mm and pressure of 0.3 MPa, an average impact of 21.43 MPa (Chanel 1) was obtained. The amount of voltage that can be transmitted into the concrete foam (voltage incidents) only amounted to 4.54 MPa. Voltage transmission factors influence the incidence of 21.18 MPa lead to concrete foam broke. Then the impact distance of 50 mm is taken to be the benchmark impact testing.
Figure 9 shows a graph of tensile strength and impact the incident for a distance of 50 mm with a pressure of 0.3 MPa. Setup is done together with the impact test without a specimen that can be compared to how the voltage occurring on the trunk and the successor to the incident voltage coming into the specimen.

The investigation of the mechanical behaviour of concrete foam has been tested and inspected to see the possibility of damage. For that purpose, by using the macro picture, the shape of cracks and the surface of the specimen can be seen in the ratio 1:1. The examination carried out on specimens of impact at a distance of 50 mm with a pressure of 0.3 MPa. Figure 10 shows the impact location and areas of damage to the specimen. It appears that the incident voltage stress of 4.54 MPa, the specimens have been a failure.

The damage to the specimen due to tensile stress, not by compressive stress. This is shown in the form of the specimen fracture, where the fracture occurred in flat plot. If specifically look on the surface of the specimen fracture, there are fibres that drawn out (not breaking) and leaving holes that look like grains of air inside the specimen.

3.2. Discussion

Impact test conducted on concrete specimens with the EFB fibre reinforced foam density of 1281 kg/m³ and the modulus of elasticity of 43.8 MPa at the age of 28 specimens a day. The impact test results obtained by average compressive stress is 6.3 MPa and maximum tensile stress by an average of 4.54 MPa and 21.18 MPa transmission factor with impact distance of 50 mm and pressure of 0.3 MPa which resulted in this material failure (cracking). Failures that found in the specimen are due to tensile stress, not by compressive stress. When compared with the results of the indirect tensile test on foam concrete results obtained 2% of the value of compressive strength of 5.4 MPa. The impact test results obtained from the tensile stress value of 4.54 MPa or 83.3% of the compressive strength. It can be concluded that
the strength of fibre-reinforced concrete foam TKKS much more able to accept or absorb the collision as a result of impact loads compared with other types of lightweight concrete blocks on the market.

4. Conclusion

High-speed impact test results obtained as follows: as for rod calibration, from the results of the study were informed that the incoming voltage to the successor of steel rod at (σ₂) = 21.44 MPa, and incident stress 4.54 MPa with the impact time (t₁) = 3.12x10⁵ impact μs at a distance of 50 mm and a pressure of 0.3 MPa. The higher the impact distance the higher the voltage response received by the rod successor without changing the impact time. At a distance of impact 50 mm is used as the maximum impact loads that can lead to failure of the specimen. Then as for the impact on specimen, high-speed impact test done on the specimen with the size Ø19x300 mm, the distance of impact 50 mm and pressure of 0.3 MPa compressive stresses obtained an average of 6.3 MPa and tensile stress by an average of 4.54 MPa. It can be concluded that this material is able to absorb the impact load of 4.54 MPa. Finally, as for the impact failure, mechanical occur in specimens of concrete foam caused by tension, not caused by compressive stress, this is evidenced by the failure to form cracks or fractures that occur in the middle of the trunk specimen at a distance of 150 mm.

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