Utilization of Cornstalk Fiber into the Styrofoam Matrix as a Preliminary Study for Earthquake Resistant Particleboard

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Abstract

Indonesia is a fairly large archipelago in Southeast Asia. The country is often hit by earthquakes which often claim victims due to low-quality buildings. This research is a preliminary study of making a strong particleboard earthquake-resistant for housing walls using corn stalk wastes. This research aimed to study the effect of corn fiber orientation; [$0^0/0^0/0^0$], [$0^0/90^0/0^0$], and random [$0^0/45^0/90^0$] to a styrofoam/xylene matrix with the concentration 17.5%, 27.5%, and 37.5% (w/w). The product value of the particleboard composite characterizations was following the ASTM, but the justification of the feasible product was referred to as the Indonesian National Standard (SNI). Due to the test results, it was found the screw test to the product specimens did not meet the SNI which was defined as not suitable for bending application but referred from other mechanical tests it was justified as a strong material for wall housing.

Keywords
Cornstalk fiber, styrofoam matrix, earthquake-resistant particleboard, polyester resin,

1. Introduction

Indonesia is one of many other countries every year experiences on earthquakes. As the largest archipelagic country in Southeast Asia, Indonesia has a unique geographical position because it layed up at the center of the collision of the Australian Indian Tectonic Plate in the south, the Eurasian Plate in the north, and the Pacific Plate in the northeast. This has caused Indonesia to have a complex tectonic arrangement from the direction of the collision zone [1]. As a result of the phenomenon of tectonic shifts or earthquakes often occurred has causes buildings that partly were low-rise buildings or commonly known as simple housing with the poor quality wall material. According to the Indonesia Directorate of Volcanology and Geological Disaster on Mitigation (DVMBG), the meeting plate of northern Irian and North Maluku has produced stack energy in a certain strength of scale. The sudden release of the energy will be caused to impact the building damage [2]. The majority of fatalities of falling walls that occurred were made of bricks or concrete were happened not met the shock-resistant requirements.

2.Literature Review

The walls of the concrete block are waterproof, but store heat and prone to cracks and breaks due to shocks. Concrete was a material made from a mixture of cement, water, coarse, and fine aggregates with certain additives. The mixture must be homogeneous with no segregation occurred. The smaller cavity in the concrete mixture will result in high-pressure strength. There are some disadvantages of using concrete; 1) execution of work requires high accuracy 2) heavy loads 3) great sound reflectivity, and 4) low tensile strength, so it easily cracks and can not withstand shocks. Based on the experience of earthquakes that occurred, the collapse of buildings claimed a large number of lives. Therefore, the building must be planned to provide a minimum performance of life safety, thus minimized the possibility of casualties. The earthquake-resistant bricks are very important for pre-earthquake preventive action because most of the concrete and brick houses that are built in Indonesia do not have good quality, so were prone to be damaged. The weight of earthquake-resistant bricks is much lighter than conventional concrete or concrete blocks. This was a distinct advantage in terms of safety. It can be made from natural fiber with a mixture of polyester and styrofoam matrices printed in the form of bricks for the foundation for earthquake walls. Utilizing edibles from corn as raw material for manufacturing earthquake-resistant bricks becomes possible [3]. Indonesia was known as an abundant maize plantation on the islands of Java, Sulawesi, and Nusa Tenggara. The national data on maize production in 2016 was around 23.58 million tons, 26.03 million tons in 2017, in 2019 was 33 million tons, and 2020 was forecasted 33.957 million tons [4], so far corn stalks were not well managed where only become wasted material after the big harvest [5]. Besides, the corn stalk fiber as the main raw material for earthquake-resistant bricks needed polyester as a binding agent for the styrofoam matrix. Styrofoam usually was used for the packaging of food, furniture, glassware, electronics, etc. It was common to non-recyclable and non-biodegradable. The unique properties of styrofoam were its bond structure consisting of granules with low density and lightweight, and space between the granules which result in a good heat-insulating system. The high production of styrofoam in Indonesia also produces high waste which is difficult to decompose. The use of styrofoam in this research is to increase the strength of polyester resin on particleboard.

The goal of this research was to utilize the wasted styrofoam and wasted corn stalk fiber for manufacturing the earthquake-resistant particleboard following the national standard of industry (SNI) SNI was the only standard that applies nationally formulated by the Technical Committee and stipulated by the National Standardization Body. The product material provides solutions for pre-disaster prevention and solved the problem of wastes in Indonesia.

3. Methodology

Weigh the unsaturated polyester resin as the catalyst, with a ratio of 1:50 grams, stir until homogeneous to a weigh crushed styrofoam (PS) in liquid form after adding proper xylene, stir until curing. Applied talc powder on the surface of the molding approximately 10% of the total matrix before the mixture of the composite was arranged. This aimed to easily the demolding process. In the mixture of polyester and the catalyst, add the styrofoam matrix and talc, stir until homogeneous. Put the corn stalk fibers into the mold and arranged according to variations adding the matrix mixture until evenly and the fibers are not visible. Place the mold containing the corn fiber and matrix in the oven for one hour. Remove the hardened composite particleboard and remove it from the mold and then let it cool.

3.1. Corn Stalk Preparation

The stalk was the most important part of corn morphology which functions to support the corn plant. The shape of the corn plant stalk is thin, segmented, and branched. The corn stalks have an average thickness of 2 - 4 cm depending on the variety. Genetics has a high influence on plants. This highly variable plant height is a very influential character in the classification of the character of the corn plant.

The corn stalk received from a village in East Java were crushed and dried. The corn fiber is managed in stainless molding and bonded by polystyrene addition (PS) in three formulations: 17.5%, 27.5%, and 37.5% in a designated dimension. The corn fiber is managed in three orientations [$0^0/0^0/0^0$], [$0^0/90^0/0^0$], and random [$0^0/45^0/90^0$] to compare the effect of fiber orientation to the strength of the specimens.

Figure 1. Preparation of the cornstalks to proceed the laboratory processing

The main components of corn stalks are cellulose, hemicellulose, and lignin, as shown in table 1.

Table 1. The Compounds of cornstalks

Compound	Percentage (%)
Cellulose	30-50
Hemicellulose	15-35
Lignin	13-30
Water	9-11
Ash	6

Source: Luo, 2016 [6]

3.2. Styrofoam Preparation

The styrofoam was made from the main ingredient polystyrene a fairly strong plastic material. Polystyrene was a polymer that was made from a mixture of 90-95% polystyrene and 5-10% gases of n-pentane or n-butane which was subjected to suspension, polymerization, then heated to soften it. Styrofoam or commonly known as non-recyclable and non-biodegradable expanded polystyrene [7]. The physical properties of styrofoam were tabulated in Table 2.

Table 2. The physical properties of Styrofoam

Material Properties	ASTM	Unit
Low temperature working resistance		Bad
Tensile strength 256 (h/12)	ASTMD256	0.13-0.34 N/mm^2
Modulus elasticity	ASTM D747	27.4-41.4 (MNm x 10^{-4})
Compressive strength	ASTM D696	74.9-110 MNm)
Thermal expansion	ASTM 696	6-8 (mm ^{0}C x 10)
Melting point	ASTMD 87	82-103 (soft ^{0}C)
Specific gravity	ASTMD 792	1.04-1.1 (g/cm^3)
Voltage elongation	ASTM 638	1.0-2.5 (%)

Source: Krundaeva, 2016 [8]

3.3. Characterization of Fiberboard

a. Density

Density was counted as mass per unit volume. The volume of the fiberboard will be greatly influenced by the compressed pressure when making earthquake-resistant particleboard. Density greatly affects physical and mechanical properties. The density test is the physical properties of the particleboard with the formula

$$\rho = m/v \quad (1)$$

where :

ρ = density (gr/cm^3)
m = mass (gr)
v = volume (cm^3)

b. Water absorption (Wa) of particleboard

The water absorption was the physical property of particleboard which reflects the ability of the board to absorb water when immersed in water. Water absorption was influenced by the number of cavities /pores on the particleboard. The water absorption value is calculated by the formula:

$$Wa = ((m2 - m1) / m1) \times 100\% \quad (2)$$

Where:
Wa = water absorption (%)
m1 = weight before immersion (g)
m2 = weight after immersion (g)

c. Screw Hold Strength Test

Strength was the ability of a material to carry loads. The resistance of the material to the deformation where was compressed, twisted, or bent by a load that hits the particleboard surface [9]. One of the mechanical properties of particleboard that was no less important is the holding strength of the screw that was inserted in the building materials. In this research, the value required by JIS A 5908-2003 was 31-51 kg. Data on the results of the test for the grip strength of the particleboard screw was carried out using two repetitions. The test sample measuring 10 x 5 x 1 cm^3 was tested using a screw 2.7 mm in diameter, 16 mm in length was inserted to a depth of 8 mm. The value of the holding strength of the screw was expressed by the amount of the maximum load achieved in kilograms (kg).

d.Impact strength test

The impact of strength testing is an important criterion for determining the resilience of polymer materials. Impact testing aims to measure the energy of material absorbs until the material breaks. Impact testing is a response to shock loads or sudden loads [10]. This test used the Charpy method every minute, the impact value can be seen in the following formula:

$$\Delta E = W.l.(\cos^{\beta} - \cos^{\alpha}) \quad (3)$$

Where:

W: pendulum swing (joule)
l: Pendulum length (mm)
A: area (mm^2)

$$HI = \Delta E/A \quad (4)$$

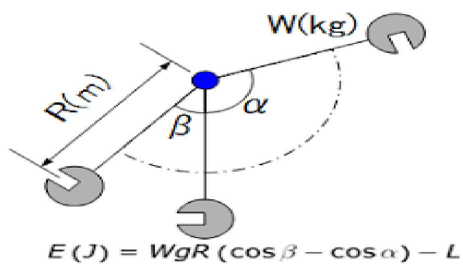

Figure 2. Illustration of Impact Measurement
Source: Callister [9]

4. Result and Discussion

4.1. *Density*

Table 3. Density-based on Fiber Orientation

No	Fiber Orientation	Composition	Long (cm)	Width (cm)	Height (cm)	Volume (cm3)	Mass (gr)	ρ	ρ average
I	$[0^0/0^0/0^0]$	17.5% PS	15.13	2.64	0.73	29.158	30.2788	1.038	1.005
	$[0^0/90^0/0^0]$		15.26	2.60	0.80	31.740	32.1807	1.0100	
	$[0^0/45^0/90^0]$		15.20	2.63	0.85	33.9796	32.8901	0.9670	
2	$[0^0/0^0/0^0]$	27.5% PS	15.15	2.63	0.76	30.281	31.2799	1.0320	1.004
	$[0^0/90^0/0^0]$		15.23	2.61	0.80	31.800	31.2908	0.9830	
	$[0^0/45^0/90^0]$		15.22	2.65	0.78	31.459	31.4041	0.9980	
3	$[0^0/0^0/0^0]$	37.5% PS	15.22	2.60	0.76	30.074	30.4999	1.0140	0.982
	$[0^0/90^0/0^0]$		15.33	2.64	0.79	31.9722	31.2158	0.9763	
	$[0^0/45^0/90^0]$		15.31	2.65	0.78	31.645	30.3272	0.9580	

The density value of the fiberboard can be concluded that the lowest density value of corn stalks was the specimens with a styrofoam content of 37.5% with an average density value of 0.982 gr/cm^3 and the highest density was a fiberboard specimen with a styrofoam content of 17.5% with a value the average density was 1.005 gr/cm^3 (Table 3). In this research, the brick was included in the category to meet the requirements of SNI 03-0349-1989 because the value was < 1.8 gr/cm^3.

The sample tested was 0.9-1 g/cm^3 to the fiber amount of 30% of the total weight. Fiberboard density was influenced by the specific gravity of the particles used. The greater the specific gravity of the particles, the greater the density of the fiberboard, and the greater the styrofoam content, the smaller the density.

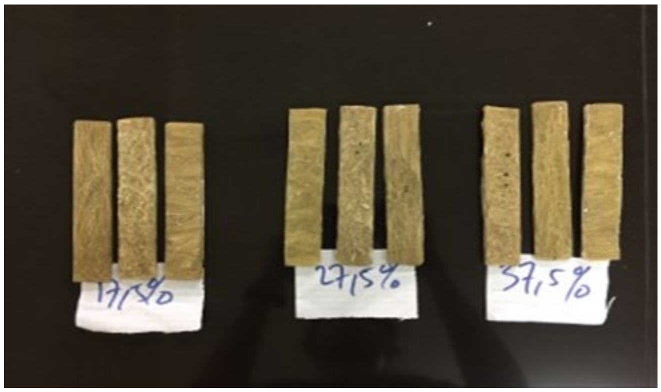

Figure 3. The specimens for Characterization

4.2. *Particleboards Water Absorption*

The water absorption in (table 4) shows that the lowest water absorption value was with 17.5% styrofoam adhesive mixture content in $[0^0/90^0/0^0]$ fiber orientation, the value of water absorption was 0.22% and, the highest water absorption value was particleboard with a mixture of styrofoam adhesive mixture (PS) content of 37.5% with the orientation of $[0^0/90^0/0^0]$ the highest water absorption value of 2.51 according to SNI 15-2094-2000 standards, namely < 20% of the total average water absorption styrofoam adhesive mixture (PS) 37.5% with an average absorption value of 1.77%. Another factor that affects absorption is the existence of extreme conditions such as bubbles and unevenness of the test sample, which affects the absorption of the sample.

Table 4. Water Absorption of Particleboard

No	Fiber Orientation	PS Composition	Initial weight (gr)	Final weight (gr)	Water Absorption (Wa)	Wa Average
1	$[0^0/0^0/0^0]$	17.5%	13	1.3220	1.10	0.683
	$[0^0/90^0/0^0]$		1.1497	11.523	0.22	
	$[0^0/45^0/90^0]$		17	17.354	0.73	
2	$[0^0/0^0/0^0]$	27.5%	1.7826	1.8080	1.42	1.66
	$[0^0/90^0/0^0]$		2.0023	2.0450	2.13	
	$[0^0/45^0/90^0]$		1.7762	1.8020	1.45	
3	$[0^0/0^0/0^0]$	37.5%	1.5211	1.5485	1.80	1.77
	$[0^0/90^0/0^0]$		1.4854	1.5228	2.51	
	$[0^0/45^0/90^0]$		2.2236	2.2464	1.02	

c. *The Screw Holder Strenght*

The value of screw holding strength with variations in the resulting fiber orientation does not meet the JIS A 5908-2003 standard because it was at 19 kg to 27 kg. The holding strength of particleboard screws increases as the amount of fiber used was at least 20 to 30% this allows the tested specimens to meet the JIS A 5908-2003 standard (Table 5). This is presumably because more fibers will affect the strength of the individual particleboard. The level of the Styrofoam matrix in the specimen can affect the strength and density of the specimen, in general, the more styrofoam matrices contained in the specimen, the lower the density so that it was unable to hold the screw according to standard.

Table 5. The Screw Holder Strenght

No	Fiber Orientation	PS Composition	Screw Holder Strenght (Kg)
1	$[0^0/0^0/0^0]$	17.5 %	27
	$[0^0/90^0/0^0]$		26
	$[0^0/45^0/90^0]$		22
2	$[0^0/0^0/0^0]$	27.5%	26
	$[0^0/90^0/0^0]$		23
	$[0^0/45^0/90^0]$		21
3	$[0^0/0^0/0^0]$	37.5%	22
	$[0^0/90^0/0^0]$		20
	$[0^0/45^0/90^0]$		19

The holding strength of the screws was important for household uses, cabinets, and other industrial parts. The holding strength of nails and screws is largely determined by board density and resin content. Efforts that can be made to improve the grip strength of the screws are the use of fibers and the styrofoam matrix content and applying appropriate pressure because this is related to the density of the fiberboard. The greater the density value, the greater the value of holding the screw because the tighter fiberboard can bind the screw tighter.

d. *The Fiberboard Impact Strenght*

Table 6. The Impact Strenght of Particleboard

No	PS Composition	Fiber Orientation	Width (mm)	Height (mm)	A (mm^2)	α	β	Breaking Force (Joule)	Impact Value (J/ mm)
1	17.50%	$[0^0/0^0/0^0]$	12.4	12.4	153.76	30°	20	1.801	0.011
		$[0^0/90^0/0^0]$	12.4	12.4	153.76	30°	15	2.439	0.015
		$[0^0/45^0/90^0]$	12.4	12.4	153.76	30°	18	2.078	0.013
2	27.50%	$[0^0/0^0/0^0]$	12.4	12.4	153.76	30°	23	1.333	0.008
		$[0^0/90^0/0^0]$	12.4	12.4	153.76	30°	21	1.652	0.010
		$[0^0/45^0/90^0]$	12.4	12.4	153.76	30°	20	1.801	0.011
3	37.50%	$[0^0/0^0/0^0]$	12.4	12.4	153.76	30°	24	1.163	0.007
		$[0^0/90^0/0^0]$	12.4	12.4	153.76	30°	20	1.801	0.011
		$[0^0/45^0/90^0]$	12.4	12.4	153.76	30°	23	1.333	0.008

*W= 50 joule; l = 0.6 m

Test using the same specimen dimensions and corn fiber length is 3-5 cm. Overall, from the test results it was found that the orientation of the [$0^0/0^0/0^0$] fiber at all matrix concentrations was the smallest value of 0.011 J/mm^2 (17.5%); 0.008 J /mm^2 (27.5%), and 0.007 J/mm^2 (37.5%). This assumes that if the fiber was made in one direction would not provide good mechanical strength. Meanwhile, if the fiber was made in [$0^0/90^0/0^0$] orientation at a matrix concentration of 17.5% and 37.5%, the highest strength was 0.015 J/mm^2 and 0.011 J/mm^2 respectively, the result will be different if the matrix concentration was 27.5%. It can be concluded that the strength of the particleboard was much better if the fiber orientation is not in one direction, which was [$0^0/90^0/0^0$] and [$0^0/45^0/90^0$].

Conclusion

From the results of testing the physical and mechanical properties of earthquake-resistant bricks using fibers from corn stalks waste with variations in the direction of fiber [$0^0/0^0/0^0$], [$0^0/90^0/0^0$], and [$0^0/45^0/90^0$] combined with the styrofoam matrix with w / w 17.5%, 27.5%, and 37.5% can be concluded that;

1. The results show that the density of particle board ranges between 0.982-1.005 gr /cm^3 (meets the requirements of SNI 03-0349-1989). The water absorption capacity of particleboard ranges from 0.683% to 1.77% (meets the requirements of SNI 15–2094–2000). The screw holding strength values range from 19 kg to 27 kg (not yet meeting the requirements of JIS A 5908-2003). The impact strength of particleboard ranges from 0.007 to 0.015. The factors of the amount of styrofoam in the matrix, fiber orientation, and the fiber compositions in the manufacture of the test specimens have a significant effect on the density, water absorption, screw holding strength, and impact test of earthquake-resistant particleboard.
2. The results of all physical test studies meet the existing SNI standards. Meanwhile, the mechanical test did not meet the standards because the fiber composition used in this study was only 30% of the total weight of the specimen tested. But on the other hand, the effort to use cornstalk fiber has other advantages, the use of cornstalk fiber and styrofoam has a positive impact on the environment because it uses wasted resources so that it can produce new materials and it is hoped that in the future it can overcome the problems of handling earthquakes in Indonesia.

Future Work

1. It would beneficial to using the old age cornstalks fiber this related to the maturity of the fiber and the amount of fiber for every corn stalks
2. Avoid the bubbles formed during the process it would be effected the several tests
3. The drying temperature of the composites should not exceed 100 ^{0}C because the polyester matrix was thermosetting so that the board becomes softening.
4. It is necessary to carry out further tests such as bending tests, tensile tests, gas emission tests, and SEM, it would be necessary to collaborate work to civil engineering to test the construction of building structures of the material that potentially efficient new material to be used as a foundation, temporary shelter walls aftermath earthquake or can also be a permanent wall material specifically for earthquake-prone areas in Indonesia.

References

1. H. Th. Verstappen, Indonesian Landforms and Plate Tectonics, Jurnal Geologi Indonesia, Vol. 5 No. 3 September 2010: pp.197-207
2. Hamzah, L., Puspito, N. T., & Imamura, F. (2000). Tsunami Catalog and Zones in Indonesia. Journal of Natural Disaster Science, 22 (1), 25–43.
3. Firdaus, FE, An Environmental Friendly Material: Epoxide-Based Resin from Vegetables Oil for Bio-Fiber Reinforced Composites, International Journal of Applied Engineering Research, pp. 5152-5155, 2016, https://www.researchgate.net/profile/Flora_Elvistia_Firdaus/publication/302492290_An_Environmental_Friendly_MaterialEpoxide-Based_Resin_from_Vegetables_Oil_for_BioFiber_ Reinforced_Composites/ links /5730aaec08ae6cca19a1ee21/An-Environmental-Friendly-MaterialEpoxide-Based-Resin-from-Vegetables-Oil-for-Bio-Fiber-Reinforced-Composites.pdf
4. Juli Etha Ramaida Manalu - https://ekonomi.bisnis.com/read/20190923/ 99/1151275/dewan-jagung-pesimistis-target-produksi-2020-bisa-tercapai

5. Jirleska Flandez, Israel Gonzalez, Jordi Baye Resplandis, Nour Eddine El Mansouri, Fabiola Vilaseca, and Pere Mutje, Management of Corn Stalk Wastes as Reinforcement for Polypropylene Injection Moulded Composites, Bioresources, 7(2), 2012, pp 1836- 1849
6. Zhangfeng Luo, Ping Li, Di Cai, Qiushi Chen, Peiyong Qin, Tianwei Tan, Hui Cao, Comparison of performances of corn fiber plastic composites made from different parts of corn stalk, Industrial Crops and Products, https://doi.org/10.1016/j.indcrop.2016. 11.005, Volume 95, January 2017, Pages 521-527
7. Firdaus, FE, M Dachyar, Production of Tailored Reinforcement of Rattan Fiber Composite, Proceedings of the International Conference on Industrial Engineering and Operations Management (IEOM), pp.419-427, 2019, http://ieomsociety.org/pilsen2019/ papers/124.pdf
8. Anastasia Krundaeva, Guido De Bruyne, Francesco Gagliardi, Wim Van Paepegem, Dynamic compressive strength and crushing properties of expanded polystyrene foam for different strain rates and different temperatures, Polymer Testing, Volume 55, October 2016, Pages 61-68
9. Bekir Cihad Bal, Screw And Nail Holding Properties of Plywood Panels Reinforced With Glass Fiber Fabric, CERNE vol.23 no.1 Lavras Jan./Mar. 2017, https://doi.org/ 10.1590/ 01047760201723012210
10. William D. Callister, Jr., Materials Science and Engineering, John Wiley & Sons, Inc, 8 th edition, 2010

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