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Analysis of the Concept of Force Balance in the Atag Warehouse, Jember Regency

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Abstract

Physics learning is rarely associated with the local wisdom of the local community, so most people assume that the two topics are very different. This article analyzes the concept of force balance in the Atag warehouse building in Jember Regency. This study used qualitative research using content analysis techniques in which there is unitizing, sampling, coding, reducing, inferring, and narrating. Data were collected through field observations, literature studies, interviews, and documentation. The research indicates that the Atag warehouse building has several parts, namely doors, windows (tabing lambung), columns (rooms), warehouse roofs, and foundations. In the Atag warehouse, there is the concept of static balance, namely the equilibrium of rigid objects found in the frame, rope ties, foundation, semat, and Atag warehouse doors. Then there is the concept of a heavy point found in the bottom cover and the center of the Atag shed. Furthermore, there is the concept of dynamic balance, namely the moment of force that can be found in the warehouse window and the moment of inertia in the bamboo part whose bonds loosen when stepped on by warehouse workers. Integrating Atag warehouses in learning activities can make it easier for students to understand physics concepts. This article concludes that the Atag warehouse has a static and dynamic balance that can be used as physics learning material and can also help preserve regional culture.

Keywords: *Atag warehouse, physics concept balance, local wisdom*

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INTRODUCTION

Culture is an important aspect in the context of education. Incorporating culture into learning is a way to preserve the culture [1]. Incorporating local cultural aspects into learning is one way to improve the quality of the learning process [2]. In addition, it needs to be done considering that many young people are more interested in foreign cultures because they are considered interesting [3]. Ethnoscience learning is the integration of culture into learning [4]. Ethnoscience learning is important for the exploration of indigenous knowledge from certain communities to be studied so that it becomes a bridge to formal science as school learning [5]. Knowledge gained from the experience of paying attention to the culture that continues to

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develop is also the definition of ethnoscience [6]. One of the efforts in overcoming students' problems in understanding the material is by integrating local wisdom into learning materials [7].

Local wisdom is a local cultural value that is used in regulating people's lives [8]. It is also referred to as a way of life and philosophy that is realized in various fields such as social values, traditional architecture, economy, health, environment and so on [9]. This article specifically deals with traditional architecture in regard to incorporating a part of the local wisdom into education content. Traditional architecture is an architectural concept that still prioritizes elements of local culture and tradition [10]. The *Atag* warehouse building in Jember Regency is an example of traditional architecture.

Atag warehouse is a building used for the air curing process, and its manufacture is passed down to the next generation. Air curing is the process of drying tobacco using wind inside the building. The materials for making *Atag* sheds are still very traditional using local materials such as bamboo, dried sugar cane leaves and dried bamboo leaves to make them easy to find [11].

Figure 1. Atag warehouse

The *Atag* warehouse still retains its traditional form. This can be seen from the structure of the columns and roof trusses made of bamboo and tied using wire along with the steel foundation [11]. These parts have their own uniqueness and cannot be separated from the concept of physics so it is very interesting to study. One of the physics concepts that can be applied to the Atag warehouse building is the concept of balance.

The integration of culture in various learning can use ethnoscience-based learning. Learning physics through an ethnoscience approach is based on local culture which involves extracting general understanding from students about certain local cultures and turning it into scientific knowledge [12]. Incorporating scientific knowledge in physics learning with an ethnoscience approach can help students understand physical phenomena in the surrounding environment [13,14]. The physics learning process that applies general science and local science can help students, teachers, parents, and the community in learning physics concepts without leaving local culture [15]. Physics is a learning process that tries to solve problems from human observation and thinking [16]. Incorporating cultural values in learning can improve social attitudes and make students more appreciative of local culture [17].

In addition to integrating daily life into physics learning, it is also necessary to have teaching materials to create effective and efficient learning [18]. The use of ethnoscience-based textbooks can train critical thinking skills in linking culture with material [19]. The culture in the Jember area that can be observed is the Atag warehouse building.

There have been several previous studies on the balance of rigid bodies against several traditional soldiers and traditional houses. Among them is the study of the analysis of the concept of balance in the traditional dance of Banjarkemuning Sidoarjo dance [19] and the dance of Dhadak Merak [20]. Research on the analysis of the physics of the center of mass and balance concepts in the traditional dance of the Balapan dance, West Sumatra [21]. Research related to traditional houses includes research on the physical concept of the pillars of the Toraja traditional Tongkonan house which contains the concept of a balance of rigid bodies [22]. In addition, the Tongkonan house has a rotating dynamic glass concept on its roof covering [23]. But so far no one has studied the concept of Atag equilibrium, previous research still discussed the analysis of material selection in the Atag warehouse building in Karanganyar Village, Jember Regency [11]. Despite Jember Regency's reputation as a prominent tobacco-producing area in Indonesia [24], historical records in Jember district reveal a lack of physical concept analysis regarding roof sheds.

Despite frequent usage, the underlying theory of the *Atag* warehouse remains unknown to many people. Limited literature and research exacerbate this lack of understanding, as individuals primarily rely on their feelings and direct observations of the building's stability. To address this, researchers seek to analyze the balance concept in the *Atag* warehouse and propose it as a school textbook. This approach integrates the surrounding culture, facilitating students' comprehension of balance through everyday experiences and observations while preserving local traditions**.**

METHOD

The research uses qualitative research with the main topic of the *Atag* warehouse building. This research focuses on the structure of the *Atag* warehouse which contains the concept of balance in its windows, building frame, wire rope ties, building foundation, semat, and the front cover of the *Atag*. This research was conducted in November 2022 at Curah Buntu Hamlet, Jenggawah Village, Jenggawah District, Jember Regency. Data were collected through direct observation, documentation and interviews with three informants. The informants of this research are the crop assistant, the warehouse maker, and the warehouse worker. The steps of this research can be seen in Figure 2.

This research utilizes a content analysis approach. It consists of six steps, namely unitizing, sampling, recording, reducing, inferring, and narrating. Informant triangulation is employed to check data validation by seeking input from different informants. Unitizing is the collection of information about the warehouse in the form of text, photos or videos. The data is collected through direct observation, semi-structured interviews and documentation. The interview data is transcribed from voice recordings into conversational text. In the interview process, the interviewees were assigned s1 as plant assistants, s2 as workers, and s3 as producers. Sampling is a step to limit clear data related to the concept of *Atag* warehouse balance. The sampling can also be integrated with informant triangulation. Reducing is the elimination of irrelevant data to the topic of *Atag* warehouse balance. Inferring is a step to analyze the concept of *Atag* warehouse balance. The last step is narrating to display the results of the analysis in descriptive text, making it easier for readers to understand the concept of *Atag* warehouse balance.

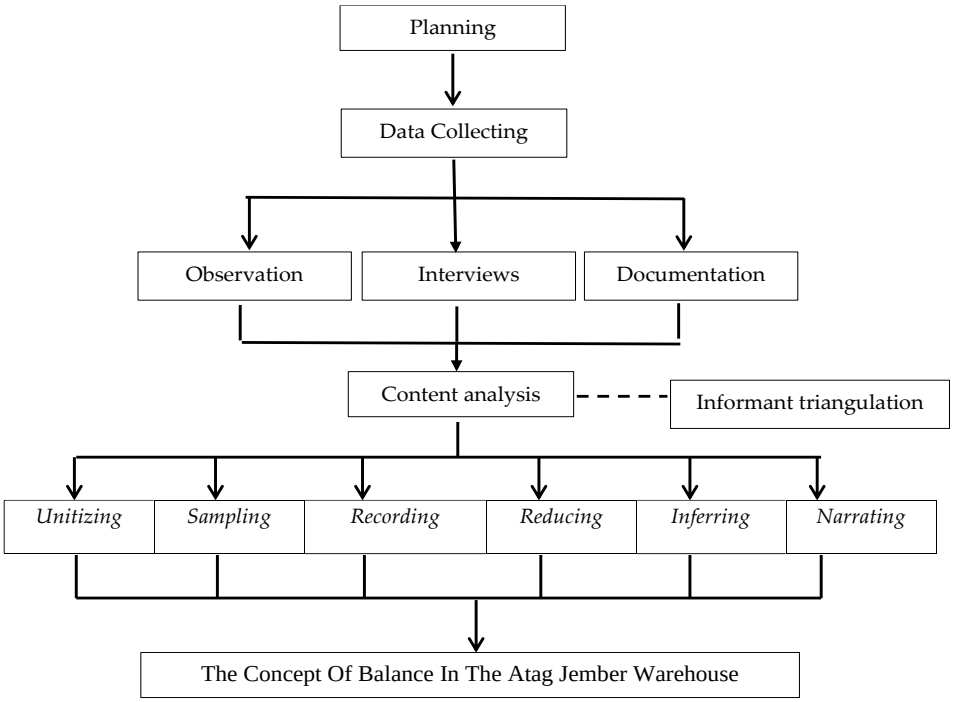

Figure 2. The steps of research design.

RESULTS AND DISCUSSION

The *Atag* warehouse building has an average size of 62 meters long, 20 meters wide, and 13 meters high with a lot of Javanese bamboo and also blabat as raw materials [11, 25]. This is in accordance with the statement of the source,

"The height is 13 meters, the length is 62 meters, and the width is 20 meters" (Interview, S2, 19 November 2022).

"The *Atag* warehouse is a tobacco drying warehouse made of bamboo and blabat, for short" (Interview, S3, November 29, 2022).

Warehouse construction usually still determines the direction of construction. North-south facing warehouses tend to be dry, while west-east facing warehouses are more humid [26]. This is reinforced by the statement of the source,

"... Just to minimize when the warehouse is facing north-south, it is usually drier, so usually the floor or soil is watered. If it faces west, it means that it is more humid, so usually all the windows are opened" (Interview, S1, November 19, 2022).

"Some look at the direction and some look at the land. Usually, many look at the direction to the north and south so that they don't get hit by the wind" (Interview, S3, November 29, 2022).

The *Atag* warehouse has several parts such as doors, windows, columns (rooms), roofs and foundations. The first part is the warehouse door using a traditional sliding door model with waring and triber materials arranged and sandwiched with bamboo. This was revealed by the informant,

"The door is usually made of triber and waring. Triber is like black plastic that keeps the temperature inside. The triber will be sandwiched with bamboo. The term is usually jebhak" (Interview, S3, November 29, 2022).

"We use the traditional method, so we only use bamboo and then the outside is given a large

bamboo so that the *Atag* bamboo can enter. The throat is still traditional using bamboo, the important thing is that it can be opened sideways" (Interview, S1, November 19, 2022).

The second part is the window (tabhing lambung) which functions as an air vent for the air-curing process [25]. The materials and how the window works were explained by the following interviewees,

"The windows are made of plastic covered with burlap sacks or usually called kadhut and flanked with bamboo. The side windows are made of plastic covered with waring and lined with bamboo. So, the function of the kadhut is as a heat absorber and the outside is coated with plastic so that it is durable because if it rains it does not reach the burlap sack, so the first two functions are heat absorbers, the second is to make it more durable so that every year it is not made continuously. In the past, we used sugar cane leaves, the term is blabat, but the disadvantage of blabat is that in terms of durability, it is less durable" (Interview, S1, November 19, 2022).

"To make it easier to open the lid, especially if it is upstairs, we just need to be given the term if in tobacco in the toa the wind can enter, it is open. There is also to make it faster, in the making of the whole toa so just lift it all open, there is a tool. If it is made sideways it is more difficult to open it, it also takes longer so the opening is made upwards. The same with the side ones so that it is easier to open" (Interview, S1, November 19, 2022).

The fourth part is a column (room) made of Javanese bamboo tied with BWG 16-type wire [26]. The size of the room is explained by the following sources,

"So, in one warehouse, there are 3 road rooms, each measuring 2.5 meters in length, then for the rooms themselves, there are 2 parts, this one is 5 meters long, the other is 7.5 meters" (Interview, S1, 19 November 2022).

"What is the language of bamboo, Javanese bamboo or pring kilis here if you call it" (Interview, S3, November 29, 2022).

The fifth part is the warehouse foundation made of cement in the form of blocks with the aim of not being easily mouldy and eaten by termites [11]. The sixth part is the roof of the warehouse. The roof structure is explained in the following interviewee statement,

"On the roof, besides the blabat, there is usually a waring and two crossing bamboos, the purpose of which is to hold or weigh if there is wind so that it does not pick up. The anchoring bamboo is called cecek which is placed in one room. There are two bamboos installed across the bamboo 4 meters. Then underneath it, there is a wuwung from the kadut" (Interview, S1, November 19, 2022).

The structure of traditional architecture has its own uniqueness. It is unique to ordinary houses that make buildings in traditional architecture more robust [27]. From the direction of development, building area, and interior design, to the materials used, special materials are also used so that they can gain value and uniqueness. This is also found in the *Atag* warehouse building which cannot be separated from the concepts of physics. In these parts, there are several balance concepts that can be found, namely the moment of force, equilibrium of a rigid body, weight point and moment of inertia.

Moment of Force

The moment of force is the quantity that the force acting on the object can make the object rotate [28]. The moment of force can be found in the *Atag* warehouse window, namely when opening the window. The way to open the window was explained by the following source,

"To make it easier to open the lid, especially if it is upstairs, we just need to be given the term if in tobacco in the toa, the wind can already enter, it is already open. There is also to make it faster, in the making of the whole toa so just lift it all open, there is a tool. If it is made sideways, it is more difficult to open it, it also takes longer so the opening is made upwards. The same with the side ones so that it is easier to open them" (Interview, S1, November 19, 2022).

This explanation is also supported by the statement below.

"Yes, the hinges use wire" (Interview, S3, November 29, 2022).

The window has a shaft to rotate, causing rotation. This is what causes the moment of force on the *Atag* warehouse window. The moment of force results from a force acting at a certain distance from its center point which tends to rotate [29]. Figure 3 is an illustration of the moment of force in the *Atag* warehouse.

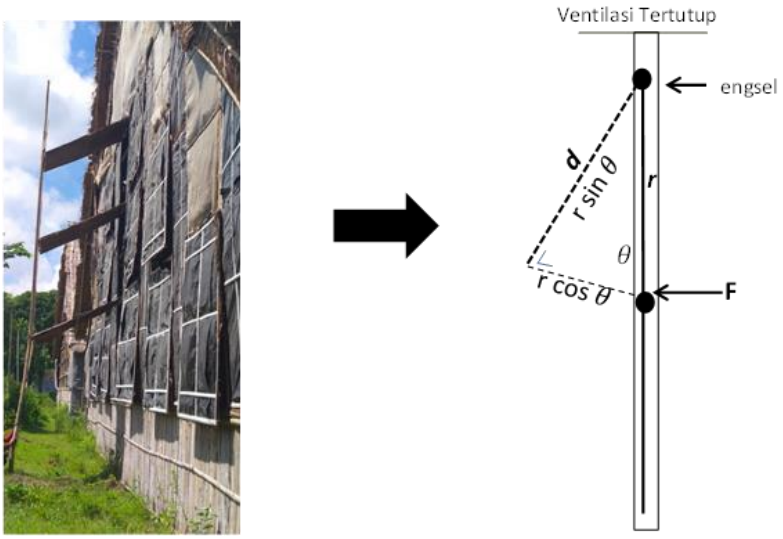

Figure 3. Illustration of the Moment of Force

In Figure 3, it can be seen that the greater the value of the arm (d) and the force, the greater the moment of force released.

$$\vec{\tau} = \vec{F} \times \vec{r}\sin\ \theta \quad (1)$$

Rigid Body Equilibrium

Objects that are balanced must fulfil the conditions of balance, namely $\sum\vec{F} = 0$ or $\sum Fx = 0; \sum Fy = 0; \sum Fz = 0$ and $\sum\vec{\tau} = 0$ [30,31]. There are several balance concepts that can be seen in the *Atag* warehouse building. The first is on the overall part of the *Atag* warehouse. Inside the framework of the building, there are columns that have a certain size, as explained by the following source,

"Columns are called rooms in tobacco, so 1 room is 2 meters wide. One room is 2 meters wide and 20 meters long, from 20 meters it is still divided into 8 columns. Each column is 2.5 meters, so 2.5 meters 8 times. So, one column is 2 x 2.5 meters" (Interview, S1, 19 November 2022).

Figure 4 shows the forces acting on the frame of the *Atag* warehouse.

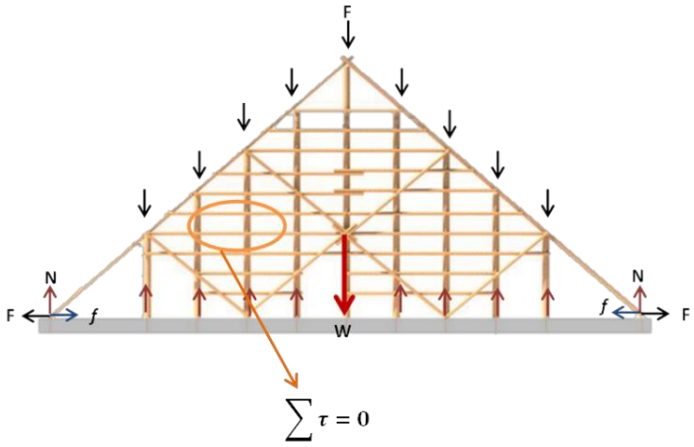

Figure 4. The Forces Acting on the Warehouse

In Figure 4, the forces in the horizontal and vertical directions must equal to zero to remain balanced. Mathematically it can be written as equation 2 and 3,

$$\sum Fy = N - F + W \quad (2)$$

$$\sum Fx = f - F \quad (3)$$

From Figure 4, it can be seen that the function of the bamboo installed across aims to prevent the vertical bamboo from rotating so that the torque is equal to zero.

Another balance can be seen in the wire rope ties at each bamboo joint. This bond has its own term according to the following interviewee's statement,

"The term is usually called warehouse rope ties, so there are special knots usually with the help of pliers too" (Interview, S1, November 19, 2022).

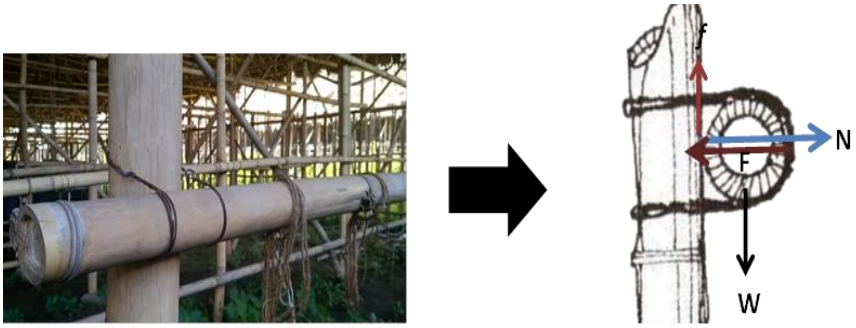

Figure 5. Force on a Wire Rope

Figure 4 is the force on the rope. Just like the rest of the *Atag* warehouse, the vertical and horizontal forces must be zero to remain in balance. Mathematically it can be written as equation 4 and 5,

$$\sum Fx = N - F \quad (4)$$

$$\sum Fy = f - W \quad (5)$$

To prevent the bamboo rope from slipping and causing rotation, the rope must be tied tightly. The concept of balance can be found on the sliding warehouse door. The way this door works is as stated by the interviewee,

"The model is a *slorokan* (sliding door) here, so the top uses a whole bamboo slide. Actually, the door is different depending on the foreman's request" (Interview, S2, November 19,

2022).

The forces acting on the styled barn door are as shown in Figure 6.

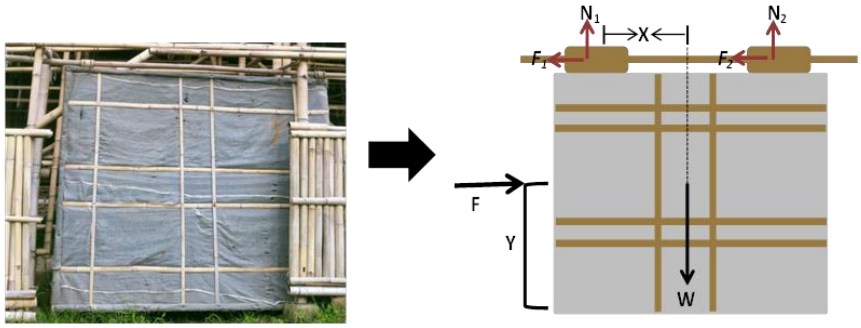

Figure 6. Illustration of door style

When the door is moved, there are forces acting. In order to remain balanced, it must meet the balance requirements. Mathematically it can be written as equation 6, 7, 8,

$$\sum Fx = F - f_1 + f_2 \quad (6)$$

$$\sum Fy = N_1 + N_2 - W \quad (7)$$

$$\sum \tau = -W.Y + N_1.X \quad (8)$$

The joints in the *Atag* shed foundation have several functions that have been described by the source,

> "The foundation structure of the *Atag* warehouse is termed using joints. Now it is made of cement that is formed into a square, the size varies, but usually, it is around 25 x 29 x 12 cm. The purpose of this is to prevent damage to the bamboo from termite attacks, and secondly, to prevent the poles from collapsing" (Interview, S1, November 19, 2022).

The Atag shed has bamboo foundation poles, which are not centrally positioned on the foundation joint. These numerous bamboo poles contribute to the stability of the building, along with its size. [21][32]. This occurs due to the displacement of the bamboo at the joint as shown in Figure 6.

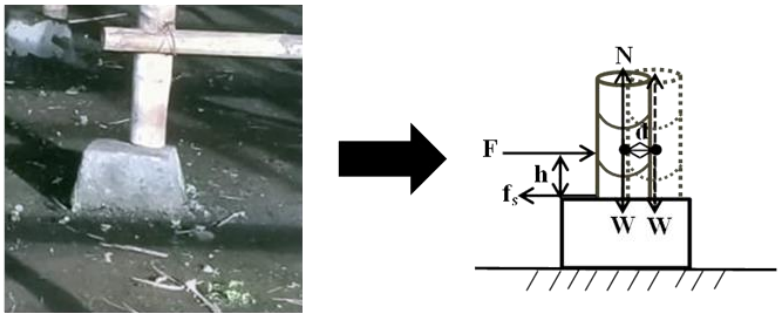

Figure 7. *Atag* shed foundation joints.

The bamboo shift is caused by an external force so that there is a distance (d) from the original state, as shown in Figure 7. Mathematically, it can be found by the formula,

$$\sum Fx = F - f_s \quad (9)$$

$$\sum Fy = N - W \quad (10)$$

$$\sum \tau = F.h - W.d \quad (11)$$

Next is the foundation of the *Atag* shed. In the foundation part of the *Atag* shed there is a *semat* that functions as a reinforcement between bamboo to withstand the load above. This is in

line with the interviewee's statement,

"Ohh that is called *semat,* which is a lock between bamboo" (Interview, S1, November 19, 2022).

Figure 8 is the forces acting on the *semat.*

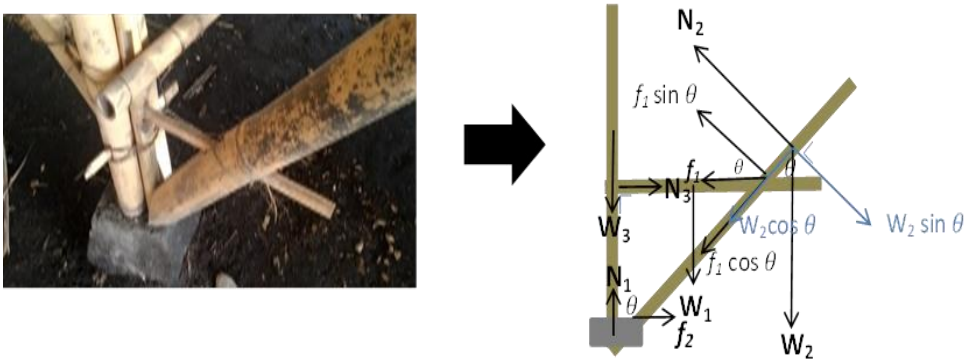

Figure 8. Force on the *semat.*

Similar to other balances, in order to be balanced, it must meet the forces of balance. The vertical force with the horizontal force must be equal to zero. Mathematically it can be written as equation 12 and 13,

$$\sum Fx = N_3 + f_1 \cos\theta + W_2 \cos\theta - f_2 \quad (12)$$

$$\sum Fy = N_1 + N_2 + f_1 \sin\theta - W_2 \sin\theta - W_1 - W_3 \quad (13)$$

It also serves to hold the bamboo so that it does not rotate $\sum\tau = 0$. From the above analysis, it is concluded that in order for the object to remain balanced, the sum of the forces acting horizontally and vertically must be equal to zero in accordance with the reference at the beginning.

Weight Point

In the *Atag* warehouse building, the application of the weight point can be seen on the front cover of the *Atag* warehouse which is made of bamboo. The point at which the resultant gravity on a particle acts is the definition of the center of gravity [33]. The bamboo is arranged vertically and then a horizontal bamboo is given in the middle so that the vertical bamboo remains balanced, as shown in Figure 9.

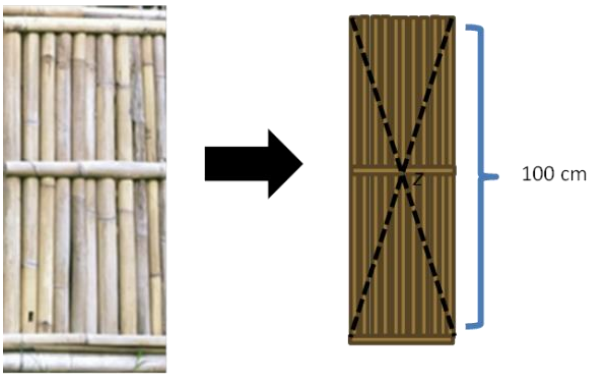

Figure 9. Illustration of shed bottom cover.

The vertical bamboo is 1 meter long, and the horizontal bamboo is placed right in the middle of the vertical bamboo. The center of gravity is also found on the inside of the *Atag* shed. Each of the two warehouse rooms has a crossing bamboo right in the middle of the *Atag* warehouse building as shown in Figure 10.

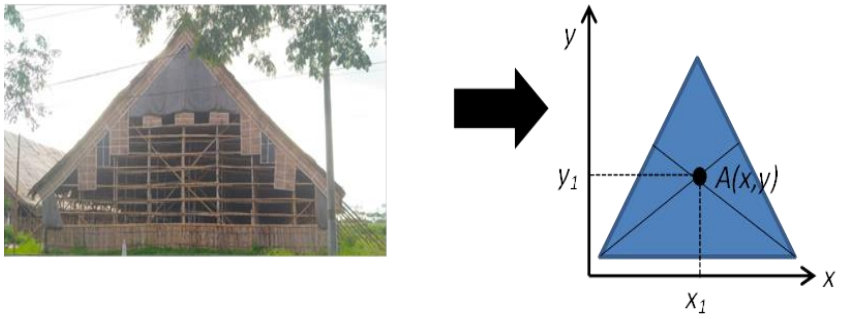

Figure 10. The center of the warehouse.

This is consistent with the interviewee's statement,

> "...Every two rooms there is a bamboo crossing right in the middle of the building which functions as a reinforcement" (Interview, S3, November 19, 2022).

The *Atag* shed has a 90° angle on the roof, so the *Atag* shed is an isosceles triangle. Two-dimensional gravity can be found with the formula,

$$\bar{x} = \frac{A_1x_1+A_2x_2+A_3x_3+\cdots}{A_1+A_2+A_3+\cdots} = \frac{\sum_{i=1}^{n} A_i x_i}{\sum_{i=1}^{n} A_i} \quad (14)$$

$$\bar{y} = \frac{A_1y_1+A_2y_2+A_3y_3+\cdots}{A_1+A_2+A_3+\cdots} = \frac{\sum_{i=1}^{n} A_i y_i}{\sum_{i=1}^{n} A_i} \quad (15)$$

Moment of Inertia

In the *Atag* warehouse building, the moment of inertia can be seen in the bamboo that is climbed by warehouse workers. This causes the bamboo to rotate because there is loose bamboo, as seen in Figure 11. Warehouse workers climb the bamboo to move tobacco from the top to the bottom so that it is not damaged, in accordance with the statement of the informant,

> "So, if the tobacco is put on top first, then down so that it is easy to climb..." (interview, S1, November 19, 2022).

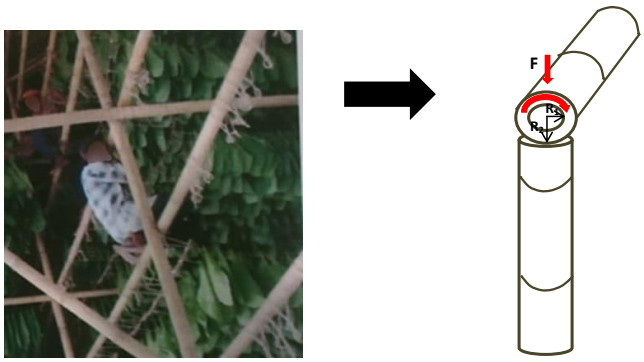

Figure 11. Moment of inertia in bamboo.

Moment of inertia is the tendency of objects to maintain themselves [34]. When the barn rope ties loosen, the bamboo will rotate slightly. This is what causes the moment of inertia in the bamboo. The moment of inertia in bamboo can be found in equation 16.

$$I = \frac{1}{2}m \cdot (R_1^2 + R_2^2) \quad (16)$$

According to this study, there are six *Atag* warehouse structures namely doors, windows columns, roofs, and foundations. This *Atag* warehouse which is related to scientific knowledge is limited to only a few parts. The concept of *Atag* warehouse balance only focuses on high school physics balance material, even though there are still many physics concepts in the *Atag* warehouse that can be analyzed. Further research shall raise this issue on the *Atag* warehouse culture.

The concept of balance can be applied in school learning to make it easier for students to understand the material [32]. In addition, by raising the culture of the *Atag* warehouse, students can get to know and become more familiar with the natural, social, and cultural environment. In addition, it can develop abilities and skills as well as knowledge about their region that are useful for themselves and society in general. Furthermore, it can equip students with attitudes and behaviors that are in harmony with the values of the rules that apply in their region to further preserve and develop them. This study endorses integrating local wisdom when making teaching materials for further research

CONCLUSION

The *Atag* shed building has several parts, consisting of doors, windows, columns (rooms), shed roof, and foundation. The concept of balance that exists in the *Atag* warehouse building is the concept of static balance (equilibrium of a rigid body and a heavy point) which occurs in the entire *Atag* warehouse building, wire rope ties on bamboo, *Atag* warehouse foundation, on semat and the bottom cover, as well as the center of the *Atag* barn. Furthermore, the concept of dynamic balance (moment of force and moment of inertia) occurs in the warehouse window and in the bamboo part that loosens when stepped on by warehouse workers. The results of the study can be used in applying the *Atag* warehouse-based ethnoscience approach through the physics learning process, especially in the equilibrium chapter. The limitations of this research are focused only on some parts of the *Atag* warehouse that are in accordance with high school balance material. The *Atag* warehouse balance concept is suggested for further research related to the three-dimensional plane.

AUTHOR CONTRIBUTIONS

Alfrida Diftia Vestnanda: Writer, Conceptualization, and Researcher; Rif'ati Dina Handayani: Main Supervisor, Validation, Review and Editing; Albertus Djoko Lesmono: Formal Analysis on Physics Concepts, Validation and Template Formating.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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