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AN ALTERNATIVE STUDY OF ADAPTIVE PARTITION DESIGN FROM COW DUNG

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ABSTRACT

The use of cow dung as a local and organic building material in Indonesia has been carried out in various forms because it has similar characteristic of cement. The choice of using cow dungs is based on recent sustainable issues and the effects on the built environment such as farming sector and natural resources. One of the solutions to the sustainable issues that occur is the adaptive building concept, where this concept will focus on the user life cycle, building materials, and construction such as wall or partition panels. The cow dung material will act as an adaptive medium and it will be constructed as partition wall. This paper presents the design of an adaptable construction with modular partition wall from cow dung mix. The result is a sustainable cow dung partition wall that applied in an apartment layout unit which can adapt to different user life cycle and demands.

Keywords: Adaptive; sustainable; waste material; partition wall.

INTRODUCTION

Due to its recent development, design priority becomes more complexed nowadays. The need from diverse social backgrounds regarding the components and functions of design will keep changing and developing. This phenomenon produces an adaptive concept in life and for buildings. The concept of adaptive building itself has developed for some decades especially in the construction sector. According to Geraedts et al., 2014, the existence of adaptive buildings will maintain their function to adapt to the life cycle of the users and the buildings themselves in a certain condition and need. Meanwhile, the interest in a flexible life as one principle of the adaptive concept also develops and becomes a new perspective on a vertical residential building. Adaptive building will become a design approach on apartment buildings because they have a narrower space that creates a design problem, and the adaptive concept can solve the problem. Furthermore, various users and needs make the adaptive concept quite relevant for residential buildings like apartments. The limited availability of residential area makes people choose vertical buildings as an alternative for living. The population growth and the price of land and house that increase each year (3,04%) also play a part for the increasing phenomena of vertical residential buildings or apartments in Indonesia, especially in big cities (Zarfan, 2017). An adaptive and flexible life becomes a new solution for the low rate of rented houses due to the economic crisis and the rise of awareness and interest for a sustainable life.

The concept of adaptive building itself, especially in vertical residential buildings, namely apartments, will be closely related to sustainability issue. A building that can accommodate some different types of users in their entire life cycle has a long-term utility value. This value is a crucial condition for sustainability (Geraedts et al., 2014). The concept of adaptive building in apartments can be applied for a construction solution on the material sector, that is by using wall media that can adapt and create a flexible room. The material usage on this wall media has the potential to adapt to its sustainable value. One of the materials is a local one in the form of cow dungs that are used by the local community as a building material such as for wall coating, bricks, and other usages. Moreover, the choice for this waste material also considers comparing it with the existing material in terms of its material characters and weight to be used as an adaptive wall. In Indonesia, the average breeders have two to five cows in different places. Each day, a cow can produce ten to fifteen kilograms of waste. A cow that weighs 450 kg produces wastes in the form of dungs and urine about 25 kg per cow each day. In general, the breeder handles the cow dungs by making them into compost fertilizer, biogas, or even by spreading them directly to the agricultural lands. However, cow dungs have silica contents which can be useful for building materials. Another assumption is that they contain fiber derived from the food eaten by the cows such as grass that is digested into dungs that can be used to make materials for wall to get a smooth surface and does not crack easily (Hardjito, 2021). The effort done for this research is to make use of the material to be a building material in the form of modular adaptive wall. The usage of cow dungs will become one of the alternatives for processing waste materials to solve the need for rooms, especially in apartments with an adaptive concept as a strategy and solution for a sustainable life.

ADAPTIVE BUILDING AND SUSTAINABILITY

An adaptive building can accommodate various user types if their life cycle has a long-term utility value that makes it one important requirement to achieve sustainability (Geraedts et al., 2014). The adaptive concept itself derives from the need of the people, clients, or users, namely the need for building or residential place with the location, building characteristics, and unit suited for their specific need. If they are not satisfied with the existing building, there might be some solutions, namely moving to another building, developing the existing building by providing a temporary accommodation, and adapting to the existing unit, building, or location. Moreover, according to Geraedts et al., 2014, the adaptive concept also brings about some social perspectives. From the users' perspective, they want an accommodation that can adapt to their needs. The owners will also try to find the most profitable possibilities so that the users can stay longer, and it suits their ownership cycle. From the people's perspective, they will also think of a residential building that contributes to a sustainable living which is also attractive to them. The adaptive concept will apply the flexibility approach in its implementation phase. This adaptive concept has three types of capacity. First, it is organizational flexibility, which will respond to the changes according to the need on the scale of the built environment. Next, it is process flexibility, namely the capacity to respond to the changes from the design to the construction phase. Finally, it is the product flexibility, that is the capacity to respond to the changes in the building utilization phase. The process flexibility and product flexibility will be closely connected because even in the utilization phase, they both involve a design process in it.

ADAPTIVE CONSTRUCTION AND FRAMEWORK

In terms of construction, in the details of the building, adaptive construction has the characteristic indicator of flexibility. Partition wall with knock-down joints gives a high adaptive value that can be changed and arranged into a different function. Besides, the higher the value of its changeable construction components, the higher the flexibility value and its room adaptation (Geraedts et al., 2014). Furthermore, this research is also supported by the research by Eguchi et al., 2011, from their journal article on *The Cultivation of Adaptability* in Japan. There are six strategies to create an adaptable framework, namely *flexible, refitable, available, scalable, movable,* and *recyclable.*

- *Flexible*
  The room or component flexibility can be achieved by using partition wall, furniture types, ceiling distance, and others.
- *Refitable*
  It is the easiness to change, replace, or dispose a component. This can be achieved by designing a new system, module, simple joints, replaceable panel, and others.
- *Scalable*
  It is to enlarge and reduce the size of building or room. It can be achieved by putting stackable units, modular units, portable products, and others.
- *Movable*
  It is to change the room or location configuration. It can be done by knocking down, folding, moving, and doing other things with a component in a room easily.
- *Recyclable*
  It is the capacity to reuse or apply a renewable resource, recyclable materials, biodegradable, local materials, and others.
- *Available*
  It uses the existing materials. It can be done by using fabricated materials or standard components that are commonly used.

COW DUNGS AS WALL MATERIAL

Cow dungs are derived from the processes in cow farms or from the metabolism process that is not environment friendly. Small or big farms always produce wastes in the form of liquid (washing water for the cattle and the cage), solid wastes (dungs), and gas wastes. The environment impact from animal husbandry can be land, water, and air pollution that potentially harms cattle and human health (Fawaid, 2019). *Pozzolan* is a natural or synthetic material that contains a lot of reactive silica. According to the ASTM C 618-94a standard, *pozzolan* is a material containing silica or silica-alumina. Silica has little or even no characteristics of cement, but in soft granule form accompanied with humidity it can chemically react to calcium oxide in normal temperature to form a compound which has the characteristics of cement. Cow dung ash is derived from burning the cow dungs. Cow dung ash is a *pozzolanic* material, and it has silica content of 79.22% (Kumar, 2015). Cow dung ash is produced from cow dung that is dried by the sunlight and burned until it turns dark.

Fig. 1. Earthbag House with wall from cow dungs (Source: jogja.tribunnews.com)

The cow dungs can be used as the material for wall or floor coating. Cow dungs that have been removed from its gas content are mixed with straw and lime, and they are used as adhesive materials and wall coating with the ratio of 70%:30% (Suparma, 2021). Moreover, another benefit from land material and cow dungs for wall is to stabilize the temperature inside the building. On daytime, the temperature inside the house is cool enough, and at night the temperature inside the house is not too cold (Suparma, 2021).

Fig. 2. Imigongo wall from cow dungs (Source: instagram.com/nyungwehouse)

The cow dung materials have also been used by Central Africa people as an art form named Imigongo (Denisyuk, 2019). Imigongo is an art form in Rwanda (Central Africa) that is made traditionally by women by using cow dungs that are usually black, white, and red in color. Design can be in a spiral or geometric form drawn on the wall, earthenware, and canvas. The origin of Imigongo was from the 18th century when the Crown Prince named Kichara wanted to find materials that were sticky to decorate the room interior of his house. Finally, cow dungs were used as the main materials. This was because cows were the most bred cattle. Besides, other decoration materials were taken from vegetables for coloring. The process was very similar to making cow dung wall, namely the cow dungs were mixed with cement, ash, and white glue and then were stirred to form a texture like clay and molded as expected (Ashimwe, 2020). The ash and white glue that could function as cement were also used as odor remover from the cow dungs.

ADAPTIVE CONCEPT OF COW DUNGS

There are a lot of materials that can be used as a partition wall on an apartment building. Some materials that have been commonly used such as gypsum, light bricks, GRC or cement board can be easily found in the market as materials for apartment walls. However, not all materials can fit in with the adaptive wall principles. Gypsum and GRC or cement board materials will be analyzed in comparison with cow dung walls because of their common usage as partition wall in apartments and their potential as adaptive walls. Furthermore, the material similarity in terms of their characteristics also becomes the basis for the comparison.

Based on six strategies of adaptable framework by Eguchi et al., 2014, gypsum material will be flexible and suitable for making a movable wall. The material is also available in the market and its fabrication can suit the scale of need. Gypsum can also be recycled due to its decomposable characteristics in land after its usage time. This makes gypsum unable to be reused in its original condition. However, the characteristics of gypsum board that easily cracks if it is given little load and that it can be perforated make gypsum un-refitable as an adaptive wall. Furthermore, the usage of gypsum will need a regular maintenance due to the resultant flakes so that it is not suitable for making an adaptive wall in apartments. Next, GRC material or commonly called *Glass Reinforce Concrete board* or cement board material is also often used for apartment wall to replace brick or light brick wall. This material has a weight about 30-50 kg and is

Table 1. Analysis of adaptable framework gypsum, GRC, and cow dung panel

	Flexible	*Available*	*Refitable*	*Scalable*	*Movable*	*Recyclable*
Gypsum	✓	✓	✓ / x	✓	✓ / x	✓ / x
GRC / Cement Board	✓	✓	x	✓	x	x
Cow dung Panel	✓	✓ / x	✓	✓	✓	✓

9 mm thick per board (1.2 x 2.4 m^2, depending on the brand) that makes it unsuitable for movable wall. This material is also available in the market and is fabricated. Unfortunately, this material cannot be recycled because it has cement element. Finally, the wall material from cow dungs has the potential to be used as the material for movable wall because of its lightweight characteristics and of being an organic material that can decompose in land after its life cycle. The only weakness of this material is that it is not available yet in the market and not fabricated although its raw materials can be found easily. This material is also still in the development phase even though a lot of case studies that apply cow dung materials for wall have been done, but further research about the material characteristics still needs to be done.

METHODOLOGY

In designing an adaptive partition wall from cow dungs, some steps need to be done, namely literature study, case study, experiment, and design process.

- Literature study
  Literature study is carried out to study the concept of adaptive building. This needs to be done to understand the basic concept, the characteristics, and the technical aspects of the adaptive building especially from the material, construction, and characteristics of cow dungs.
- Experiment
  The experiment process is done to know the potential and composition of the material mix from cow dungs that are suitable for adaptive walls.
- Design process
  Finally, construction design and modular partition wall from cow dungs are carried out through a literature study, case study, and experiment results and by implementing the adaptive concept.

RESULTS AND DISCUSSION

Experiment Results

The experiment results are in the form of six samples carried out according to the research variables. The following is the discussion of each experiment sample.

- Sample A
  In sample A, we mix 500-gram cow dung, 110-gram lime, dried straw cut into ±5-10 cm, and 600-ml water. The procedure is as follows: mix all materials into a casting bucket and stir them with a cement trowel until it creates a dark grey mix. The ratio consists of 70% cow dungs and 30% cement material (lime and straw). The mix is applied to a sack producing a dimension of 30 x 60 cm^2 and 3 mm thickness. The result after it is being dried is the mix gets hardened, turns light grey, and cracks easily. Too much addition of water makes the mix get broken easily. During the drying process in 24 hours, it was raining, and the mix was not exposed to sunlight. Besides, 3 mm thickness that was produced could be categorized as thin.

Fig. 3. Sample A

- Sample B
  Sample B consists of cow dungs, lime, and similar straw like in sample A. However, the water was reduced to 450 ml to avoid it from being too liquid and easily broken. This mix produced a dimension of 30 x 60 cm^2 and 3 mm thickness that was still thin. The result was a mix that was not perfectly dried after the drying process of 24 hours and little sunlight, but it was hard enough. The mix was a little sticky, a little brighter than the previous one, and a little cracked.

Fig. 4. Sample B

- Sample C
  With the same ingredients, the number of cow dungs was reduced into 170 grams, and the cement material and water were also reduced. This is because on the thickness variable it was determined to be 9 mm (regarding the usage of panel or wall partition board that was commonly used according to the reference, namely 9 mm). The procedure of mixing was the same as the previous one, and it produced the dimension of 12 x 50 cm^2, and 9-mm thickness. The result showed that the mix was stickier, and because it was thicker than the previous sample, it was more hardened. This was because the amount of water was also reduced.

Fig. 5. Sample C

- Sample D
  The procedure and treatment of sample D and the next samples were a little different from the previous ones. The sample was made with a variable of 20 x 20 cm^2 dimension and 9 mm thickness. Furthermore, weight variable started to be counted and there was another material with a percentage of no more than ±10% as a binding material, so the main material, namely cow dung, became a dominant material while considering the organic material being used. The straw of 15 grams was arranged on top of a sack. The arrangement procedure was done in accordance with clay plaster application (Iskandar, 2016). Next, 200 grams of cow dungs, 30 grams of lime, and 20 grams of cement were mixed into a casting bucket, and 150 ml of water was added. Then, the mix was pressed with any available pressing tool made from balsa wood. This would help the mix to be stickier. The result was the color turned light grey, got dried perfectly, and got easily broken. Water addition was too much so that the initial mix was very liquid, and the back of the sack leaked.

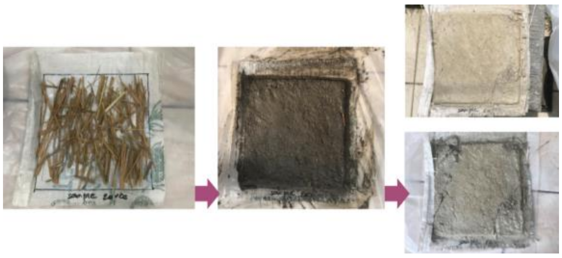

Fig. 6. Sample D

- Sample E
  With the same procedure and ratio like sample D, the number of cow dungs and cement material was changed by adding the same binding material, namely cement. The ratio of the new mix was 250 grams of cow dungs, 30 grams of lime, 10 grams of straw arranged on a sack, and 50 grams of cement. The dimension was determined to be 20 x 20 cm^2 and 9 mm thickness. The mix was a bit more and produced a thicker sample than 9 mm, namely 14 mm. Weight variable was also included, and after being weighed the sample turned to be 431 grams (a bit heavier). The result of sample E was the color turned light grey and got hardened. The drying process was also done like the previous sample.

Fig. 7. Sample E

- Sample F
  In sample F, the cow dungs were reduced into 200 grams, with the cement material also being reduced according to the initial ratio to avoid leftover mix. White glue of 20 grams as cement material was added. Due to less water than that in the previous sample, the consistency of the mix was a bit solid and dark in color (color of the dominant material, namely cow dungs). With the same procedure of arranging the straw and the drying process with sample E, a brownish grey panel with a dimension of 20 x 20 cm^2 and 9 mm thickness weighing 252 grams (light enough) was produced.

Fig. 8. Sample F

From all six samples, samples E and F had better final physical results than the other samples because of the different procedure of arranging the straw, of enough amount of cement material, and of little amount of water in the mix. The physical results were better because they did not break easily when being moved, they had a smooth surface due to the straw on the lower layer of the mix, and they were also stronger than the other samples. However, when considered from its weight variable, sample F had a lighter weight of 252 grams per 20 x 20 cm^2 (with 9 mm thickness).

Therefore, from the experiment results, especially in samples E and F, there are some important things to consider in making the panel, namely:

1. The ratio of cow dungs and cement material being used
   The ratio of the materials will show whether natural or organic material is being used. This will also influence the material cycle that will decompose in the environment naturally
2. The procedure of arranging the straw
   The straw arrangement will help the binding process of the mix when it is put on the lower layer before the mix is laid down
3. The addition of other materials as binding materials
   The addition of inorganic materials such as cement or white glue as the binding materials that is no more than 10% will help a lot in the making of the panel. This binding material will help a bit in producing the characteristics of the physical panel, such as the color and solidity.

Partition Wall Design

Movable partition wall basically has some systems, namely sliding, folding, and pivot. The choice of the system in cow dung wall should consider the configuration of the apartement unit layout which commonly has a limited or small space. Besides, from seeing the characteristics and construction of panel wall from cow dungs, the folding system will give difficulties and take too much space. It is the same with pivot system that has an axis that is usually put at the end of the panel. Therefore, combining siliding and pivot system whose axis is at the center of the panel will give enough space if the panel is not being used.

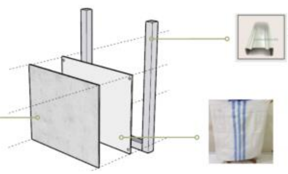

Fig. 9. Schematic Construction

Table 2. The comparison of experiment results from sample A to F.

Sample	eight (gr)	ickness (mm)	mension (cm2)	Cement Material Addition	Notes	
A	-	3	30 x 60	-	hin, brittle, inappropriate procedure of arranging the straw	x
B	-	3	30 x 60	-	hin, brittle, inappropriate procedure of arranging the straw	x
C	-	9	12 x 50	-	hin, brittle, inappropriate procedure of arranging the straw	x
D	330	9	20 x 20	20 gr cement	rittle, inappropriate drying procedure	x
E	431	9 - 14	20 x 20	50 gr cement	ick, not smooth, and too much of main material	✓ / x
F	252	9	20 x 20	20 gr white glue	-	✓

The wall structure from this waste is using a framework system with metal stud material of 7.6 cm. The application of this system is in accordance with partition wall framework system that has been commonly applied. Next, a sack will be attached on the framework by using gypsum bolts with a drill. The bolts must be equipped with rings to keep the sack from being ripped when installing or using it. After that, a binding material in the form of straw is arranged and laid over by the mix from the cow dungs.

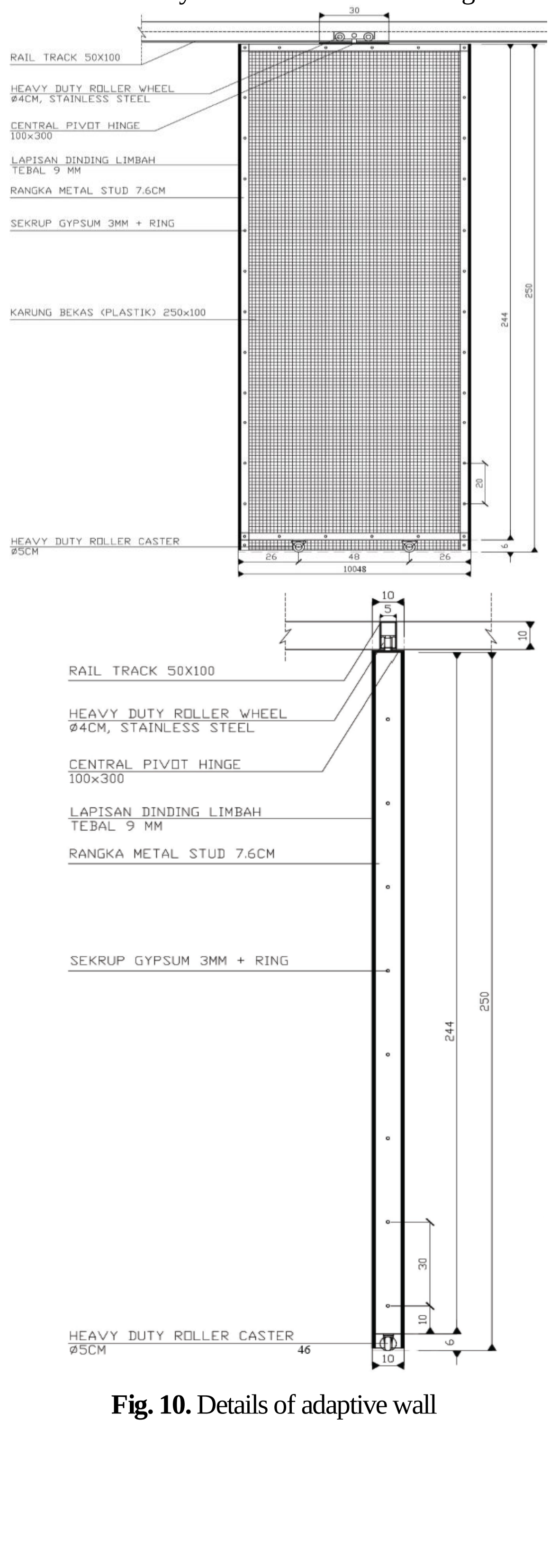

Fig. 10. Details of adaptive wall

In accordance with technical flexibility construction indicators for units with adaptive concept, modular design has components that can be found or bought easily in the market, and the installing details are simple so that it is easy to knock it down or replace the components. The initial modular construction uses a metal stud so that it is lighter. This will be supported with sliding wheels with a diameter of 4 cm on the lower parts that have a specification to uphold heavy loads (for example 75 kg/wheel pair with the brand *dekkson* double roller heavy duty wheel). The wheel installment functions to avoid installing sliding rails on the floor that makes the space even more limited and disturbs people's movement. Next, pivot system will be supported by pivot hinge component with a central type (for example the brand of *dekkson* stainless-steel pivot hinge that can uphold a load of maximum 250 kg/component). This pivot component will also help uphold the load of the modular wall. Then, the rails and upper wheels will also be designed to use simple rail component (for example the brand of *dekkson* track aluminium sliding rail and stainless-steel wheel that can uphold a load of maximum 100 kg). The sliding rail path is also designed in such a way that it looks neat from the outside by inserting the rail component inside the ceiling.

CONCLUSION

Partition wall that uses material mix from cow dungs has good performance and potential as adaptive wall for apartment units. This performance covers the analysis result of adaptable framework by Eguchi *et all*, 2011 and the experiment results showing that the panel has a fair light weight, namely with a sample of 20 x 20 cm^2 weighing about 250 gr which in comparison with a gypsum board and RRC of the same size it is lighter so that it can be categorized as flexible. It is also solid and can be made by anyone, and the component is available in the market and is easy to find. This also gives an added value to the adaptive wall concept and apartment units. Moreover, with relatively the same price with gypsum board, this panel is also easy to be made and applied. The making procedure is also easy enough to follow, and it has the ratio of 70% material of cow dung and 30% of organic binding material such as straw and inorganic one such as cement or white glue. However, it needs to be remembered that since bending and hardness test on the material was not done, a definite measurement of its strength is not known. This opens an opportunity for further research in testing its strength, solidity, and bending capacity of the material. Moreover, this research can also be continued with a configuration of different apartment buildings so that it provides a more developed modular and findings. Modular wall panel produced was 1 x 2.5 m^2, which has been accorded with the width and height configuration of the commonly used wall panel in the hope that it can be used as a measurement that is produced or fabricated.

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