



# Enhancing Material Experience through Quail Eggshell Waste

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**Abstract.** Since the landfill closure in Yogyakarta, boiled quail eggs merchants in Pasar Legi Kotagede have had difficulty disposing of their daily trash. This study aims to explore quail eggshell waste and the most suitable combination to enhance the material experience. Material Driven Design (MDD) was used to facilitate the researcher's developing of a material design. In sensorial experiences, users defined quail eggshell material had physical characteristics such as opaque, hard, rigid, matte, non-reflective, smooth, cold, light, odorless, and strong. Users' interpretation of this material is creative, unique, modest, water resistant, functional, contemporary, affordable, comfortable, and terrazzo-like. In affection experiences, the quail eggshell material made users feel interested, admired, loved, excited, surprised, nostalgic, and satisfied. According to users, buffalo horn is the most potential material to combine with quail eggshell. In the design development, quail eggshell material and buffalo horn were applied in the bathroom set product, which exposed their physical properties and visual characteristics and was inspired by the local architectural heritage design style near there.

**Keywords:** *buffalo horn, quail eggshell, material experience, material-driven design*

## 1 Introduction

Since the landfill closure in the Piyungan area, Yogyakarta residents have had difficulty disposing of their daily trash [1]. This predicament is also experienced by local merchants in Pasar Legi Kotagede (Kotagede traditional market), who are required by the Department of Trade and Market Management to take home their waste generated while selling. The quail eggs merchants who used to sell boiled quail eggs became one of the affected parties in this incident. They need clarification about where to dispose of their eggshell due to the limited space in urban housing. Almost all urban houses in narrow alleys have no more yards to bury the organic waste. Moreover, all merchants in this market sell approximately 5-10 kgs of quail eggs daily. If the eggshell signifies almost 8.4% w/w of the overall weight (10-15) grams of quail egg [2], it means that all the merchant produces 0.42-0.84 kgs quail eggshell daily.



Fig. 1. Quail Egg Waste in Kotagede Traditional Market

The high sales of quail eggshells are probably due to the need for hawkers who must provide quail egg satay. Quail egg satay is a daily menu usually sold by hawkers as Yogyakarta is popularly known for the street food called *angkringan*. Increased consumption of quail eggs over the last few years affected the production of eggshell waste, which has also grown consistently [3]. Quail eggshells are discarded materials primarily placed in a landfill without pretreatment, creating stinks, ending microbial action, and decreasing soil quality [4]. Proper utilization of quail eggshells can help solve waste problems and open wider opportunities for product development. Despite odor and flies, other challenges of the reluctance of people to treat this waste are cost and insensitivity[2]. Whereas avian eggshells, including quail eggshells, are considered potential biowastes that have been utilized in material sciences [5], for example, as a substitute natural source of  $\text{CaCO}_3$  [2], [6]. However, there has yet to be research on processing quail eggshells to become material for a product. This study aims to enhance the material experience by exploring quail eggshell waste. The importance of material experience is that materials in product design determine the physical products and support the function and meaning of a product [7].

## 2 Method

This research began by thinking about the most efficient way to process piles of eggshells into material ready to be used in product design. To find it, researchers conducted several experiments using various methods and adhesives. The composite technique is currently considered the most efficient method because the eggshell waste obtained is in the form of small pieces and flakes. Next is to look for the type and composition of adhesive most likely to form a composite from quail eggshell.

After the composite from quail eggshell was produced, research continued to determine the potential for product development from quail eggshell material. This research used Material Driven Design (MDD) method (Figure 2) to investigate how end-users respond to the proposed material. For years, most designers have spent significant investments in materials development. Nevertheless, they need more curiosity in analyzing how consumers interact with these materials [8]. Thus, this method facilitates the user to enrich the meaningful experience of a novel material to help the researcher develop a material design beyond its utilitarian [9]. This method consists of four steps. The first step is Understanding the Material. In the first step, Giaccardi and Karana [10] proposed four foundations related to building a whole experience of material: sensorial,

interpretive, affective, and performative. The second step is Creating a Material Experience Vision. In this step, the designer is required to incorporate all the findings from Step 1. To generate a vision statement, designers must map and reflect on material characterization and purpose. The third step is Manifesting Materials Experience Patterns, where designers are expected to use his/her intuition to interpret the results and arrange the relationships between the formal properties and the explored meanings. The last step is Designing the Material or Product Concept. In this fourth step, the designer finally integrates all his/her prominent findings into a design phase.

Recently, this method has been applied to study user experience in DIY materials [11], [12]. A material-driven design process differs from most conventional contemporary design processes because designers can actively create, develop, or manipulate the material from the beginning rather than simply choosing a suitable material to fit the form after the design process has been completed [13]. This method has been developed as Material Driven Design for Sustainability, which provides specific guidance for product designers who want to work with sustainability in a current, highly interdisciplinary material reality. Through employing this strategy, the designer is better equipped to consider alternate, easily accessible resources like enormous amounts and different types of inexpensive waste from the manufacturing sector [13].

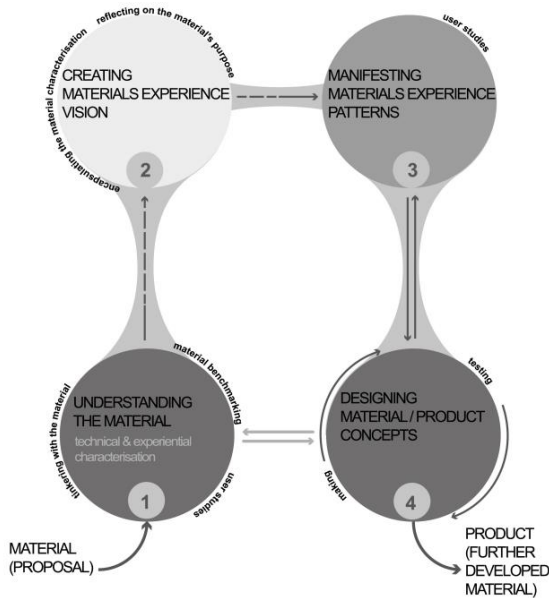


Fig. 2. Material Driven Design Method [9]

### 3 Findings

These pieces were mixed with two kinds of binder agents to make a composite. The first binder is bio-PVAc glue, and the second is water-based resin. The reinforcement was the quail eggshell, and the matrix was bio-PVAc glue or water-based resin. These two binders were used because bio-based sustainable materials had been progressively demanded to diminish the carbon footprint and emissions of pollutant gases [14]. This experiment aimed to find the most appropriate technique to reveal the quail eggshell properties. Materials and processes, as we know, strongly influence the form of a design. Therefore, a good design optimizes the material's properties efficiently and their ability to be shaped [15]. Not all binders can be used to hold quail eggshells together. Quail egg waste with a suitable binder can be processed to become material for product design. The result of using water-based resin is also different from epoxy resin. The water-based resin is more eco-friendly and provides a different visual than epoxy resin.



**Fig. 3.** Sample Product from Quail Eggshell

In the first step (Understanding the Material), the results of this experiment were discussed with end users. Sixty students majoring in Product Design, aged 18-23 years old, represent the end users. At first, they were tinkering with the materials, and then they filled in the online form to express their responds toward material from quail eggshell. There are four levels of materials experience as: sensorial, interpretative (meanings), affective (emotions), and performative. In order to comprehend materials, a hands-on approach called tinkering with material (Figure 4) appears to be essential to the MDD technique [16]. This step allows the material designer to comprehend how to use material using a learn-by-doing technique effectively [17]. The sensory experiences of a user have an impact on their affective and performative responses to material [12].



Fig. 4. Tinkering with the Quail Eggshell Materials

At the sensorial experiences, all respondents agreed to similar physical characteristics of quail eggshell composite: opaque, hard, and rigid. Most respondents answered that quail eggshell composite also has other physical characteristics. They are matte, non-reflective, smooth, cold, light, odorless, and strong (Figure 5).

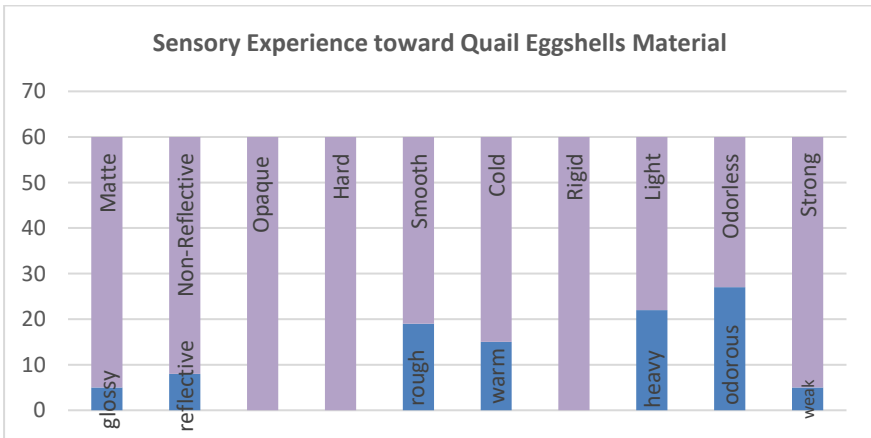
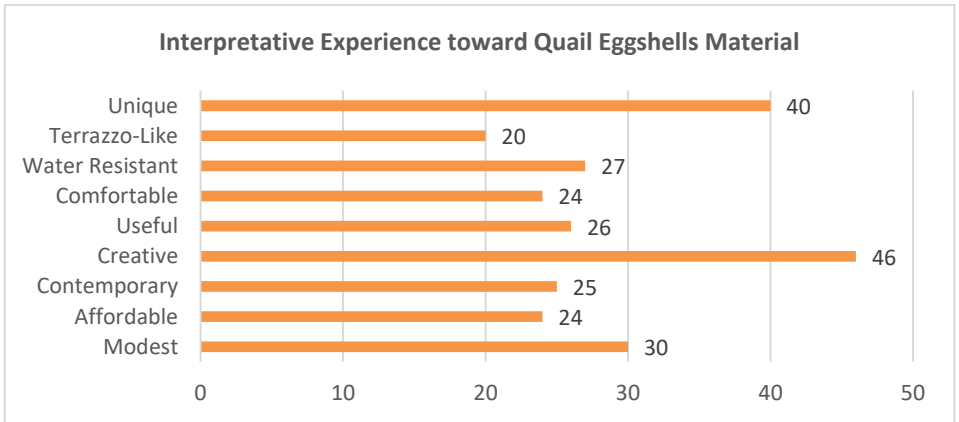


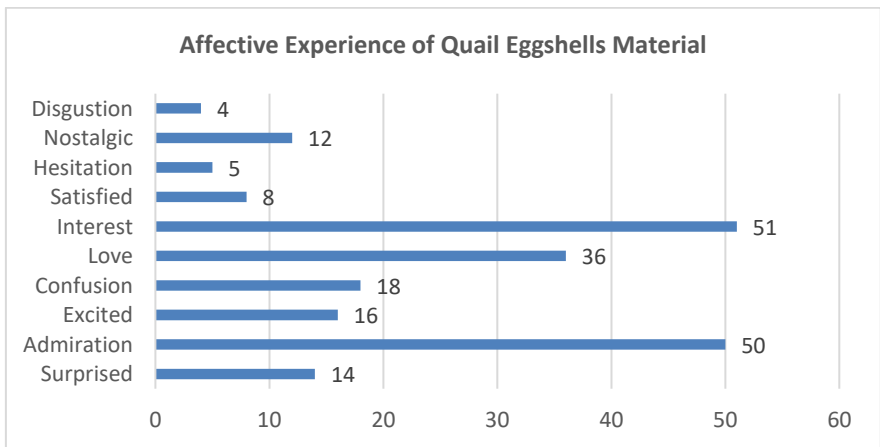
Fig. 5. Sensory Experience toward Quail Eggshell Material

At the next level of experience, the most frequently mentioned interpretation was creative because all respondents were discovering composite materials from quail eggshells for the first time. There are forty times “unique” interpretations, and thirty times “modest” interpretations were mentioned by respondents (Figure 6). Respondents also mentioned other meanings in their mind when they were interacting with quail eggshell material, such as water resistant (27 times), useful (26 times), contemporary (25 times), affordable (24 times), comfortable (24 times), and terrazzo-like (20 times).



**Fig. 6.** Interpretative Experience toward Quail Eggshell Material

The third level of material experience is affective or emotional experience. As can be seen in Figure 7, the most frequently answered emotions by the respondents were interest (51 times), admiration (50 times), and love (36 times). Besides, quail eggshell material also made them feel excited (16 times), surprised (14 times), nostalgic (12 times) and satisfied (8 times). Nonetheless, there were negative emotions that evolved when the material at hand was appraised by the respondents, such as confusion (18 times), hesitation (5 times), and disgustion (4 times).



**Fig. 7.** Affective Experience toward Quail Eggshell Material

At the last level of materials experiences, the research observed how the users respond to the quail eggshell material. These responses explained the performative levels of materials experiences (Figure 8). Most of them rubbed (50 times) and pushed (40 times) the surface of the quail eggshell. They also tried to lift (28 times), squeeze (14

times), slam (13 times), and hit (11 times) the quail eggshell material. The respondents took these various kinds of action because they wanted to know further about the characteristics of this novel material. Many of them also tried to burn and pour water on it to know the performance of this material.

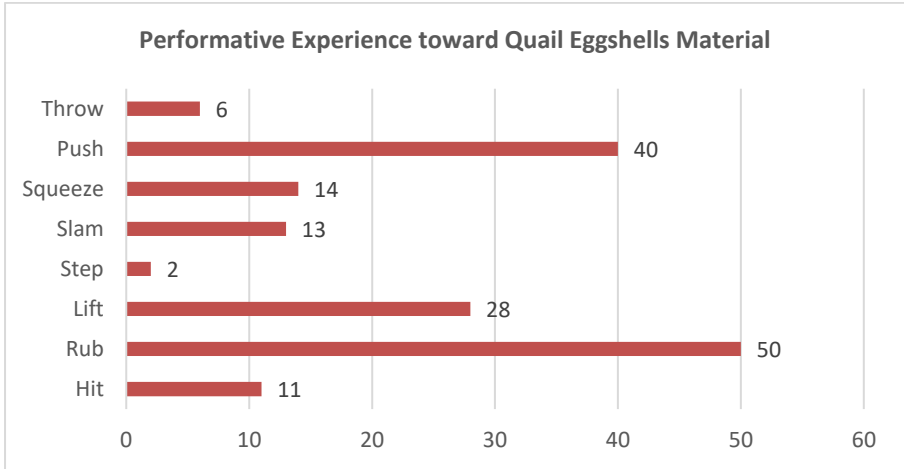


Fig. 8. Performative Experience toward Quail Eggshell Material


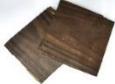


In the second step of MDD (Creating Materials Experience Vision), the designer summarizes and considers the material characteristics. The unique technical qualities of quail eggshell material are hard, rigid, strong, opaque, matte, non-reflective, smooth, cold, light, odorless, and water resistant. As a novel material, quail eggshell composite will make a significant difference because of the positive interpretation of users. It is a unique yet modest, functional yet affordable, and contemporary yet comfortable material. According to the affective experience analysis above, this quail eggshell material can fulfil a hedonic need because it elicits interest, admiration, and love from people. For instance, this material can make people more appreciate products made of waste materials. This material’s unique contribution is in its physical characteristics and visual appearance, which looks like a terrazzo, and its low ecological impact due to biodegradable constituent materials. Hence, the vision statement for quail eggshell material is an alternative material that exposes its physical properties and visual characteristics in everyday functional and aesthetic products so consumers will desire it.

Next, in Step 3, Manifesting Materials Experience Patterns, the quail eggshell material is projected as a material of product that can be molded to a specific form, safely direct skin contact, easily lifted, resist water, and expose its terrazzo-like appearance. Spots on quail eggshells provide visual uniqueness that can be applied to a valuable product design. A product made from quail eggshell material must also be functional, create comfort for the user, and be relatively affordable. Due to its non-reflective and opaque characteristics, it is better to use this material except for lighting. Products for

cooking or serving meals are also not recommended using this quail eggshell material because it has not been tested for food-grade certification.

A material benchmarking was also conducted to develop a combination possibility with other materials with similar color elements to strengthen the material's manifestation. Based on their physical appearance, quail eggshells are graded as white to light sand color with black to brown spots [18]. According to Hasan et al. [19] quail eggshell colors can be categorized as light eggs (without or tiny spots), dotted eggs (small and many spots), spotted eggs (large and many spots), and dark eggs (huge and few spots). In addition, quail eggs have brown or reddish-brown patterned areas on a light background [20]. Quail eggshells exhibit assorted colors and patterns because of adaptation to distinct habitats of quail. These colors and patterns have functioned as camouflage for the predator as well as specific signs for parents to find their eggs [21]. Despite these various patterns, it does not alter egg quality characteristics [22]. The visual appearance of quail eggshell can give users a novel material experience if combined with other material that supports the concept of black and brown spots of quail eggshell. Several materials have a suitable color with quail eggshells, such as lava stone, rosewood, Java black bamboo (Wulung bamboo), or buffalo horn (Table 1). Based on material benchmarking, all these materials can be potentially combined with quail eggshell materials. They have specific uniqueness, authenticity, and naturalness. Each material has advantages and disadvantages that can be optimally used according to the need.

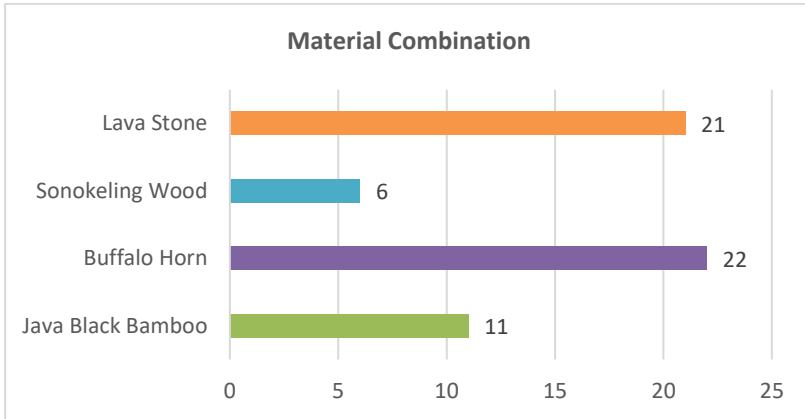
**Table 1.** Material Benchmarking

	Lava stone	Rosewood	Java black bamboo	Buffalo horn
				
<b>Applications</b>				
Functional	yes	yes	yes	yes
Structural	yes	yes	yes	no
Decorative	yes	yes	yes	yes
<b>Experiential Qualities</b>				
Waste Materials	no	no	no	yes
Smoothness	no	yes	yes	yes
Roughness	yes	no	no	yes
Scent Intensity	neutral	neutral	neutral	neutral
Uniqueness	medium	medium	medium	high
Authenticity	high	medium	medium	high
Naturalness	high	high	high	high

To enhance the material experiential, end users were interviewed to observe user reactions and perceptions about this material benchmarking (Figure 9). Respondents selected the buffalo horn most notably because of its visual suitability and unique potential. According to respondents, quail eggshell material looks like concrete or stone,



so it is most suitable to pair this material with lava stone or buffalo horns with rough surfaces. Considering the interview results, these two materials were the most frequently chosen. Moreover, both materials can display smooth and rough textures on one surface. However, buffalo horns have the advantage of being lighter than lava stone, so it will be reasonable to support the light characteristic of quail eggshell material.



**Fig. 9.** Material Combination Quail Eggshell Material

Buffalo horns have physical characteristics as a textured, thick, hollow material with a strong and durable structure. It is made up of a dense, rippled shape layer of keratin [23]. Buffalo horn is categorized as a waste material because it is taken when the buffalo is dead after it has been raised and farmed in the agricultural industry. Contrary to antler, which come off and regrown each year, bovid horns only grow once in a lifetime [24]. If the horns are broken, they will not grow back because it does not identify as living tissue [25]. Buffalo horns have been recognized for thousands of years in Traditional Chinese Medicine [26] as a valuable treatment to reduce fever and arrest convulsions [27]. It is categorized as an abundant availability yet low-price material [28].

Using the buffalo horn also empowers local artisans around this area. There is a village 450 metres away from Kotagede traditional market called Kampung Kembang Basen, where the residents have been working to make craft products from buffalo horns since the 1970s. Several alleys were named after the speciality of artisans who live in the alley. Cow Horn Alley and Buffalo Horn Alley describe that artisans there were skillful in making craft products from cow and buffalo horns. These local craftsmen used buffalo horns for various products such as hair pins, hair combs, bracelets, bowls, and traditional massagers. Buffalo horns are commonly known as resilient, vigorous, and tenacious material. Therefore, artisans in Vietnam or Indonesia widely used

it for jewellery and household equipment [29]. Water buffalo horn is also used as drinking horn intended for traditional and contemporary users in Grassfield, Cameroon [30].



**Fig. 10.** Buffalo Horn Artisan in Yogyakarta

In the final step (Designing the Material or Product Concept), it was decided to design the home decoration products from composite quail egg materials combined with buffalo horn. This decision considers that home decoration products prioritize function and aesthetic aspects. Most users mention that home decoration products can expose the beauty and energy of these two materials. The horn sheath has a coarse texture, high stiffness, strength, and durability to anticipate breakage [24] so it can be applied on parts of a product that need a handle for safety. There are many options for home decoration products that could be developed using these two materials.

In this design development phase, the concept can be profoundly explored by adding elements of heritage buildings around Kotagede to convey the cultural identity to which these products belong. There is one cultural heritage site located near Kotagede called Pesanggrahan Warungboto. Geographically, Warung Boto is included in the Umbulharjo sub-district area. However, when this site was built in 1765-1792 by Sultan Hamengkubuwono II, it was in Rejowinangun, which was part of the Kotagede area. That is why this site is also well known as Pesanggrahan Rejowinangun. As its name “pesanggrahan” this site was a resting and bathing place for families of the Ngayogyakarta Hadiningrat Palace. Hence, Pesanggrahan Warungboto was equipped with gardens, freshwater, ponds, and gardens on the east side. Meanwhile, on the west side, there is a complex of buildings with rooms and two bathing pools. Compared to other sites, such as Tamansari Water Castle, the Warung Boto site receives less publicity and

attention from the public. Accordingly, this development selected the Warung Boto site as design inspiration to gain more attention and recognition.



**Fig. 11.** Inside and Outside of Warung Boto Site

The architecture of the Warung Boto building is marked by the strength of its walls, and the building structure with hallways, doors, and windows with curved accents at the top. Besides its curved accents, this site also has a circular pool in the middle with a water pennant from a very clear spring, that streams to the rectangular pool downside. This uniqueness of the site is inspiring to design a bathroom set such as a soap dispenser, hand towel tray, candle holder, and soap dish. According to its origin, hopefully,

this bathroom set could remind the users about bathing place or *pesanggrahan* atmosphere.



**Fig.12.** Design of (a) Soap Dispenser, (b) Hand Towel Tray, (c) Candle Holder, and (d) Soap Dish



**Fig. 13.** Bathroom Set from Quail Eggshell and Buffalo Horn Material Inspired by Warung Boto Site

## 4 Discussion

This research offers an application of MDD method in understanding user perception that leads designers to find novelty in design. Therefore, there is no significant difference in processing the quail eggshell than other waste processing. It does not rule out the possibility that there will be other ways to process quail eggshell waste other than using water-based resin, which will also give different perceptions from users. Water-based resin in this research can indeed be applied to other types of waste. However, the

most efficient and low ecological impact method for processing flakes and quail eggshell granules recommended in this research is to use water-based resin.

Another thing that can be discussed in this research is that in the first stage of the MDD method, especially in sensorial experiences, 27 people answered that the quail eggshell material still had an odor. In comparison, 33 people answered that the quail eggshell material was odorless. This odor must be overcome in more comprehensive applications, for example, by washing quail eggshells with soap twice and drying them in the sun for longer. In the prototyping process, accurate composition and precision in the moulding process should be considered because even a tiny bubble in the composite making could cause imperfections. It explains that five respondents stated that this quail eggshell material was weak in sensorial experiences. In Designing the Material or Product Concept phase, developing the design allows an uncountable opportunity to use the buffalo horn in various shapes by cutting it into a ring, sheet, or others.

This exploration is expected to solve the quail eggshell waste problem initially. However, this idea could become an opportunity to develop designs for a broader issue even after the waste problem in Yogyakarta has been resolved, such as presenting sustainable design or preserving local heritage issues.

## 5 Conclusions

As described in the introduction, this research aims to explore quail eggshell waste and the most suitable combination to enhance product experience using the Material Driven Design (MDD) method. In the first step of MDD or Understanding the Material, there are four foundations to build experience of the material: sensorial, interpretive, affective, and performative. At the sensorial experiences, the users mentioned that the physical characteristics of quail eggshell composite are opaque, hard, rigid, matte, non-reflective, smooth, cold, light, odorless, and strong. At the next level of experience, the users interpret quail eggshell material as creative, unique, modest, water resistant, functional, contemporary, affordable, comfortable, and terrazzo-like. The third level of material experience is affective or emotional experience. The quail eggshell material made them feel interested, admired, loved, excited, surprised, nostalgic, and satisfied.

Nonetheless, negative emotions evolved when the respondents appraised the material, such as confusion, hesitation, and disgust. At the last level of materials experiences, the users respond to the quail eggshell composite by rubbing and pushing the surface of the quail eggshell. They also tried to lift, squeeze, slam, hit, burn, and pour water on it to know the performance of this material.

In the second step of MDD (Creating Materials Experience Vision), the vision statement for quail eggshell material is as an alternative material that exposes its physical properties and visual characteristics in everyday products that are useful and aesthetic so consumers will desire it. In Step 3, Manifesting Materials Experience Patterns, the quail eggshell material is projected as a material product that can be molded to a specific

form, safely direct skin contact, easily lifted, resist water, and expose its terrazzo-like appearance. Through material benchmarking with lava stone, rosewood, Java black bamboo (Wulung bamboo), and buffalo horn, the respondents selected the buffalo horn most notably because of its visual suitability and unique potential. In the final step (Designing the Material or Product Concept), it was decided to design the home decoration products from composite quail egg materials combined with buffalo horn. The concept was profoundly explored by adding elements of a heritage building around Kotagede Yogyakarta, called Pesanggrahan Rejowinangun, well known as Warung Boto site. Pesanggrahan Rejowinangun, or Pesanggrahan Warung Boto is a royal bathing place that receives less publicity and attention from the public. Therefore, this project selected this site as inspiration to design a bathroom set from quail eggshell combined with buffalo horns to expose their physical properties and visual characteristics. This last step resulted in a soap dispenser, hand towel tray, candle holder, and soap dish, which follow the design style in Pesanggrahan Warung Boto site.

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