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Conceptualizing D-Honeycomb Artificial Coral Reef Structure (DHARS) through Stoneware Ceramic Artwork

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Abstract
The Artificial Reef Structure D-Honeycomb (DHARS) is a study that reflects the design needs of natural coral reefs. It focuses on ceramic material (stoneware) that can invertebrate, penetrate and grow on natural corals. It will theoretically allow corals to bounce back faster with the structural analysis of Dual-Honeycomb. Overall, DHARS offers simple, effective and inexpensive design structures for artificial coral reefs that are important for the underwater environment and remote island communities that need them for their habitat.

Keywords: Stoneware ceramic; Artificial Coral Reef; Honeycomb

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1.0 Introduction

Coral reefs in Malaysia are being damaged at an increasing rate, and it faces natural and anthropogenic stresses. There are about 4,006 km2 with over 550 coral reefs in Malaysia, contributing to the nation's economy. Coral reef studies and threats in Malaysia have been reviewed. Perspectives are addressed as coral reefs studies, threats, gaps, and future studies. Corals are incredibly brittle and fragile, just like ceramics. Human activities of uncontrolled fishing, such as dynamite fishing, as well as development projects, are affecting their habitats. Other factors such as global warming and pollution increase seawater temperature, straining and damaging these precious and diverse ecosystems. Coral reef repair process is prolonged, so they need artificial structures to support their growth.

1.1 Research Motivation

Corals face several threats globally. Prolonged separation kills coral and algae, leaving nothing but a bone-white skeleton. A recent approach by researchers and designers in promoting new designs for artificial coral reefs is by introducing a 3D printer on technique for their artificial coral reef design. 3D printers have become faster and more accurate in the past decade, allowing enthusiasts to develop neat trinkets such as toothpaste squeezers and custom pasta makers. However, in Malaysia particular, 3D printers can still be considered the best option for more significant volume production due to technology, cost and time consumption for production. Therefore, further research on the mass production of artificial coral reefs is necessary, potentially leading to moderate technology implementation, cheaper production, and encouraging rapid production compared to the 3D reproduction of coral reefs in design. This research aims to design

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stoneware artificial coral reefs based on a basic hexagonal shape of honeycomb cells that is a simple yet effective and inexpensive design structure for artificial coral reefs that are important for the underwater environment.

2.0 Literature Review

2.1 Artificial Coral Reefs

Collective studies show that the development of artificial fish reefs has been studied worldwide to enhance fish abundance and diversity, recover coastal and marine habitats, and restore damaged coral reefs [Duarte et al. (2020); Bohnsack JA, Sutherland DL (1985); Bohnsack JA (1990); Bohnsack JA, Johnson DL, Ambrose RF (1991); Seaman W (1996); Spieler RE, Gilliam DS, Sherman RL (2001); Coral Reef Seeding Units (2019)]. Various materials have been used in the construction of artificial reefs worldwide. They include bamboo, concrete blocks, ceramic structures, fibreglass, pipes, reinforced plastic, metal, and marine alloys [6]. Every material, however, has some drawbacks when used as artificial reefs. Bamboo and wood are quickly scattered by water currents, lose their fish-aggregating integrity, and cause further degradation of the sea bed, according to Cognetti G (1987). Concrete blocks are robust. They can be structured in different configurations, but because of their cost, they have limited applications. Placing any material in the marine environment risks causing pollution, which would harm aquatic ecosystems. Therefore, selecting materials with minimal negative impacts on marine habitats is essential and improving fish colonization by considering adverse effects rather than benefits. Santos et al. also studied the fish colonization of artificial reefs made of ceramic, concrete, and polyvinyl chloride (PVC) pipes. They found that ceramic reefs were more effectively colonized than concrete and PVC reefs. Although there have been some studies on the colonization of fish in ceramic reefs, few studies have shown effective reef design and functionality of ceramic materials in a shallow sea environment.

2.2 Hexagonal Shape of Honeycomb Cells as Value Added in Design

The hexagonal shape of the honey bee cells is an intriguing subject to be observed, both in the construction and design as a system. According to Nazzi, F. (2016), bees produce cylindrical cells, which only then change into hexagonal prisms through a process that is until today still being debated. He added that there are other theories to the mysterious explanation of the hexagonal form, which was created basically through physical forces and some may involve mechanical shaping skills during the construction. This geometrical form constructed, however, only arises through an isodiametric pattern that is arranged uniquely that each one is surrounded by six other similar cells, creating a construction of a hexagonal shape of bee cells that is strong.

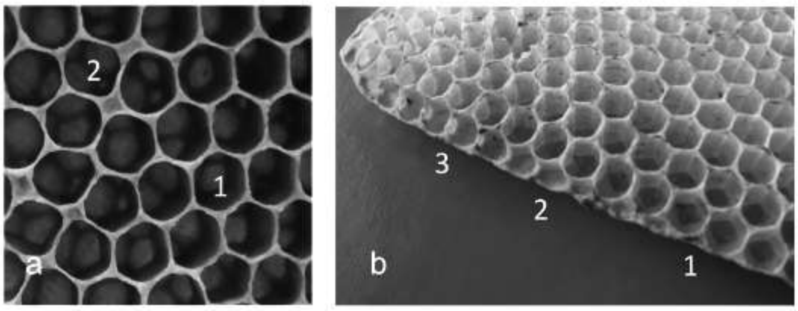

Fig. 1: Geometry and construction of the honeycomb. (a) The pattern of cells influences their final shape: cell 1, surrounded by six other cells, has a hexagonal shape, with 120° angles between sides, whereas cell 2 has a different shape, with 90° angles between some consecutive sides. (b) The margin of a comb with stubs of cells at different stages of construction suggests a possible construction scheme (1: the construction of the cell base is started in the groove between two pre-existing cells; 2: when the cell base is as large as the cell diameter, the walls are started; 3: the walls encircle the first stub of the cell).

(source was taken from: https://www.nature.com/articles/srep28341)

2.3 Stoneware Ceramic as Medium for Artificial Coral Reef

Referring to the Applied Ceramic Technology (Volume II) module in 2002, ceramic is considered as any product, having a form made up of non-metallic inorganic raw materials (whether mineral or artificial) which, from an incoherent powdery state, are transformed, via various processes, into a semi-finished item, which, through firing becomes a solid object of partially crystalline and partially vitreous structure. Every so-called ceramic must undergo a state of revolutionary transformation process from raw material to a fired product to get a rock-solid form by fusing and joining each particle inside by performing a very high-temperature firing and pressure (Vermol et al., 2011). Ceramic stoneware, however, is a type of ceramic body that is dense, impervious and hard enough to resist scratching by a steel point among ceramic body classification. It can appear in both vitreous or semi-vitreous conditions, which makes it's partially vitrified. Ceramic stoneware firing maturity point is around 1100°C to 1300°C depending on the flux content and it has water absorption of less than 1% (J.S. Reed, 1995). Stoneware is one of the ceramic body types commonly used in the industry, especially for tableware and sanitary ware due to its sturdiness and chip-resistant characteristics. It is also known for its durability and deficient water absorption (Vermol et al., 2013). Due to its factors, this material has a considerable potential to be further explored as the primary material for building solid and long-lasting sustainable ceramic stoneware coral reefs.

2.3 Aesthetic Values and Properties in Design

One of the highlights of DHARS can be seen in its Aesthetic Values and Properties in Design. Aesthetics is a core design principle that defines a design's pleasing qualities. In visual terms, aesthetics includes balance, color, movement, pattern, scale, shape and visual weight. Designers use aesthetics to complement their designs' usability and so enhance functionality with attractive layouts. Polak, O., and Shashar, N. 2013 explained; Visitor appreciation of natural scenes such as coral reefs have been documented as a critical value in fostering people's enjoyment to observe its biological component. Using the contingent valuation method (CVM), they have examined divers' willingness to pay for changes in the fish and coral attributes over an artificial reef. In their study, using image manipulations, different levels of community descriptors, such as richness, abundance, and biodiversity of corals and fish, were isolated, and the willingness to pay for proposed factors was examined. The results showed that divers were willing to contribute towards all increases in reef community attributes and could partially discriminate between them. Biodiversity was the most valued index, while fish abundance was the least favored. These results, which demonstrate that visitors understand the fundamentals that constitute a coral reef community and value its diversity, may help direct conservation efforts undertaken in designing marine reserves and pre-planned artificial reefs.

Fig. 2: Ceramic artwork entitled 'Our Changing Seas' by Courtney Mattison, 2014, draws the world attention to climate change
(source was taken from: https://www.trendhunter.com/trends/courtney-mattison)

2.0 Methodology

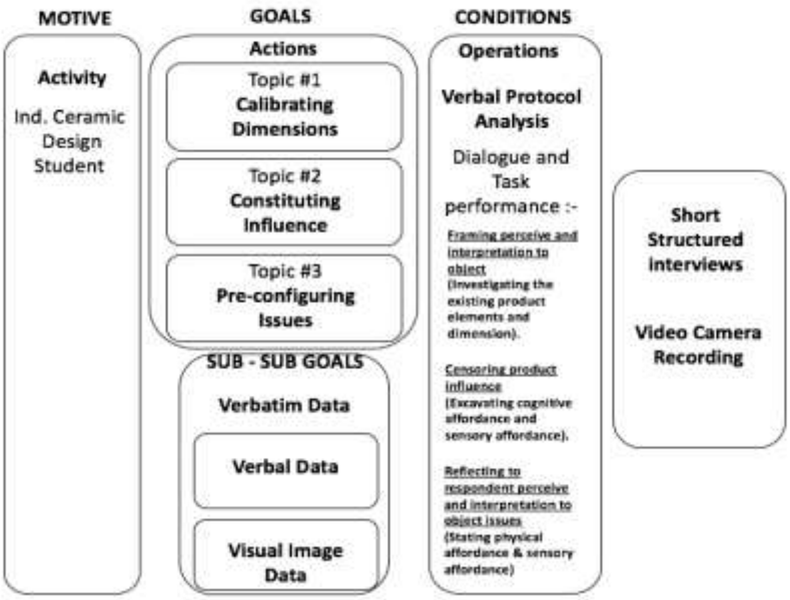

Fig. 3: Model of VPA design investigation adapted from Vermol et al 2017

The overall approach of this research can be elucidated through Verbal Protocol Analysis (VPA) design investigation adapted from Vermol et al. 2017 VPA activity, as shown in Figure 3. The motive of the study overviewed a group of ten (10) final year students of Industrial Ceramic Design Universiti Teknologi MARA as a sample and challenged through a given project design brief within the semester. Three (3) tasks were given to achieve the action topic goals to determine the sub-goal of samples eliciting their inner thoughts during the activity; video cameras were used to record their action and discussion. By committing to this model, the researcher expected to gather samples reflection as DHARS design attributes.

- Framing perceives and interpretation to subject – *Samples investigating the existing product (subject) elements and dimensions.*
- Censoring product (subject) influence – *Samples excavating cognitive affordance and sensory affordance*
- Reflecting respondent perceive and interpretation to subject issues – *Stating physical affordance and sensory affordance*

3.1 Design Activity (Operations)

Before the design brief is given, each student has to align to the given hexagonal shape as master control preferences. From the given brief, twenty (20) final year students of Industrial Ceramic Design Universiti Teknologi MARA play their role as samples by collecting data before proceeding to the actual project. Three challenges that they need to put up on this project will be looked into:

- **Interlocking**; the idea of how each of the designs can be interlocked from one and another. This is important as the below sea current is unpredictable. By securing the design tightly together, an excellent interlocking system is needed for a more extended period.
- **Section (Parting-line)**; the idea of having a section on the designed form so that it is detachable from one another as a construction. Having design construction detachable will significantly ease the trouble of carrying and delivering the artificial coral reef from land to sea bed.
- **Texture and construction detailing**; to support the continuous and rapid growth of the coral, intrigued texture and detailing is needed. The textured surface is needed for them as the foundation for clinging before fully grow. Nevertheless, the construction detailing also plays an essential feature in promoting habitat for the small fishes.

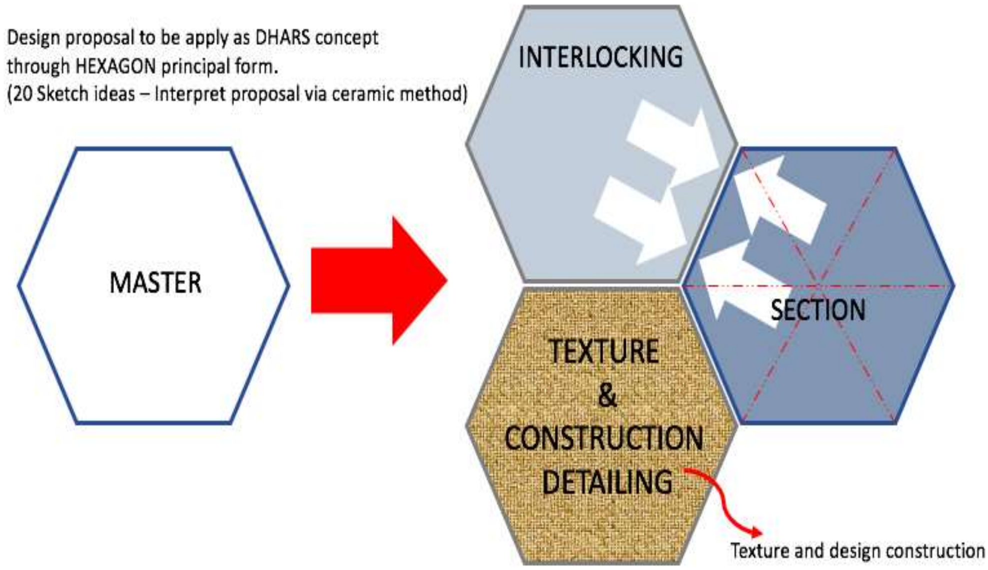

Fig. 4: Technical construction configuration of DHARS model overviewing from interlocking, section, texture and construction detailing.

3.2 Design Ideation and Characterization

Twenty (20) final-year students of Industrial Ceramic Design Universiti Teknologi MARA ideation sketches were collected and analyzed through the topics explored. The progressive ideation sketches can be widely seen through the overlapping of each topic. Through the process, prominent lines from the sketch ideation can be accommodated through the Designer Sketch Design Ideation (DSDI) model adapted from Vermol, 2017. Each improvement determines the influence received through the task of the design brief discussed. As shown in Fig. 5, the design development indicates students' reflection and ideation proposal on the technical construction configuration of DHARS model overviewing from interlocking, section, texture and construction detailing.

The generation of ideas is an essential element in the process of DSDI for not only form development or styling but also to improve the attributes of how the design will serve its purpose. Figure 6 indicates the use of ropes as a potential idea for a newly developed coral reef to attach. Throughout the generated view, the researcher can trace back the critical attributes of components involved in the discussion and the extent of design elaboration. At this observation stage, researchers will be examining the chronology of silhouette of sketch ideation inflicted from the DSDI process.

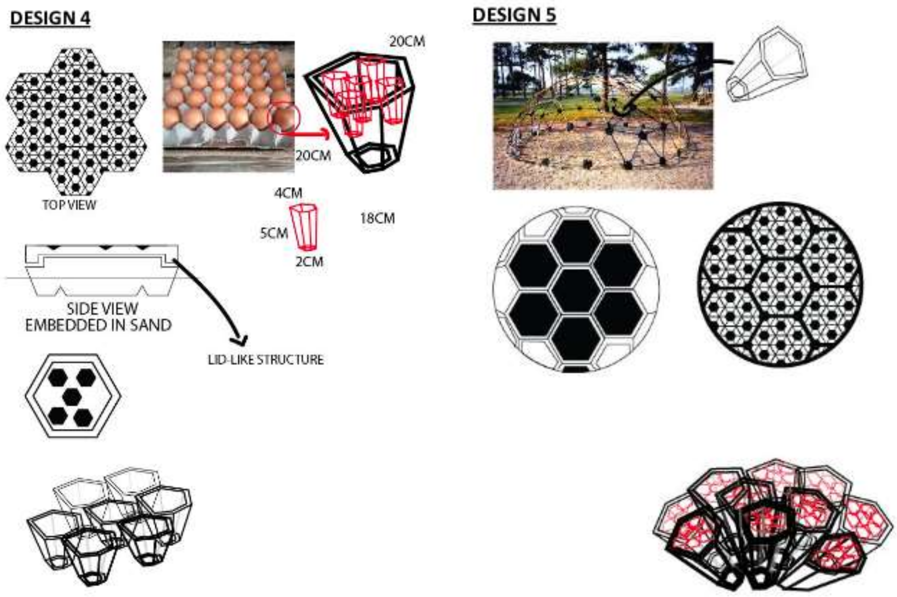

Fig. 5: Technical construction configuration of DHARS model overviewing from interlocking, section, texture and construction detailing.

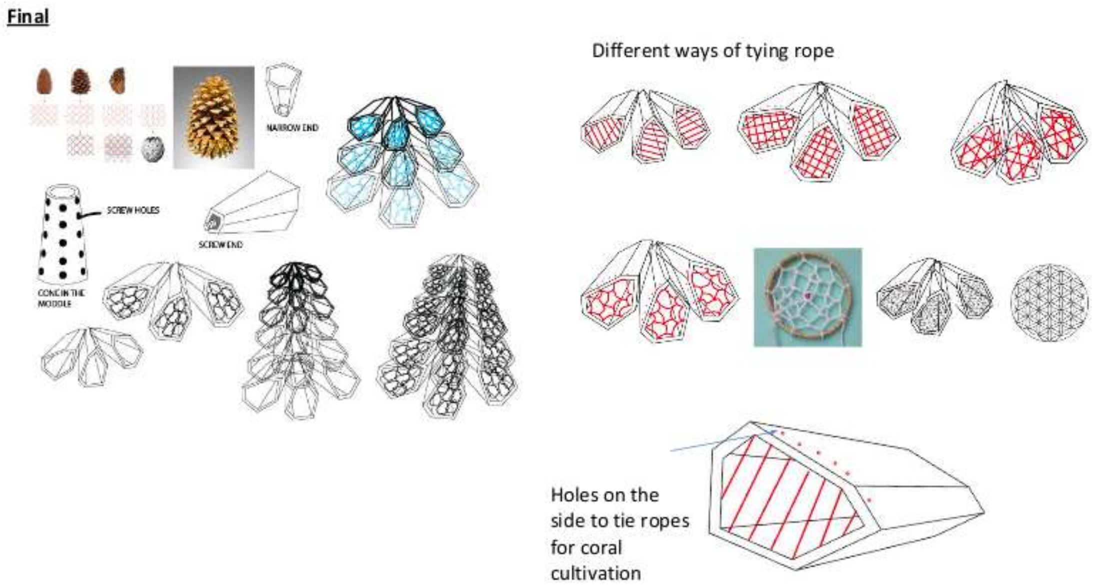

Fig. 6: Technical construction ideation and configuration of DHARS model overviewing through DSDI analysis

4 Findings and Discussion

From the activity, 60 ideation sketches were collected, compiled, and scanned as digital images. Through Adobe Photoshop software, all the design ideation of sketches from DSDI 1 – Topic 1, DSDI 2 – Topic 2 and DSDI 3 – Topic 3 (Refer to Fig.3) results were overlapped against the technical master drawing. This way, the improvement according to the chronology can easily be determined and observed to overview prominent lines as the final selected design form for prototyping. Overall the activities conducted in this ideation sketch activities of DSDI 1, 2 and 3, the researcher observed the dynamics of the task influencing the designer's decisions in design thinking that were presented through their verbal's feedback and confirmed through their collective sketches. The prototype was formed using stoneware clay ideated through sketches, and each detail was highlighted.

In order to present alignment to the improvements of ideation developed, the researcher found three (3) criteria that are important for DHARS development. These criteria serve the principle that needs to be explored by designers and working out their design potential by finding a solution that can bridge altogether. Figure 7 demonstrates three criteria that become the foundation to DHARS development: aesthetic, performance, and technical in supporting the pragmatic and empirical of the research. In order to tabulate this conducted project, the researcher established the understanding that experienced through observing twenty (20) final year students of Industrial Ceramic Design Universiti Teknologi MARA perform product development process within their design capacity of knowledge and through group discussions; result, however, may vary when it comes to working the imagination on paper individually. Nevertheless, the procedural activities educate and levitate designers' awareness sensitive when developing design within awareness and livings.

Fig. 7: Prototype construction of DHARS

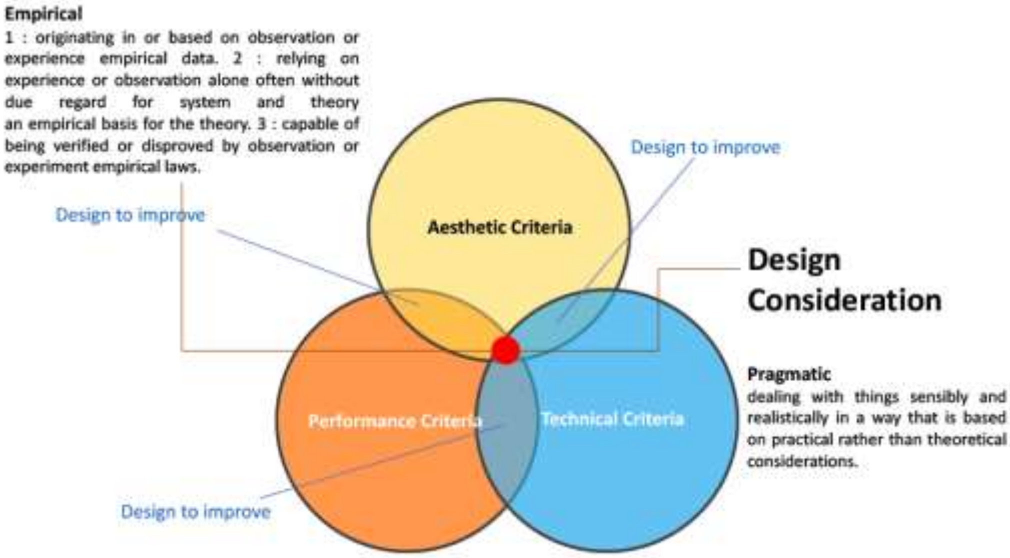

Fig. 8: Overviewing DHARS foundation for development which is aesthetic, performance and technical in supporting the pragmatic and empirical of the research.

5. Conclusion and Recommendations

Ceramic stoneware works well to be powered as the critical component of the artificial coral reef. It serves the natural needs of coral reefs where they have to invertebrate, infiltrate and grow. Therefore, the main idea of this research was to promote ceramic stoneware as artificial ceramic coral reefs that are cheaper than 3D prototyping built as artificial coral reefs with easy installation, functional and affordable for implementation. The idea behind DHARS is depicted through the concept of a beehive. Its 'natural hexagon' formed was unique. It creates mathematical terms that divide a volume into shapes of equal size through a minimum amount of resources and yet provides strength and compactness in design. Despite the principle structure of the natural hexagon of honeycomb, this gives the advantage of studying further on DHARS design needs to fit natural coral reefs. Therefore, as state of the art, it offers targeted potential qualities which promote Aesthetic Values and Properties in Design. However, further investigation needs to be conducted as findings from this research have not yet been tested for actual coral planting. The objective is to combine design knowledge with creating an artificial reef that overthrew the concept of a beehive and its habitat. The natural hexagon formed was unique as it makes a mathematical term. The shape taken as a design subject filled the perfect gaps just like bees did to their hive to avoid using too much wax. It is more compact than any other structure built. This is shown in the picture; a hexagon fills the gaps better than a circle. This is how the idea came for the artificial reef design, as the configuration is attachable and easier to stack to each other.

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