Recycling *Padas* Stone Waste as Material for Architectural Ornaments in Gianyar, Bali

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Abstract. Traditional Balinese architectural ornaments have symbolic, historical, aesthetic, and allegorical meanings that characterize traditional Balinese buildings. Padas stone, a local material from the Petanu River and Wos River in Gianyar Regency, is often used for these ornaments. The development of tourism in Bali since the early 20th century encouraged the use of Balinese ornaments in the construction of tourist accommodations. Post-independence, this trend continued with regulations requiring public buildings in Bali to adopt traditional Balinese architectural styles. However, the increasing demand for padas stone ornaments led to environmental damage due to over-mining. Gianyar Regency's Regional Regulation No. 15 of 2015 banned the mining of padas stone, triggering difficulties in obtaining the material. Craftsmen began to use artificial padas stone from recycled padas stone waste, although the quality is not yet uniform. This research aims to find the right mix composition to produce high-quality artificial padas stone, resembling natural padas stone. The results of the research are expected to provide solutions for natural resource efficiency and preserve the culture and industry of traditional Balinese architecture while creating employment opportunities. The finding of a raw composition that produces quality ornaments is also a form of respect for Balinese culture and environment.

Keywords: Artificial padas Stone, Recycling, Traditional Balinese Architecture

1 Introduction

The embodiment of various architectural ornaments, especially traditional Balinese architectural ornaments can be witnessed to this day. Ornaments in traditional Balinese architecture have symbolic, historical, aesthetic, and allegorical meanings (Siwalatri, 2012). Ornaments characterize and seem to be an integral part of traditional Balinese buildings (Dwijendra, 2008). One of the materials commonly used as carved ornaments in traditional Balinese buildings in the past was *padas* stone. The use of *padas* stone as an architectural ornamental material is increasingly massive inseparable from the development of tourism in Bali. In the early 1920s to mid-1930s, the policy of the Dutch East Indies government, regarding the direction of tourism development in Bali, preserved Balinese architecture (Putra, 2024). After Indonesian independence, in 1982, Ida Bagus Mantra the governor of Bali at that time issued a regional regulation on Balinese style, urging that public buildings in Bali assimilate a variety of Balinese

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styles. (Westa, 2023). Similarly, the issuance of Bali Province Regional Regulation No. 5 of 2005 concerning Architectural Requirements for Buildings characterized by locality, makes *padas* stone a material that can display local Balinese characteristics. As Bali became known internationally, *Padas* stone sculpture ornaments began to be exported to the United States, Australia, and Europe (Sutika, 2015). *Padas* stone ornaments that were once made by craftsmen traditionally are now starting to enter industrialization which opens up employment opportunities in Bali.

The irony is that the increasing demand for *padas* stone architectural ornaments has caused natural damage that is difficult to restore. *Padas* stone mining has an impact on river morphology changes, is prone to landslides, disruption of *subak* irrigation, dirty rivers due to *padas* stone waste, damaged ecosystems, high river erosion rates so that the supply of sediment becomes greater and also land damage that occurs is difficult to recover (Aryastana, 2015). Damage to the main irrigation tunnel on the Petanu River resulted in more than 1800 hectares of rice fields covering 40 Subak in Sukawati District and Blahbatuh District experiencing crop failure (Suriyani, 2017). Finally, through the Regional Regulation of Gianyar Regency No. 15 of 2015 concerning *Trantibum* related to the business of quarrying *padas* stone. *Padas* stone mining is prohibited by the Government of Gianyar Regency.

The ban on *padas* stone mining has made it difficult to obtain *padas* stone as an architectural ornament material. The increasing demand for *padas* stone architectural ornaments is not matched by an adequate supply of material (Sutirta, 2024). The difficulty of obtaining *padas* stone blocks was responded by several craftsmen by experimenting and switching to using "molded" *padas* stones or artificial *padas* that utilized recycled *padas* stone waste. Previously, the abundant amount of *Padas* stone waste was simply thrown away and polluted the river (Astajaya, 2018). Unfortunately, recycled waste *padas* stone has not been optimally utilized and does not have a standardized composition mix, and is sometimes of poor quality.

Previous research by Pranajaya and Erotodi, with the title "Creativity of Balinese Traditional Architectural Ornament from Artificial *Padas* Stone", discusses the creation of artificial *padas* stone for ornaments measuring 20×40×5 cm in Tabanan Regency, Bali. However, this study does not present specific information about the ratio of the composition of the mixture of artificial *padas* stone. In addition, there is research by Anak Agung Gede Sutapa, entitled "Proportion of Mixture and Characteristics of Artificial Palimanan Stone with Natural Palimanan Stone Powder Waste Material". This research determines the proportion of the mixture to make artificial Palimanan stone made with two layers, consisting of a surface layer and a body layer.

As for the gap between this research and the aforementioned studies, there is a need to determine the proportion of the right mixture in the manufacture of artificial *padas* stone in order to have characteristics similar to natural *padas* stone, as well as an alternative to natural stone. This research aims to fill the gap by identifying the optimal mixture to create artificial *padas* stone with characteristics close to natural *padas* stone.

Based on the above exposure, it is interesting to conduct research on the recycling of natural *padas* stone waste as an architectural ornament material, based on the exposure of architectural ornament craftsmen in Gianyar Regency, Bali. This research focuses on finding the composition of the artificial *padas* stone block forming a mixture

that has characteristics resembling natural *padas* stone based on the assessment conducted by the *padas* stone architectural ornament craftsmen. It is expected that the results of this research can be used as an architectural ornament material and make a significant contribution to present solutions for natural resource efficiency, especially the recycling of *padas* stone waste towards sustainable green construction materials. In addition, the results of this research are expected to maintain the sustainability of the architectural ornament industry which has proven to employ many people, as well as preserve Balinese culture.

2 Methodology

This research uses qualitative methods and the paradigm used is naturalistic (Groat & Wang, 2013). The type of data used consists of qualitative data and quantitative data. Data sources are primary data obtained directly in the field and secondary data. Data collection was carried out using observation, interviews, literature studies, and documentation. The data analysis used is a qualitative method consisting of data reduction, data presentation, and conclusion drawing stages. This research was conducted in the workshop of a solid stone carving craftsman in Banjar Silakarang, Singapadu Kaler Village, Sukawati, Gianyar, Bali, from April to September 2024. The research focused on the manufacture and testing of an artificial cushion stone mixture utilizing cushion stone waste. Data were collected through observation, interviews with 5 craftsmen, literature study, and documentation. The research stages include data collection, modeling of test objects using the Sketchup application, selection of tools and mixture materials, designing and determining the percentage of the mixture, and making, and testing test objects by craftsmen. Data analysis was carried out by observing the characteristics of the test results, including color, strength, texture, workmanship, and the final result of the artificial cushion stone mixture. The data obtained was then analyzed to determine the mixture that best resembles the characteristics of natural cushion stone. The results of the study are expected to provide guidance in utilizing cushion stone waste more optimally and producing quality artificial products.

3 Result and Discussion

3.1 Modeling of Test Objects

The test specimen is an artificial *padas* block with a size of 100×50×50 cm. Formwork is designed using a metal plate with a hollow frame, with dimensions of 150×50×50 cm. In the center, there is a divider board that functions as a test piece length regulator. The bottom or floor of the formwork uses multiplex, each corner meeting will be installed with 3 screws each. To avoid corrosion, the entire surface of the metal formwork is coated with paint.

3.2 Selection of Tools and Materials for Artificial *Padas* Stone Mixture

From the results of the initial survey, data were obtained regarding the tools and materials for artificial *padas* stone mixtures that are commonly used by craftsmen. The materials used as aggregates in the manufacture of artificial *padas* stone are Silakarang *padas* stone powder, Belayu Tabanan *padas* stone powder, and type I Portland cement.

Figure 1. Waste location of *padas* stone mining area

3.3 Design of Percentage Mixture of Test Objects

Based on direct interviews with *padas* stone craftsmen in Gianyar Regency, the percentage of the mixture that is commonly used is obtained. Subsequently, some final test mixtures will be selected and presented in a table, printed, and tested by the craftsmen.

Preliminary Mix Design. The initial mixture design was carried out in the form of data collection of 8 craftsmen regarding the artificial *padas* stone mixture commonly used by each craftsman. This data collection was carried out to obtain a raw initial mixture

that has characteristics resembling natural *padas* stone. The results obtained are presented in Table 1.

Table 1. Preliminary mix design

Carving craftsman	Composition				
	Silakarang *padas* stone	Belayu *padas* stone	portland cement	Fine sand	Mill calcium
I	√	–	√	–	√
II	√	√	√	√	–
III	√	√	√	–	–
IV	√	–	√	–	–
V	√	√	√	–	–
VI	√	√	√	–	–
VII	√	√	√	–	–
VIII	√	√	√	–	–

Interviews with eight artisans of *padas* stone ornaments showed that the composition of artificial *padas* stones was produced through a lot of trial and error over a period of nearly 20 years and more than 40 attempts. Each craftsman has a different mix of materials to make artificial *padas* stone. Here are the details of the mixture:

Craftsman I. Uses *padas* stone powder, Portland cement, and calcium mils. This mixture is considered vulnerable and quickly weathered when placed outdoors, less hard when dry, and less dark in color.

Craftsman II. Uses Silakarang *padas* stone powder, Belayu *padas* stone powder, Portland cement, and sand. This mixture is weather-resistant, and light gray in color, but has a rough and hard texture that makes it less comfortable to carve.

Craftsman IV. Using Silakarang/Kemenuh *padas* stone powder, sand, and Portland cement. This mixture produces an artificial *padas* stone block with a texture that is not hard when chiseled and a dark grey color that resembles natural *padas* stone. However, the mixture is prone to cracking when dry, especially in areas exposed to the sun.

Craftsmen III, V, VI, VII, and VIII. Use a mixture of Silakarang/Kemenuh *padas* stone powder, Belayu Tabanan *padas* stone powder, and Portland cement. This mixture produces a weather-resistant, easy-to-chisel artificial *padas* stone, with a dark gray color when wet and light gray when dry. The texture is smooth, slightly hollow, water-absorbent, and weather-resistant.

A mixture of Silakarang/ Kemenuh *padas* stone powder, Belayu Tabanan *padas* stone powder, and Portland cement was chosen as the base mix due to its characteristics that resemble natural *padas* stone. However, the five craftsmen do not have a standardized measure of the weight ratio of each mixing material, so it is necessary to make a Final Mix Design based on the weight ratio that is often used by craftsmen.

Final Mix Design

The Final Mix Design is the development of the initial mixture accompanied by the percentage or weight ratio of each mixture based on the craftsman's exposure. Silakarang *padas* stone powder, Belayu *padas* stone powder, and Portland cement were measured based on the weight ratio, so as to obtain the raw final mixture that would become the test object. These final mix materials will be collected, measured according to each mix, mixed in a tub, water added, and molded according to the final design in a size of 50×50×100 cm.

Table 2. Final mix design

Mixture name	Weight comparison		
	Silakarang *padas* stone	Belayu *padas* stone	Cement
Mixture I	2	2	1
Mixture II	4	4	1
Mixture III	6	6	1

3.4 Molding of Test Objects

The process of artificially molding *Padas* stone begins with mixing portland cement with water. After mixing perfectly, add Silakarang *padas* stone waste powder, Belayu *padas* stone waste powder and add water again so that all mixtures are united. The dough is stirred evenly, then poured into a 50×50×100 cm formwork, stirring so that all the space in the formwork is filled. Until the dough is 18-24 hours old, the formwork is ready to be opened. The same process was repeated until a total of 3 test specimens of 50×50×100 cm and 50v50×100 cm artificial *padas* stone blocks were obtained. Each specimen had the same weight ratio as the final aggregate mix design.

Figure 2. Molding process of artificial *padas* stone

3.5 Testing of Test Objects

The test specimens were 3 blocks of artificial *padas* stone measuring 50×50×100 cm, each having the weight ratio of the formers according to the final aggregate mix design. Each test specimen was tested by the five craftsmen in turn by chiseling a sculpture

ornament. The artificial *padas* stone were tested when they were 24 hours old, or when they had not dried completely. Furthermore, the five craftsmen gave a review of the characteristics of each test specimen, which will be presented in the table of test results.

Figure 3. Testing process of artificial *padas* stone beams

3.6 Analysis of Test Results

Test objects in the form of 3 blocks of artificial *padas* stone measuring 50×50×100 cm, were tested by the five craftsmen by making sculptures. Each test object has its own characteristics, according to the ratio of mixed materials. The following test results of the three test objects are presented in Table 3.

Table 3. Basic characteristics of test objects 1, 2, 3

Silakarang *padas* stone: Belayu *padas* stone: Cement	Characteristics				
	Color	Strength	texture	Engraving	Final result
2:2:1	slightly dark gray	very hard	slightly rough, porous	difficult to chisel	hair cracks
4:4:1	gray	hard	smooth, porous	easy to chisel	no cracks
6:6:1	slightly light gray	less hard	many pores	very easy to chisel	somewhat brittle

The analysis of three mixtures of *Padas* stone waste tested as architectural ornamental materials in Gianyar, Bali, showed significant differences in the characteristics of each mixture. Mixture I (2:2:1) has a slightly dark gray color and is very hard, with a slightly rough and porous texture. Despite its potential strength, artisans had difficulty in sculpting this blend. The final result showing hair cracks indicates that the material mix is not well fused, making it not ideal for ornaments that require solidity. The cracks could potentially reduce the ornament's resistance to weathering, especially rain and sun, making it less recommended for applications that require high durability.

Mixture II (4:4:1) stands out as a superior choice and is widely preferred by craftsmen. Its gray color, with a fair degree of hardness, offers the perfect balance between strength and workability. Its fine texture with few pores makes it easier to chisel, allowing craftsmen to produce fine and precise ornamental details. The absence of hair cracks in the finish indicates that this blend has a more stable and well-fused composition, resulting in more durable and quality ornaments. The advantages of Mixture II in terms of stability, workability, and finish quality make it the most suitable material for architectural ornaments made from solid stone waste.

Meanwhile, Mixture III (6:6:1), which is lighter gray, has a lower level of hardness and a very porous texture. Although it is very easy to chisel, its high brittleness makes it less ideal for ornaments that require durability. Its finish, which is not as strong as that of natural cushion stone, suggests that this blend is not suitable for ornaments that require long-term strength and durability.

Overall, Mix II provides advantages in terms of the balance of strength, workability, and finish quality, making it the best choice for architectural ornamental materials utilizing waste cushion stone in Gianyar, Bali.

Figure 4. Final results of test items I, II, III in the form of architectural ornaments

4 Conclusion

The mixture of Silakarang *padas* stone waste powder, Belayu *padas* stone powder, and Portland cement is the raw mixture that produces artificial *padas* stone. The greater the amount of Silakarang *padas* waste powder and Belayu *padas* waste powder used, the brittle strength of the artificial cinderblock results. However, if a small amount of both of these waste powders is used, it results in a sculpture with a hard texture due to excess cement. The right dosage is needed in order to obtain an artificial *padas* stone that has the characteristics that most resemble natural *padas* stone. Mixture II, which uses a mixture of Silakarang *padas* stone waste powder, Belayu *padas* stone powder, and Portland cement in a ratio of 4:4:1, has a smooth texture, is not hard, is easy to sculpt, has a dark gray color when wet and gray when dry, or has the most characteristics like natural *padas* stone.

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