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Manufacturing technology of Garuda Mulia concrete roof tiles/wave roof tiles and Mulia flat roof tiles using Padang cement at the port of Gresik

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Abstract: Wave roof tiles and flat roof tiles are effective roofing materials. The Malang area possesses significant iron sand potential, especially from Mount Arjuno. Iron sand has high tensile strength, making it suitable as a mixture component for manufacturing wave and flat roof tiles. This research employs experimental methods to investigate the effects of Padang Cement on the production of these tiles, with specific compositions including 40% sand, 15% stone ash, 30% cement, 15% fly ash, and supporting materials for wave roof tiles. Additionally, the study compares wave roof tiles made using a mixture of Malang sand. Comparative testing of concrete roof tiles with Padang Cement involved flexural load tests and water seepage resistance tests on wave roof tiles, as well as water absorption tests on both wave and flat roof tiles. The results indicated an average bending load of 2122.68 N. Water resistance tests showed that water did not penetrate the tiles, and no droplets were observed at the bottom of the concrete or flat roof tiles. Regarding water absorption, the average wave tile exhibited an absorption rate of 3.8%, while the flat tile had an absorption rate of 3.3%. Based on these findings, it can be concluded that both flat and wave concrete roof tiles meet the standards specified in SNI 0096-2007 and PUBI-1982, demonstrating their suitability as durable roofing materials.
Keywords: *Flat roof tile, Flexural test, Malang iron sand, Water absorption, Water seepage resistance, Wave roof tile.*

1. Introduction

East Java Province is geographically located between 111°0′ East Longitude and 114°4′ East Longitude and 7°12′ South Latitude – 8°48′ South Latitude, with an area of 47,963 km², which includes two main parts, namely East Java mainland and Madura Islands. One of the impacts of population growth in the Golden Indonesia (*Indonesia Emas*) of 2045 is certainly an increase in housing needs for the Indonesian people. However, it has prepared the current housing strategy to face the challenges of fulfilling the public housing needs, in addition to what kind of housing provision strategy might be applied. Industry and housing require quality building materials. Roof tiles as a complementary building material must also be well available in terms of quality, as well as their useful value. Many factors must be considered to determine whether a quality tile roof can be accounted for by the community or not. Further, a method for making a good tile roof is also needed, so that tile roof users feel safe in having a tile roof that has this quality. The roof of a house acts as a protector of the roof frame of the building to protect the influence of hot weather, rain, and wind. In addition, concrete tile roofs are required for good roof coverings to be durable and strong.

The growth and development of housing and buildings require a good roof covering material, namely a cover that meets the requirements of strength, light, and waterproofing. This is a good roof covering, concrete tile, where people who use concrete tile, in addition to the price, which is expensive when compared to other tiles, concrete tile, which includes a roof covering that is quite heavy, so it requires a strong roof frame construction, so that it can withstand the weight of the tile.

The weaknesses of concrete until now are still being addressed, both increasing compressive, tensile, and flexural strength, as well as efforts to make concrete lightweight but have high strength.

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Wave concrete tile is an application of using concrete as a non-structural building material that automatically has the same weaknesses. Moreover, concrete tile is a building element made from a mixture of materials, such as Portland fine aggregate, which can be used for roofing. Wave concrete tile is very strong and weighs heavily, reaching 4.4 kg per piece. This is a problem in its use because the weight of the roof covering affects the size of the battens. Wave roof tiles that are thinner than the usual tile size are needed so that they can lighten the construction of the roof frame and also save the use of quality materials that meet the requirements of SNI.

Malang, as part of the East Java region, is surrounded by mountains, namely Mount Arjuno to the north, Mount Semeru to the east, Mount Kawi and Panderman to the west, and Mount Kelud to the south. The Malang Regency Government has estimated that the potential of the beaches scattered in the Malang Regency area, East Java, is considerable, with considerable mining potential, especially iron sand mining. The Head of the Malang Regency Energy and Mineral Resources Agency (ESDM) said that at least 14 beaches in the southern coastal area of Malang have the potential to contain mining products. It is just that the potential for mining products is quite large, so far it has not been able to be exploited optimally because no investor has dared to propose management due to being hampered by the Forestry Law. Almost all beaches that contain iron sand mines, he said, are in the area (land) of *Perum Perhutani* [1].

Several studies related to concrete tile manufacturing technology have been conducted. It has been explained that using iron ore tailings instead of limestone powder significantly improves the physical and mechanical properties of concrete roof tiles, meeting international marketing standards and reducing environmental impact [2]. The two-layer spray coating process can produce sunlight-reflecting non-white concrete roof tiles and asphalt shingle roofing materials, which have the potential to save energy and reduce urban heat islands [3]. Another study developed a method of producing lightweight geopolymer concrete roof tiles using fly ash, sodium silicate, and sodium hydroxide, which resulted in 35% to 50% lighter weight and better thermal conductivity compared to traditional methods [4]. There is also research showing that fired clay from industrial waste as a pozzolanic material in concrete roof tiles meets market standards, with increased flexural strength after 28 days [5]. Taguchi method and confirmatory experiments can improve the compressive strength and variability of concrete roof tiles, with an optimal composition of 0.9 kg: 0.5 kg: 0.4 kg: 0.3 kg [6]. Fractured roof tiles as a substitute for sand and gypsum powder as a substitute for cement produce environmentally friendly concrete with a compressive strength of 19.04 MPa, close to normal concrete [7]. The use of rice husk ash up to 10% can effectively replace cement in green concrete roof tiles, maintaining good performance and meeting the requirements of Malaysian Standards [8]. Based on the five materials considered for selection in roof tile production, the optimal material for roof tile production is POL-02, consisting of 2% by weight GD, 98% by weight polypropylene, which is a durable and sustainable polymer composite with the highest benefit number value of 14.43 [9]. Related research on glass fiber concrete roof tiles offers good strength, heat resistance, and water seepage resistance, with minimal cost and high flexural strength compared to ordinary concrete roof tiles [1]. Substitution of asphalt tile waste and fly ash in concrete mixtures reduces compressive strength, slump, water absorption, and density, but still maintains the same compressive strength as normal concrete [10]. The addition of nylon as cement reinforcement in concrete roof tiles reduces water absorption and flexural tensile strength without affecting flexural tensile strength [2]. *Pre-pressed Burnt Sandy Clay Tiles* (PBSCT) offer a sustainable alternative to traditional concrete roof coverings, offering higher compressive strength and reduced conductive properties [11]. Recycled clay tiles as coarse aggregate in self-compacting concrete significantly improved compressive strength, weather resistance, and resource efficiency, leading to reduced construction costs and sustainable development [12]. Coconut shells and coir can be used as reinforcement in concrete roof tiles that are environmentally friendly, lightweight, and durable, thereby reducing the environmental impact of agricultural waste and proving feasible to produce and market [1]. Concrete mixtures of M4 and M5 gradation groups, using 80 percent Bangkalan aggregates and 20 percent Lumajang or Pasuruan + Bangkalan aggregates, achieved the highest compressive strength and improved water absorption and absorbency [6]. Based on the description above, it is interesting to conduct research related to concrete roof tiles by utilizing Lumajang iron sand as a mixture in the manufacture of concrete roof tiles in the hope that the technological results of making wave roof tiles are better and perfect as required in SNI 0096: 2007 Concrete Tile. The problem that is of concern in this research is how the technology of making wave concrete roof tiles by utilizing Lumajang sand as a mixture for making concrete roof tiles. The purpose of the research is to develop the technology of making wave concrete roof tiles and flat concrete roof tiles with these mechanical properties.

2. Research Method

2.1. Place of Research

The place of manufacture of flat concrete roof tiles is carried out at *PT Abadi Utama Genteng*, which is located at Raya Karangpandan street number 265 Bendo Pakisaji T-junction Kepanjen, Malang Regency, East Java. This company is a Home Industry company, while flexural testing, seepage resistance testing, and water absorption testing were carried out at the Faculty of Civil Engineering, Brawijaya University, Malang, East Java.

2.2. Research Methods

The research method used in this research is an experimental method using iron sand and ordinary sand, fly ash, Padang cement, and stone ash as research materials. In addition, in the research method when conducting hardware experiment research where in this experiment, the technology of making flat concrete roof tiles using iron sand from Malang is used in this study as the resulting hardware. In addition, this research method contains several samples of test objects with the percentage of the composition of the addition of 30% cement, 40% iron-containing fine sand, 15% stone ash, and 15% fly ash mixed evenly and dissolved in water adjusted to the material.

2.3. Tools and Materials

The equipment used in the process of making wave concrete roof tiles is Hydraulic Process Machines, *Mulen* Tools, Steel Mat Tile Trivets, and Mold Masters. and Water Pumps. As for the materials used in the manufacture of wave concrete roof tiles, they consist of Malang iron sand, cement stone ash, fly ash, and ordinary iron sand. Supporting materials are Bio Solar and Palm Oil.

In addition, the tools used in testing wave concrete roof tiles at the Civil Engineering Laboratory of Universitas Brawijaya, Malang are Digital Scales, Oven Tools, Loadcell, and Frame.

2.4. Production Process of Flat Concrete Tile

1. Selection of Main Raw Materials. Raw materials in the production area will be subjected to a Quality Control process to determine which raw materials are still suitable for use.
2. Measuring the composition of the main raw materials for flat concrete roof tiles, which consists of fine iron sand (40%), stone ash (15%), fly ash (15%), and Padang cement (30%).
3. Mixing is the process of melting the main raw materials that have gone through the selection process and the dosing process to become the perfect concrete material.
4. Mixing of Supporting Materials, as a lubricant on the iron mat.
5. Lubrication of the molding mat, the gar is not sticky to the molding mat, so that it can produce a good and maximum product.
6. Molding

a. Placing the steel master on the hydraulic table.
b. Taking the concrete material from the *Mulen* machine that has been mixed evenly into the *Cintung Takaran.*
c. Pouring concrete material that has gone through the process of pouring.

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d. Leveling the concrete material. The process of pushing the steel master along with the concrete material onto the hydraulic piston.
e. Pressing the concrete material

The process of removing the new wave concrete tiles from the mold is a crucial step because the newly molded tiles will be transferred from the steel master to the tile placemat using a plate cutting tool. Store in the stacking rack for 12 (twelve) hours. This process aims to produce flat concrete tiles and wave concrete tiles that are still wet after printing, allowing the water content to evaporate and enabling them to dry. Soaking process. After 12 hours in the stacking rack, go to the soaking process. After that, go to the next process, which is called drying flat concrete tile, with a drying time of 28 days, starting from the rising process after soaking. The final process of painting flat concrete tiles and wave concrete tiles.

3. Results and Discussion

The tile test is used to determine flexibility, seepage resistance, and water absorption. The results obtained are presented in Table 1 below.

Table 1.
Flexural Test Results, Seepage Resistance, and Water Absorption.

No.	Construction Type	Weight (Gram)	Max Flexural Load (N)	Average Bending Load (N)	Water Seepage Resistance	Absorption (%)	Bending Value (Sdf) N
1.	Padang Cement *Mulia* Flat Concrete Tile	4532.0 4440.0 4506.0 4988.0 4317.0	1450.4 1303.4 1715.0 1803.2 1421.0	**1538.60**	>20 Hours	3.3	210.985N
2.	*Garuda* Concrete Tile *Mulia* Concrete Padang Cement (Wave)	4394.0 4522.0 4427.0 4473.0 4491.0	2205.0 1744.4 1950.2 2165.8 2548.0	**2122.68**	>20 Hours	3.8	300.989N

Based on Table 1, the results of flexural tests that have been carried out on both types of roof tiles show that wave roof tiles (300.989N) have a greater flexural test value when compared to flat concrete roof tiles (210.985N). In the same table, the water seepage resistance of Malang Sand tile material, *Mulia* garuda concrete tile/wave tile, after being given water for more than 20 hours of water above the surface, the water does not penetrate to the bottom, and no droplets occur. So it can be said that water cannot seep into the wave tile. Meanwhile, the water absorption test for flat concrete roof tiles made from Malang sand, using a mixture of Padang cement, was soaked in a water bath for more than 20 hours, and the water above the surface of the *Mulia* concrete tile did not penetrate to the bottom; no water droplets occurred. So it can be said that water does not seep into the *Mulia* concrete tile. When compared with the wave tile, the average absorption is better than that of the *Mulia* flat concrete tile, which is 3.3%. The average wave tile water absorption test is 3.8%, while the Mulia flat concrete tile water absorption test averages 3.3%. So that the water absorption aspect of flat concrete tiles is still better than that of wave tiles in a state that has not been painted.

The third result above, in general, flat concrete tile has the durability to withstand water, so that there is no seepage that causes leakage or damage to the tile, which causes the quality of the tile to decrease. Ordinary sand flat concrete tiles, generally have better quality than wave concrete tiles even though the appearance is relatively the same, flat concrete tiles of sand and cement materials are the same from the aspect of good absorption of *Mulia* flat concrete tiles and both concrete tiles can withstand water not to seep into the pores of the tile which causes leakage and can reduce the service life of the tile. Both affect qualities and affect consumer confidence. Generally, consumers choose good quality and quality for occupancy, so that there are no problems arising from flat concrete tile products.

4. Conclusion

Based on the results of the analysis, this study concludes that the results of the concrete tile water seepage test meet the requirements of SNI 0096-2007 and PUBI-1982. Similarly, for bending tests that have been carried out on both types of roof tiles, the results show that flat concrete roof tiles with Lumajang sand base material have an average load of 1570.994 N, and ordinary sand of 595.84 N. The use of Lumajang iron sand material has a greater bending test value than ordinary sand. Seepage testing on flat concrete roof tiles using the same cement mixture, namely Padang cement, shows that both roof tiles show good performance. This is indicated by the flat concrete tile and wave concrete tile of Semen Padang material after being given water for more than 20 hours; the water above the surface of the flat concrete tile and wave concrete tile does not penetrate to the bottom (no dripping occurs). So, it can be said that water can seep into flat concrete tiles and wave concrete tiles, but only moisturizes the bottom of flat concrete tiles and wave concrete tiles. Whereas in flat concrete tiles using Malang sand material, water does not penetrate, and there are no droplets at the bottom. So it can be concluded that flat concrete tiles and wave concrete tiles meet the requirements of SNI 0096-2007 and PUBI-1982. Water absorption test of flat concrete tile and wave tile using the same sand and cement material as in the above test. First, the flat concrete tile sample is soaked in water to determine the absorption of the flat concrete tile by water. The average water absorption of flat concrete tiles of both sand and Padang cement is 8.3% *Mulia* flat concrete tile, *Mulia* garuda concrete tile, or wave concrete tile of 3.8%. The follow-up research should use other materials that are softer and smoother. In addition, further research uses other materials with a varied percentage.

Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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