INNOVATION OF SUSTAINABLE BRICK PRODUCTION BASED ON POLYETHYLENE TEREPHTHALATE AND EPOXY RESIN

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ABSTRACT: Currently, the use of plastic is one of the problems in the world. Various plastic recycling innovations have been researched. One of them is the reuse of plastic waste to be used as a mixture of building materials. One form of innovation that can be developed is sustainable brick. The use of plastic waste in the manufacture of sustainable bricks is one form of problem solving in the field of waste management. One of the innovations in making sustainable brick is by mixing PET plastic with epoxy resin. This innovation was carried out by determining the optimal formulation by design experiment. Based on the results of the design experiment using Response surface method, the optimal results were obtained, namely the epoxy resin ratio of 89.97%, particle size for PET which is 1.14 mm and curing time of 6.97 days. This shows that the use of plastic waste can be used as one of the innovations in the manufacture of sustainable bricks.

KEYWORDS: *PET, epoxy resin, innovation, waste management, sustainable brick*

1.0 INTRODUCTION

Currently, environmental problems continue to increase, one of the world's main concerns is related to pollution and waste management [1], [2]. One waste that has a large amount is plastic waste. A lot of plastic waste is packaging waste and plastic bottles [3]. PET, which is commonly used in the manufacture of plastic bottles and various other consumer products, is a highly durable material that often ends up as non-degradable waste. Therefore, innovation is needed in the reuse of PET waste.

One such innovative solution is the making of sustainable brick. From the sample of sustainable brick is eco-bricks. Eco-brick made form of recycling plastic bottles. Eco-bricks are plastic bottles densely filled with non-biological waste to create reusable building blocks [4]. This not only helps in managing plastic waste, but also offers an environmentally friendly alternative for construction materials. The innovation of eco-bricks is in line with circular economy principles, which aim to extend the life cycle of materials and reduce environmental impact. By turning plastic waste into a resource, eco-bricks help reduce the devastating effects of plastic pollution.

Some of the weaknesses of these eco-bricks lie in the strength of the PET binder. In addition, some of the complaints that arise in eco-brick workers include complaints when cutting plastic [5]. This resulted in injuries to the hands of the workers. Currently, the only eco-brick binder available is the PET bottle cap. So that the strength arising from the eco-brick is not strong, therefore it is necessary to add a binder that can increase the strength of the eco-brick. One binder that has strong strength is epoxy resin. Epoxy resins are known for their exceptional strength and high adhesion, often used in various industrial and construction applications. Combining these two materials, eco-bricks made from PET and epoxy resin offer an innovative solution to reduce plastic waste while creating high-performance building materials. Therefore, this innovation is a sustainable brick production using PET and Epoxy resin.

2.0 METHODOLOGY

2.1 Epoxy Resin Material

This study was conducted using more than 85% epoxy resin, bisphenol diglycidyl ether (E-44 and E-51), produced using bisphenol A (BPA) and epichlorohydrin (ECH). Epoxy resin has superior weather tolerance; it can also lower overall costs and improve durability. Furthermore, its toughness properties meet the mechanical requirements for pavements, particularly with regard to heat-induced surface cracks. Moreover, this resin is less viscous, which makes it easier to work with, especially in colder climates.

In this experiment, epoxy resin is mixed with hardener. Hardener is commonly utilized throughout the epoxy resin curing process. When epoxy resin and hardener are mixed together, a reaction occurs. A strong, resilient, and frequently rigid substance is the end consequence of this process. In this experiment, the ratio of hardener to epoxy resin is 1:1. The hardener serves as a catalyst, starting the cross-linking reaction between the epoxy resin molecules.

2.2 PET Particle

In this study, the PET material was obtained from a waste bank in the Yogyakarta area. The PET particles are 1 mm (small) to 5 mm (large) in size. Initially the PET particles must clean and washed with water to eliminated any surface impurities. After that PET particles mixed with Epoxy resin and cure at room temperature.

Figure 1: PET Particles

2.3 Experimental Design

In this study, epoxy resin and PET were mixed in the available molds. Subsequently, the eco-bricks were dried until they cured. This research consisted of two stages. The first stage was to optimize the formula for making eco-bricks, and the second stage was to test the compression strength of the eco-bricks.

2.4 Compressive Strength Test

The standard used in compressive strength testing uses the ASTM D695 standard. Based on ASTM D695 test method covers the determination of the mechanical properties of rigid plastic reinforces, including high modulus This test method covers determining the mechanical properties of unreinforced and reinforced rigid composites when loaded in compression at relatively low uniform rates of straining or loading. Compression test is a test that aims to determine the mechanical properties of a material when it is given pressure/load until it cracks or breaks. Speed control at 1.3 mm/min (0.050 in./min), calculate the compressive strength by dividing the maximum compressive load carried by the specimen during the test by the original minimum cross- sectional area of the specimen.

3.0 RESULTS AND DISCUSSION

3.1 Optimization of Formula

The experimental results related to eco-brick optimization are analyzed based on Response Surface Method (RSM). The response surface method (RSM) is an efficient approach used extensively to ascertain the correlation between variables and responses. Moreover, RSM also evaluates how variable interactions and individual variables affect response. Devising an RSM model comprises three steps: gathering experimental data concerning the required response, formulating the RSM framework, accuracy validation, and parameter tuning to fulfil response variable requirements. The results of experiment can see in the Table 1.

Table 1: Experimental runs and results

Run	Parameters			Compression Test (MPa)
	1 (ratio)	**2 (size)**	**3 (Curing time)**	
1	10	3	4	32.50
2	10	1	1	26.78
3	50	3	4	35.02
4	10	5	7	30.61
5	50	3	7	39.94
6	50	1	4	33.19
7	90	1	7	44.12
8	50	3	4	36.09
9	50	3	1	31.65
10	10	1	7	43.02
11	10	5	1	28.17
12	50	5	4	29.93
13	50	3	4	33.82
14	90	3	4	38.31
15	90	1	1	35.39
16	90	5	7	42.35
17	90	5	1	38.32

This research is based on an RSM framework that uses historical data to build a quadratic expression for every response. RSM provides numerous benefits like response prediction efficiency, a responsive model with a small experimental dataset, evaluating the effects of factor correlations, and determining optimal response. This research employed Central Composite Design (CCD) to assess the impact of input parameters on the response concerning the PET particle and epoxy resin combination.

Particle size and ratio are vital aspects to derive the precise polymer concrete composition [6]. Moreover, the curing period is evaluated to determine the hardening duration. The compression test response produced by the study helps understand factor correlation concerning materials research [7], [8], [9], [10]. After gathering empirical data, the polynomial framework is determined for present responses. Analysis of variance (ANOVA) was performed primarily to compute F- and P-values to verify model applicability. Model significance was based on the F- and P-values that were considered vital for the process. ANOVA outcomes are specified in Table 2.

Table 2: ANOVA Assessment Outcomes

Source	Sum of Squares	df	Mean Square	F-value	*p*-value
Model	357.01	9	39.67	19.16	0.0004
A-Ratio	185.64	1	185.64	89.66	< 0.0001
B-Size	5.55	1	5.55	2.68	0.1456
C-Curring time	115.91	1	115.91	55.98	0.0001
AB	5.30	1	5.30	2.56	0.1538
AC	0.0095	1	0.0095	0.0046	0.9479
BC	20.55	1	20.55	9.93	0.0161
A^2	5.59	1	5.59	2.70	0.1442
B^2	15.40	1	15.40	7.44	0.0295
C^2	9.01	1	9.01	4.35	0.0754
Residual	14.49	7	2.07		
Lack of Fit	11.92	5	2.38	1,85	0.3865
Pure Error	2.57	2	1.29		
Cor Total	371.50	16			

Based on the factor ranges in Table 3, the Design-Expert software was utilized to perform a numerical optimization. The results of optimization are shown in Figure 2; the ideal parameter ratio (A) is 89.97%, whereas the optimum particle size (B) and curing time (C) were 1.14 mm and 6.97 days, respectively. As a result, the desired compressive properties suggest a strength of 44.11 MPa. In terms of the response variable, desirability moving towards one was selected as the most important factor.

Table 3: Range of factor and expected target of response

Optimized Item	Unit	Lower limit	Upper limit	Desired goal
Volume	%	10	90	In range
Particle size	mm	1	5	In range
Curing time	day	1	7	In range
Compressive strength	MPa	26.7794	44.11	Maximum

In this study, a desirability value of 1 was used for validating and evaluating the compressive characteristics, under optimal conditions.

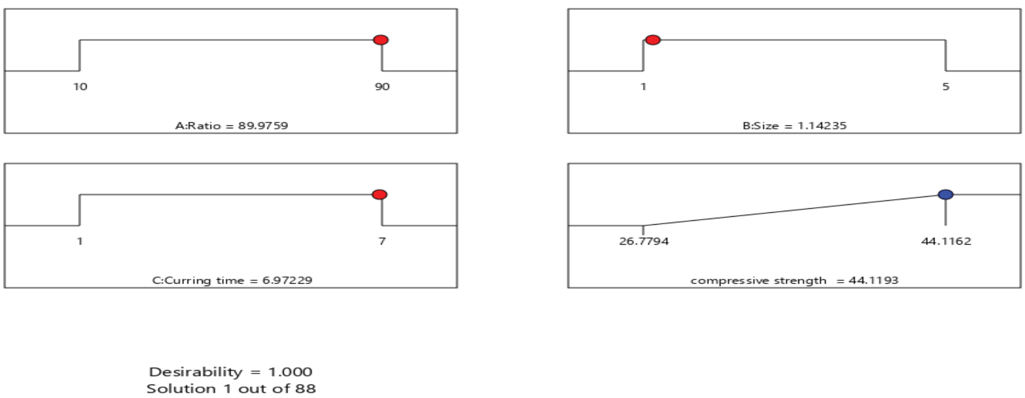

Figure 2: Ramp type - optimal operating conditions

3.2 Comparison

Epoxy resins play an important role in composite materials. Petroleum-based epoxy monomers have excellent tensile strength, high stiffness and electrical strength. Epoxy resins are used in various fields such as construction, automotive and aerospace. The use of epoxy resins is widespread because they have good mechanical strength, dimensional stability, good wettability, fire resistance, good chemical resistance and low drying shrinkage [11]. In this research, the compressive strength of Clay-PET, Cement-PET, and Eco-brick was compared. Eco-brick mixed with epoxy resin and PET have high compressive strength compared to the compressive strength of the other mixes.

Table 5: Comparison of eco-brick production based on compressive strength

Author	Year	Mixing	Maximal Compressive strength (MPa)	Reference
Del Rey Castillo, Enrique	2020	PET and Cement	20	[12]
Akinyele	2020	PET and Clay	11.02	[13]
Taaffe, Jonathan	2014	PET bottle	38	[14]
Okka et al	2023	Recycled PET-epoxy	44.12	

The addition of epoxy resin as an adhesive has a great influence on the compressive strength of the eco-briquette. This proves that epoxy resin is a polymer material that has high mechanical strength and good adhesion data [15], so the use of epoxy resin as a mixture can be used in buildings. Epoxy resin is the main thermosetting resin used in high performance development. Epoxy resin is the first choice for bonding material fragments such as steel, copper, wood, iron, cement, plastic and other composites [16].

3.0 CONCLUSION

This innovation is an eco-brick made from a mixture of PET particle and epoxy resin. This eco-brick serves as a form of innovation in the manufacture of environmentally friendly bricks. In this study, formulation optimisation was carried out in the manufacture of eco-bricks. In this study, the formulation was obtained in the manufacture of eco-bricks, namely with an epoxy resin ratio of 89.97%, particle size for PET which is 1.14 mm and curing time of 6.97 days. In making this eco-brick, it will recycle plastic waste into a mixture of sustainable construction materials.

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