

Utilization of Geodipa Waste in Making Septic Tank Culverts: Towards a Clean Environment

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ABSTRACT

Environmental issues, particularly waste management, remain a serious challenge in Indonesia. One of the industries contributing to solid waste is geothermal power generation, which produces silica residues that have not been fully utilized. This study explores the potential use of Geodipa silica waste as a partial substitute in septic tank culvert concrete mixtures to improve structural performance and support sustainable waste management. The experimental method was carried out at the Civil Engineering Laboratory of Universitas Sains Al-Qur'an by preparing cylindrical specimens with 5%, 8%, and 12% waste variations. Compressive strength tests were performed after seven days of curing. The results showed that the highest compressive strength was achieved at an 8% waste addition, reaching 97.4 MPa, which significantly exceeds the strength of normal concrete at 38.5 MPa. Meanwhile, the 5% and 12% variations showed lower performance compared to the 8% mixture. Cost analysis also indicated that the use of Geodipa waste reduced material expenses compared to normal culverts. These findings highlight that incorporating Geodipa waste into concrete not only enhances strength and cost efficiency but also contributes to environmental sustainability through industrial waste utilization. This innovation has strong potential for application in sanitation infrastructure, particularly septic tank culverts, while supporting the principles of a circular economy.

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INTRODUCTION

Environmental issues are a global challenge that require serious attention from various parties. Climate change, environmental pollution, and waste management are becoming increasingly complex issues with increasing human activity and industrial growth. One sector contributing to waste is the geothermal power generation industry ([Aditama, 2017](#)). In Indonesia, PT Geo Dipa Energi is a company operating in this sector. During its production process, PT GeoDipa generates solid waste such as silica and other inorganic residues, which have not been optimally utilized.

Solid waste from geothermal energy generation has the potential to be processed into useful products. One example is as a mixed material in the manufacture of construction components, such as culverts and septic tanks ([Bappenas, 2022](#)). This not only represents an innovation in waste utilization but also a concrete step in supporting the principles of a circular economy, which

focuses on waste reduction and reuse. On the other hand, sanitation and domestic waste management remain serious concerns in many parts of Indonesia, particularly in rural and peri-urban areas. Many communities lack proper and safe septic tank systems, resulting in the indiscriminate disposal of household waste, polluting the environment. Septic tank culverts, as vital sanitation infrastructure, should be widely accessible ([Qomaruddin, et al., 2018](#); [World Health Organization, 2018](#)).

Developing sustainable sanitation infrastructure is a critical challenge in maintaining environmental cleanliness and public health. One innovative approach in this regard is utilizing industrial waste as an alternative construction material. Geodipa waste, derived from geothermal energy production residues, has been studied as a substitute in concrete mixes. Research by Erfan Nugroho and Nasyiin Faqih shows that partially replacing cement with geodipa waste of up to 20% can produce concrete with a compressive strength of up to 18.72 MPa, meeting design concrete quality standards ([Civil & Study, 2023](#)).

The use of geodipa waste in septic tank culvert construction not only has the potential to improve the quality and durability of the structure but also supports the principles of a circular economy by reducing industrial waste and dependence on natural raw materials ([Fikroni, et al., 2023](#)). This initiative aligns with global efforts to create a cleaner and more sustainable environment. Therefore, this study aims to explore the potential use of geodipa waste in septic tank culvert construction as a concrete step towards a cleaner and healthier environment.

METHODS

The research methodology was carried out by preparing test specimens in the Civil Engineering Laboratory of Universitas Sains Al-Qur'an (UNSIQ), Central Java, Wonosobo. In this study, the researcher applied an experimental method to determine the optimum compressive strength of septic tank culvert specimens after the addition of finely ground Geodipa waste that passed through a No. 100 sieve ([International Energy Agency, 2021](#)).

The composition of the septic tank culvert mixture with Geodipa waste was prepared according to the variations applied, namely 5%, 8%, and 12%, with the specimen dimensions in the form of cylinders measuring 15 cm in diameter and 30 cm in height ([Larasati, 2016](#)). The type of cement used was Portland cement type I, obtained from a material supplier in good condition and properly sealed. The sand used was Brosot sand.

The experimental method involved incorporating Geodipa waste into the culvert mixture for septic tank specimens. For each variation, three cylindrical samples were prepared and tested. The details are as follows. This research was divided into four stages:

1. Preparation Stage

The first stage was preparation, which involved providing the materials to be used for making the septic tank culverts. These included fine aggregate (sand), Portland cement that meets minimum standard specifications and is suitable for general construction purposes (including culvert production), and additional materials such as Geodipa waste to be incorporated in the mixture. This stage included the following tests:

- a. Gradation Test
- b. Unit Weight Test of Aggregates
- c. Silt Content Test

- d. Cement Examination
 - e. Water (determination of the ideal water volume)
 - f. Geodipa Waste (passing through sieve No. 100 and weighing)
2. Manufacturing Stage
- a. Preparing the culvert mixture using a concrete mixer by combining gravel, cement, and sand, then adding Geodipa waste until evenly mixed.
 - b. Gradually adding water in small amounts while continuously mixing until the mixture becomes homogeneous.
 - c. Placing the mixture into the culvert mold: filling the mold up to 1/5 of its height, compacting it with a tamping rod, then refilling until the mold is full and compacting it again using a tamping tool until optimum density is achieved.
 - d. Once proper compaction and uniformity are reached, the specimen is removed from the mold and placed in a dry, shaded, and level location to avoid any quality distortion.

3. Curing Stage

Once the specimen has hardened sufficiently, curing is carried out by submerging it in water for 3 days prior to compressive strength testing. During curing, the specimens must be protected from direct sunlight to prevent reduced quality.

4. Testing Stage

After 3 days of curing, the compressive strength test is conducted to obtain the maximum strength of the culvert specimens. The test specimens used were cylinders with a diameter of 15 cm and a height of 30 cm. The testing procedures followed the applicable Indonesian National Standard (SNI) and included the following steps:

- a. The specimen, which had been air-dried for one day, was cleaned of any surface impurities.
- b. Measuring the unit weight of the specimen.
- c. Measuring the specimen's dimensions.
- d. Placing the specimen at the center of the testing machine.
- e. Operating the testing machine by applying a continuously increasing load.
- f. Continuing the loading process until the specimen failed (cracked or broke), while recording the maximum load applied.

RESULTS AND DISCUSSION

This study aims to explore the potential use of geodipa waste in septic tank culvert construction as a concrete step towards a cleaner and healthier environment. Geodipa waste, derived from geothermal energy production residues, has been studied as a substitute in concrete mixes. The use of geodipa waste in septic tank culvert construction not only has the potential to improve the quality and durability of the structure but also supports the principles of a circular economy by reducing industrial waste and dependence on natural raw materials. Gradation test of combined coarse aggregates.

Table 1. Gradation of Gravel or Coral Aggregates

Sieve Size	Percentage Passing			Gradation Specification of Coarse Aggregate, Max. 40 mm
	CS. 2/3 max. 1 1/2"	CS. 2/3 max. 1"	Combined	

(mm)	(inci hi)	60%	40%	Gradation	Lower Limit	Upper Limit
38.1 0	1 1/2"	60.00	40.00	100	95	100
25.4 0	1"	58.32	40.00	98.32		
20.0 0	3/4"	18.51	34.58	53.10	37	70
12.7 0	1/2"	1.45	12.25	13.70		
10.0 0	3/8"	0.92	4.08	5.00	10	40
4.76	No. 4	0.59	0.36	0.96	0	5
2.00	No. 8	0.00	0.00	0.00		
1.19	No. 16	0.00	0.00	0.00		
0.59	No. 30	0.00	0.00	0.00		
0.28	No. 50	0.00	0.00	0.00		
0.15	No. 100	0.00	0.00	0.00		
0.07	No. 200	0.00	0.00	0.00		

Based on Table 1, the gradation of gravel or coral is limited to a sieve size of 4.76 mm.

Table 2. Percentage Passing of Crushed Stone and Sand.

Sieve Size		Percentage Passing		
(mm)	(inchi)	Crushed Stone 59%	Sand 41%	Combined Gradation
38.10	1 1/2"	100.00	100.00	100.00
25.40	1"	98.32	100.00	99.01
20.00	3/4"	53.10	100.00	72.33
12.70	1/2"	13.70	100.00	49.08
10.00	3/8"	5.00	100.00	43.95
4.76	No.4	0.96	97.88	40.70
2.00	No.8	0.00	81.58	33.45
1.19	No.16	0.00	55.05	22.57
0.59	No.30	0.00	39.11	16.04
0.28	No.50	0.00	29.07	11.92
0.15	No.100	0.00	19.24	7.89
0.07	No.200	0.00	14.02	5.75

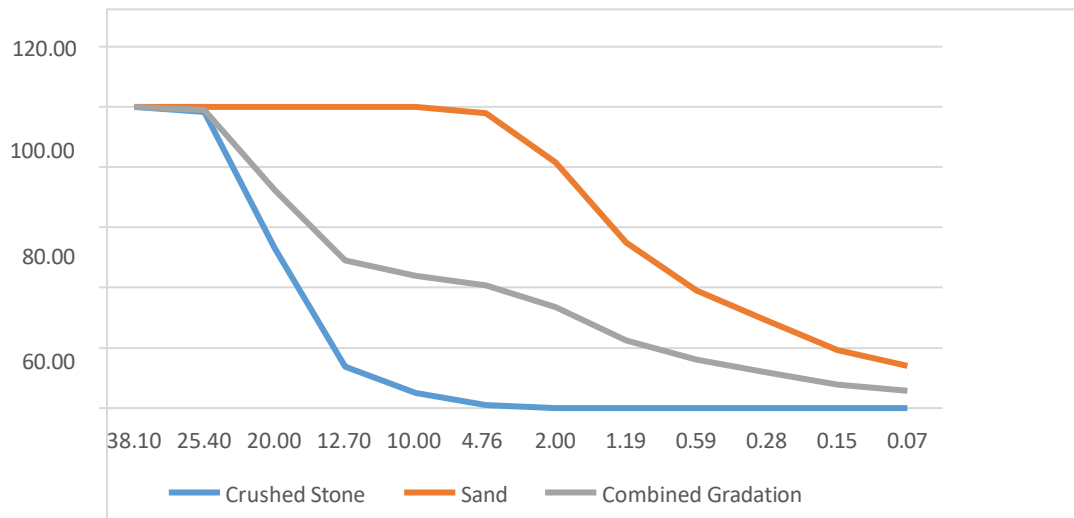


Figure 1. Sieve Analysis Graph of Crushed Stone or Sand

The above figure presents the sieve analysis results of crushed stone and sand, which are used for the calculation of mix material requirements.

Mix Design Calculation

The volume of the culvert is calculated based on its dimensions, with a diameter of 80 cm, a wall thickness of 6 cm, and a length of 50 cm. The resulting volume is 0.07 m³.

The material requirements for a single culvert with a volume of 0.07 m³. Cement= 315 Kg x 0,07 m³ = 21,98 Kg

Sand = 786 Kg x 0,07 m³ = 55,02 Kg

Gravel = 1116 Kg x 0,07 m³ = 78,12 Kg Water = 170 Kg x 0,07 m³ = 11,90 Kg

Proportion of Geodipa waste required for a single culvert

5% = 5% x 0,07 m³ = 0,0035 Kg

8% = 8% x 0,07 m³ = 0,0056 Kg

12% = 12% x 0,07 m³ = 0,0084 Kg

In this study, we used cylindrical specimens with dimensions of 15 mm × 30 mm, with the addition of silica waste from PT. Geodipa, tested using the compressive strength method ([Sidik & Nasyiin, 2022](#)). For each cylinder specimen with dimensions of 15 mm × 30 mm, three test samples were prepared. The required materials are as follows:

Table 3. Research Material Requirements

Variation	Geodipa Waste (Kg)	Cement (Kg)	Sand (Kg)	Water (ml)	Number of Specimens
Normal	-	5.464	17.676	2.958	3
5%	0.273	5.191	17.676	2.958	3
8%	0.437	5.027	17.676	2.958	3
12%	0.656	4.808	17.676	2.958	3

Compressive Strength Test

The compressive strength test was carried out at the Civil Engineering Laboratory, Faculty of Engineering and Computer Science, Universitas Sains Al-Qur'an. After casting, the concrete specimens were cured according to the planned age by immersing them in water for 7 days.

Following curing, the specimens were air-dried to achieve better compaction and maximum dryness (Mara, 2007).

This test aims to determine the compressive strength of concrete with the addition of silica waste as an admixture compared to normal concrete, using cylindrical molds with dimensions of 15 mm× 30 mm. In this experimental test, several factors affected the quality of the concrete specimens, particularly during the preparation stage using cylindrical molds with dimensions of 15 mm × 30 mm, the casting results were found to be less precise or uneven. The test results are presented in the following table:

Table 4. Normal Concrete Compressive Strength Test.

Specimen No	Specimen Mass	Dimensions (mm)		Area (mm ²)	Maximum Stress (Mpa)
		L	T		
N-1	12.07	15	30	4,242.86	37.6
N-2	12.18	15	30	4,242.86	37.5
N-3	12.31	15	30	4,242.86	40.5
Average					38.5

Table 5. Compressive Strength Test of Concrete with 5% Geodipa Silica Waste

Specimen No	Specimen Mass	Dimensions (mm)		Area (mm ²)	Maximum Stress (Mpa)
		L	T		
C5-01	11.96	15	30	4,242.86	17.7
C5-02	12.54	15	30	4,242.86	15.4
C5-03	12.56	15	30	4,242.86	13.0
Average					15.4

Table 6. Compressive Strength Test of Concrete with 8% Geodipa Silica Waste

Specimen No	Specimen Mass	Dimensions (mm)		Area (mm ²)	Maximum Stress (Mpa)
		L	T		
C8-01	12.54	15	30	4,242.86	96.3
C8-02	12.52	15	30	4,242.86	99.8
C8-03	12.43	15	30	4,242.86	96.2
Average					97.4

Table 7. Compressive Strength Test of Concrete with 12% Geodipa Silica Waste

Specimen No	Specimen Mass	Dimensions (mm)		Area (mm ²)	Maximum Stress (Mpa)
		L	T		
C12-01	12.56	15	30	4,242.86	51.6
C12-02	12.72	15	30	4,242.86	37.4
C12-03	12.4	15	30	4,242.86	62.8
Average					50.6

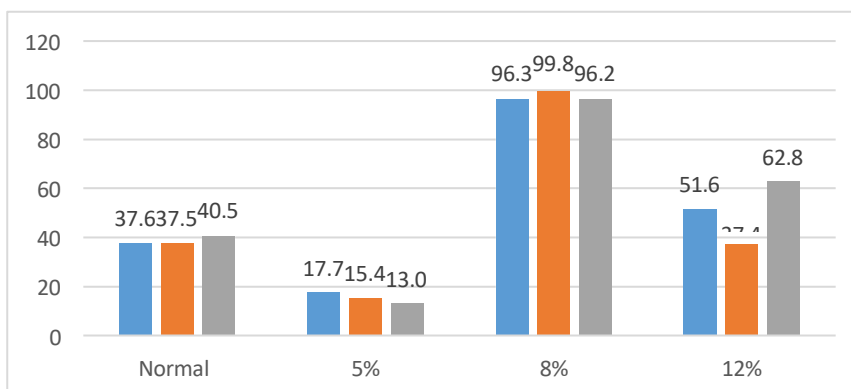


Figure 2. Compressive Strength Test Results Graph

Based on the figure above, the compressive strength test of concrete using cylindrical molds with dimensions of 15 mm × 30 mm and additional Geodipa silica waste at the age of 7 days produced the following average compressive strengths: normal concrete yielded 38.5 MPa, the 5% mixture yielded 15.4 MPa, the 8% mixture yielded 97.4 MPa, and the 12% mixture yielded 50.6 MPa (Putra, 2020). From these results, the maximum average compressive strength was obtained in the 8% mixture at 97.4 MPa. Therefore, in this study, the 8% mixture is considered the most suitable composition to be used for culvert concrete.

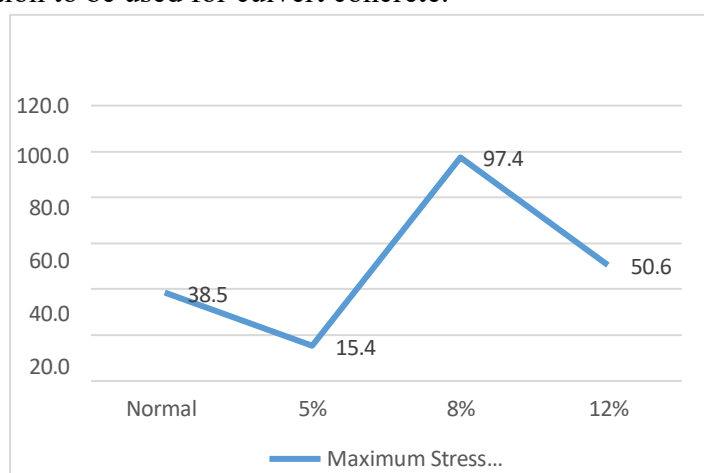


Figure 3. Graph of Average Compressive Strength Test Results

The above figure presents the average compressive strength test results of concrete mixtures incorporating Geodipa waste, which are to be applied in the culvert concrete study (PT Geo Dipa Energi, 2021).

Table 8. Effect of Adding Geodipa Waste

Percentage of Geodipa Waste	Compressive Strength (Mpa)	Effect (%)
Normal	38,5	-
5%	15,4	Decrease 0,6 %
8%	97,4	Increase 5,34 %
12%	50,6	Decrease 0,4 %

For concrete with 5% Geodipa waste, the compressive strength tends to decrease compared to normal concrete. Meanwhile, the 8% mixture shows an increase of 5.34%, whereas the 12%

Geodipa waste mixture experiences a decrease of 0.4% from the 8% mixture, which had an increase of 5.34% ([Ministry of Health of the Republic of Indonesia, 2022](#)).

Table 9. Construction Cost of Normal Concrete for Culverts

No	Requirement	Measurement Unit	Volume	Price per Unit (IDR)	Total Cost (IDR)
1	Equipment	hari		1.466	1.466
2	Manpower (MP)	m ²		15.000	15.000
3	Material				
	Air	lt	11,9	13.000	154.700
	Cement	kg	21,98	1.750	38.465
	Sand	kg	55,02	10.000	550.200
	Gravel	kg	78,12	24.000	1.874.880
				Per Unit	2.634.711

Table 10. Construction Cost of Mixed Concrete for Culverts

No	Requirement	Measurement Unit	Volume	Price per Unit (IDR)	Total Cost (IDR)
1	Equipment	hari		1.466	1.466
2	Manpower (MP)	m ²		15.000	15.000
3	Material				
	- Air	lt	11,9	13.000	154.700
	- Cement	kg	20,22	1.750	35.385
	- Sand	kg	55,02	10.000	550.200
	- Gravel	kg	78,12	24.000	1.874.880
	- Geodipa Silica Waste	kg	1,758	-	-
				Per Unit	2.631.631

Based on the comparison of the budget for normal culvert concrete and culvert concrete with Geodipa waste mixture, as shown in the table above, the cost of producing one unit of normal culvert concrete is IDR 2,634,711 per unit. Meanwhile, the cost of producing one unit of culvert concrete with Geodipa waste addition is IDR 2,631,631 per unit ([ASTM, 2001](#)).



Figure 4. Broken concrete specimens after the compressive strength test

CONCLUSION

This study demonstrates that Geodipa silica waste can be effectively utilized as an additional material in septic tank culvert concrete mixtures. The experimental results show that the optimal compressive strength was achieved with an 8% addition of Geodipa waste, reaching 97.4 MPa, which significantly exceeds the strength of normal concrete. This indicates that Geodipa waste not only enhances the mechanical properties of concrete but also contributes to cost efficiency, as the production cost of culverts with waste addition is slightly lower than that of normal culverts. Moreover, this innovation supports sustainable development by reducing industrial waste and minimizing the reliance on natural raw materials. Therefore, the use of Geodipa waste in culvert construction offers promising potential for wider application in sanitation infrastructure, while simultaneously promoting environmental cleanliness and circular economy principles.

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