Effect of Marble Powder Waste as Fine Aggregate Substitution in Rigid Pavement

Maria Sesi Nukar[1*], M.Sadillah[2], Blima Oktaviastuti[3]
[1,2,3]Study Program of Civil Engineering, Engineering Faculty, Tribhuwana Tunggadewi University, Indonesia

Article Info

Article history:

Submitted August 12, 2024
Reviewed September 18, 2024
Published October 30, 2024

Keywords:

Rigid Pavement, Waste, Marble Powder, Compressive Strength, Flexural Strength

ABSTRACT

The demand for construction materials, particularly for pavement construction, continues to rise, leading to a reduction in available material resources. To address this, an alternative approach has been developed by utilizing marble powder waste as a partial substitute for fine aggregate in rigid pavement construction. This study employs a quantitative, experimental research design aimed at determining the compressive and flexural strength of concrete when marble powder is used as a partial replacement. The compressive strength tests involved varying the marble powder content at 0%, 15%, 25%, and 35%, with assessments at both 7 and 28 days, targeting a planned concrete quality of fc' 21,7 MPa. The compressive strength values at 7 days for each variation are as follows: 0% (13,06 MPa), 15% (13,98 MPa), 25% (15,99 MPa), and 35% (14,10 MPa). At 28 days, the compressive strength results were 0% (22,00 MPa), 15% (23,79 MPa), 25% (16,97 MPa), and 35% (15,67 MPa). For the flexural strength tests, marble powder was substituted at levels of 0%, 15%, 25%, and 35% in concrete specimens measuring 12x50x120cm, with the load applied at 28 days. The maximum load recorded for each variation was 0% (4300 kg), 15% (3200 kg), 25% (4000 kg), and 35% (2500 kg). The average deflection observed was 0% (3,93mm), 15% (2,60mm), 25% (4,26mm), and 35% (2,37mm).

Available online at http://dx.doi.org/10.36055/fondasi

Corresponding Author:

Maria Sesi Nukar,
Study Program of Civil Engineering,
Tribhuwana Tunggadewi University,
Jl. Telaga Warna, Tlogomas, Lowokwaru, Kota Malang, 65144, Indonesia.
Email: *shesynukar@gmail.com

1. INTRODUCTION

Pavement is one of the elements utilized in highway construction to produce a functional and safe pavement layer between the subgrade and the vehicle wheels. Highway construction is one of the few businesses that are experiencing significant technological advancements today. Hence, the need for construction materials continues to increase, especially along with the expansion of road pavements. Rigid pavement and flexible pavement are the two most commonly used forms of road pavement in Indonesia [1], [2]. Asphalt is used for flexible pavement, and cement is used for rigid pavement. Rigid pavement is suitable for use on highways that serve high-speed high traffic [3]. Rigid pavement uses concrete as the main material. Concrete is a material from the mixing of fine aggregate, coarse aggregate, cement, and water with or without additives that form a solid mass with a certain composition [4], [5]. Rigid pavement is a pavement construction arrangement where a concrete slab is used in the top layer of the foundation or in the subgrade of the foundation or directly above the subgrade. Composite pavement is made by combining flexible and rigid pavement [6], [7], [8].

The amount of material that can be used in pavement construction is decreasing. To minimize the lack of these materials, research is carried out to create construction technology that is efficient in terms of cost and processing time and has a positive effect on the environment by utilizing waste, one of which is marble powder waste. Waste generated from marble stone processing damages the environment because it pollutes water, damages plants, makes the soil barren, and causes rice plants to die if it is flowed into the fields [9]. The use of marble powder waste as a substitute for fine aggregate in rigid pavement can provide many benefits because it has its own characteristics. This waste provides advantages including stiffening the material in the concrete layer because the compound content (CaO) in marble waste has similarities with cement so that it can bind with. This was stated in previous research where the highest CaO content in marble waste reached 52.69%. Other benefits of marble powder waste in concrete mixes are increasing strength and resistance to pressure when used in the right proportion, reducing negative effects on the environment, supporting sustainable construction efforts by recycling waste, reducing dependence on traditional natural materials such as sand, thus saving natural resources, having good binding properties, having a form consisting of fine grains so that it can be a substitute for sand, not easy to heat, not easy to crack, easy to process, and cost efficient [10].

Tulungagung City, Campurdarat and Besole Districts, East Java is one of the areas in Indonesia with the most marble producers. In one production, the volume of marble powder waste produced is estimated to reach 5-10%. If per day the marble cutting industry home produces 1000kg / day, the volume of waste generated is around 50 kg-100 kg / day, in a week it can reach 300-600kg / week and in 1 month it can reach 1300 kg-2600 kg / month, and in a year alone it has produced ± 1.3-2.6 tons of marble powder waste and that is only 1 home industry not including other home industries [11], [12].

Marble powder is the waste left over from the marble cutting process at the factory which has passed the drying and smoothing process to become powder. Physically, marble powder is bright white in color and has a specific gravity of 2.79. Marble powder has a fine grain size with 100.00% of the grains passing the Number 200 sieve with a diameter of 0.08 mm. The composition of marble consists of calcite, dolomite, and hematite. Meanwhile, based on geochemical test analysis, marble has a varied oxide content including Silicon Dioxide (SiO_2), Calcium Carbonate ($CaCO3$), Calcium Oxide (CaO) and several other compounds [13].

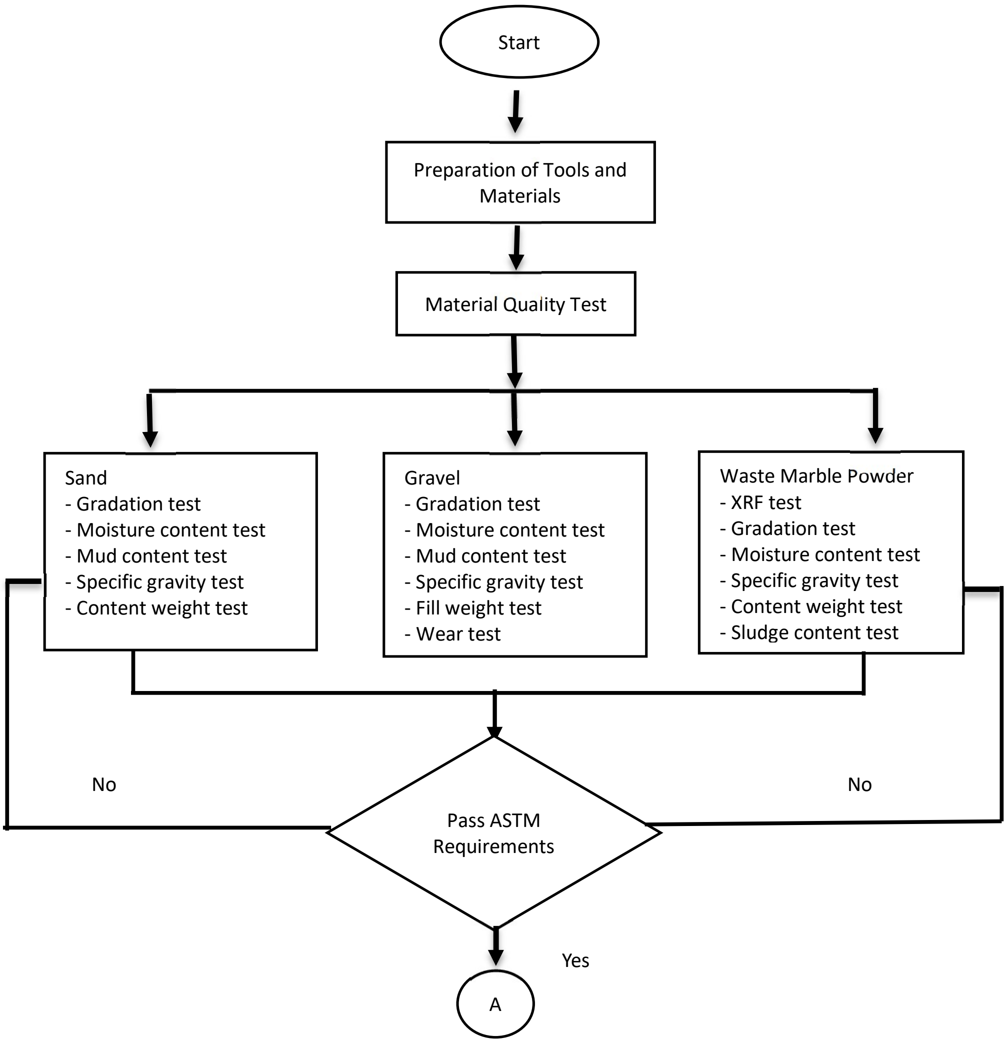
Marble powder in concrete exhibits similar physical and mechanical properties to conventional concrete, demonstrating its viability as an effective substitute for coarse and fine aggregates in structural concrete. Studies show that concrete incorporating marble powder meets the required standards for compressive strength, flexural strength, bond strength, and other critical performance metrics [14], [15].

2. METHODS

This research was conducted using quantitative research methods with the type of quantitative experimental research which involves manipulating independent variables, controlling external variables and measuring the effects of independent variables on the dependent variable [16], [17]. In this research, the assessment and testing of standard parameters of compressive strength and flexural strength of concrete on rigid pavement with added material of marble powder waste as a substitute for fine aggregate will be carried out. In this study, the samples or subjects studied by researchers include rigid pavement forming materials namely cement, fine aggregate, coarse aggregate, marble powder waste and water (1:2:2.5) for variations of 0%, 15%, 25%, 35%. The total number of samples of compressive strength test objects 24 test objects and flexural strength 4 test objects. The data collection method used begins with a literature study followed by research conducted at the Tribhuwana Tunggadewi University laboratory and State Polytechnic of Malang laboratory. The stages in the implementation of this research are the preparation of test specimens and testing stages.

2.1 Research Procedure

Research procedures refer to the systematic steps or stages followed by researchers in conducting a study. A good research process includes the selection of appropriate research methods, appropriate research design, and accurate execution and documentation. In this study, stages were carried out starting from the selection of materials for making concrete mixtures, testing materials, making concrete samples, analyzing data and determining conclusions from the results of data analysis [16], [17]. Quantitative research involves a series of systematic steps to collect, analyze, and interpret quantitative data. As a scientific research in order to be accountable, this research is divided into several stages which are clarified in the diagram below:



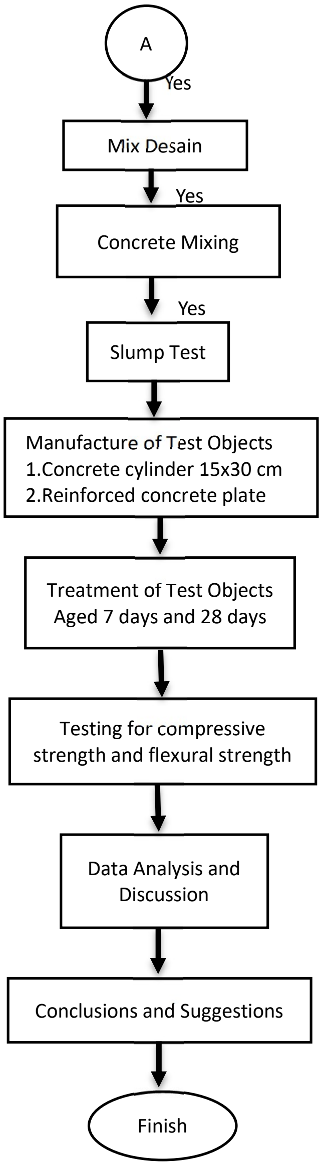


Figure 1. Research Flow Chart

3. RESULTS AND DISCUSSION

Before using aggregates as concrete mixtures, tests (gradation, moisture content, specific gravity and absorption, content weight, mud content, and wear) are carried out on fine and coarse aggregates and marble powder waste. This test was carried out to find out whether the aggregate used has met the predetermined requirements, so that the resulting concrete is in accordance with the planned concrete quality. The coarse aggregate used in this research is the natural coarse aggregate of Tunggul Wulung coral, Malang, while the fine aggregate used is sand from Lumajang, Malang Regency and marble powder waste used from Campur Darat, Tulungagung City.

3.1 Aggregate Inspection Results

The results of the coarse aggregate inspection that has been carried out can be seen in Table 1. It can be concluded from the table that the coarse aggregate, fine aggregate and waste marble powder used in the concrete mix, are qualified.

Table 1. Recapitulation of Aggregate Inspection

Fine Aggregate				
Testing Type	**Standard**	**Terms**	**Test Results**	**Remarks**
Gradation Test	1,5-3,8	SNI 03 1968-1990	2,72	Fulfilled
Moisture Content Test	< 5%	SNI 03-1971-1990	4,35%	Fulfilled
Mud Content Test	≤ 7,0	SNI 03-4142-1996	0,01	Fulfilled
Bulk Specific Weight Test	≥ 2,5	SNI 03-1970-2008	2,38	Fulfilled
Apparent specific gravity	≥ 2,5	SNI 03-1970-2008	2,76	Fulfilled
SSD specific gravity	≥ 2,5	SNI 03-1970-2008	2,52	Fulfilled
Absorption	≤ 3,0%	SNI 03-1970-2008	0,06%	Fulfilled
Content weight test	≥ 1,4	SNI 03-4804-1998	1,59	Fulfilled
Coarse Aggregate				
Testing Type	**Standard**	**Terms**	**Test Results**	**Remarks**
Gradation Test	6,0-7,1	SNI 03-1968-1990	6,21	Fulfilled
Moisture Content Test	< 5%	SNI 03-1971-1990	4,08%	Fulfilled
Mud Content Test	≤ 1,0	SNI 03-4142-1996	0,01	Fulfilled
Bulk Specific Weight Test	≥ 2,5	SNI 03-1968-2008	2,46	Fulfilled
Apparent specific gravity	≥ 2,5	SNI 03-1968-2008	2,71	Fulfilled
SSD specific gravity	≥ 2,5	SNI 03-1968-2008	2,55	Fulfilled
Absorption	≤ 3 %	SNI 03-1969-2008	0,04	Fulfilled
Content weight test	≥ 1,4	SNI 03-4804-1998	1,64	Fulfilled
Gradation Test	≤ 40 %	SNI 2417-2008	26,88	Fulfilled
Waste Marble Powder				
Testing Type	**Standard**	**Terms**	**Test Results**	**Remarks**
Gradation Test	1,5-3,8	SNI 03-1968-1990	2,67	Fulfilled
Moisture Content Test	< 5%	SNI 03-1971-2011	3,32 %	Fulfilled
Mud Content Test	≤ 7,0	SNI 03-4142-1996	0,1	Fulfilled
Bulk Specific Weight Test	≥ 2,5	SNI 03-1970-2008	2,13	Fulfilled
Apparent specific gravity	≥ 2,5	SNI 03-1970-2008	3,41	Fulfilled
SSD specific gravity	≥ 2,5	SNI 03-1970-2008	2,51	Fulfilled
Absorption	≤ 3,0%	SNI 03-1970-2008	0,18	Fulfilled
Content weight test	≥ 1,4	SNI 03-4804-1998	1,45	Fulfilled

We are a large-scale manufacturer specializing in producing various mining machines including different types of sand and gravel equipment, milling equipment, mineral processing equipment and building materials equipment.

In previous studies with the same terms and conditions, the results of fine aggregate testing were for sieve analysis 3,16, specific gravity 2,52, absorption 1,50, content weight 2,05, mud content 2,79. The test results of coarse aggregate sieve analysis 7,07, specific gravity 2,55, absorption 2,89, content 1,51, mud content 0,73 and wear 19,23. And the test results of marble waste specific gravity 2,72, absorption 1,6, content weight 0,13. This can be explained because marble fractions have water absorption (1,6%), which is lower than natural crushed stone aggregate (2,89%), so it does not have an impact in the form of a decrease in slump value [18]. Based on research using marble waste as aggregate substitution on the compressive strength value of dry geopolymer concrete mortar based on lime fly ash, the results of aggregate testing include sieve analysis 3,0, specific gravity 2,75, absorption 1,62%, mud content 3,73, CaO content 94,95% [19]. When viewed from these results with the comparison of previous research using the same provisions, the aggregate test results that have been carried out have met the required standards.

3.2 Compressive Strength Testing Results

3.2.1 Compressive Strength Testing Results Age 7 Days

The detailed 7-day compressive strength test results can be seen in the following table:

Table 2. Compressive Strength Testing Results Age 7 Days

No. Object Test	Waste Marble Powder	Weight (kg)	Dimension T (mm)	Dimension D (mm)	Field Area (mm²)	Load Press (N)	Compressive Strength (7 days) (MPA)	Average (MPa)
BU 1	0%	12,34	300	150	17662,5	233900	13,24	13,06
BU 2		12,26	300	150	17662,5	205300	11,62	
BU 3		12,22	300	150	17662,5	253000	14,32	
BU 1	15%	12,37	300	150	17662,5	259900	14,71	13,98
BU 2		12,46	300	150	17662,5	271500	15,37	
BU 3		12,43	300	150	17662,5	209600	11,87	
BU 1	25%	12,41	300	150	17662,5	309300	17,51	15,99
BU 2		12,50	300	150	17662,5	305300	17,29	
BU 3		12,33	300	150	17662,5	232600	13,17	
BU 1	35%	12,32	300	150	17662,5	238300	13,49	14,10
BU 2		12,36	300	150	17662,5	274500	15,54	
BU 3		12,44	300	150	17662,5	234300	13,27	

Based on Table 2 above, the results of the compressive strength test using marble powder waste as a substitute for fine aggregate in rigid pavement with variations of 0%, 15%, 25%, and 35% where each variation consists of three test specimens. The compressive strength was tested at 7 days and 28 days, with a planned concrete quality of fc' 21,7 MPa. The specimens were 15x30cm in size. The average results of the compressive strength test at 7 days were 0% (13,06 MPa), 15% (13,98 MPa), 25% (15,99 MPa), and 35% (14,10 MPa).

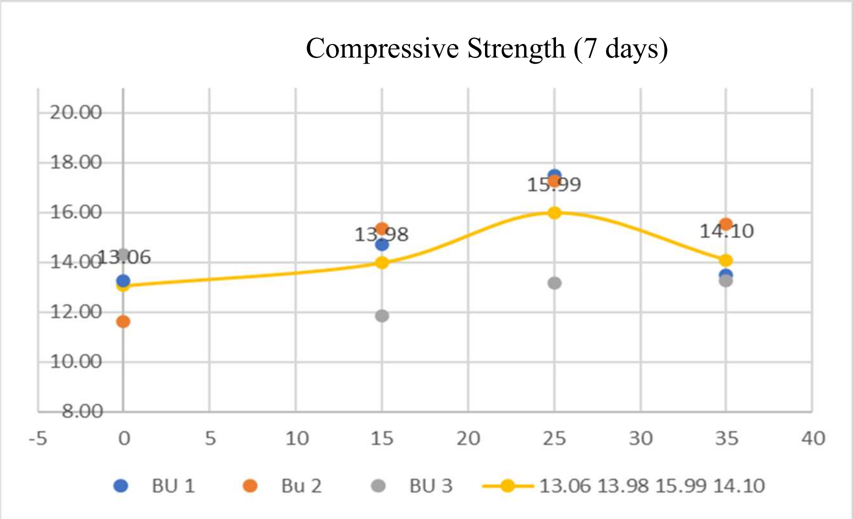


Figure 2. Compressive Strength Chart (7 Days)

Based on the above results, it can be seen the comparison of the compressive strength value of concrete using marble stone cutting waste as a substitute for fine aggregate with variations of 0%, 25%, 50%, 75% and 100%. The maximum compressive strength value is 26,92 MPa at a percentage of 75%. Meanwhile, when viewed from the results of the concrete compressive strength test with the addition of marble sawing waste, the maximum concrete compressive strength value is at a percentage of 5%, namely 26,46 MPa and the minimum is at a percentage of 15%, namely 19,32 MPa. This test is based on SNI 1974: 2011. With the addition of too much marble sawdust waste can reduce the strength of concrete. The addition of marble sawdust waste as a fine aggregate substitution can be seen that the compressive strength value at the age of 7 days with a percentage of 0%, 15%, 25%, 35% has not met the required compressive strength. However, with the addition of marble powder waste, the compressive strength of concrete has increased when compared to normal concrete and the maximum value at the age of 7 days is at a percentage of 15% (15,99 MPa) and the minimum is at a percentage of 35% (15,67).

In previous studies where the compressive strength of concrete using marble stone cutting waste as a substitute for fine aggregate with variations of 0%, 25%, 50%, 75% and 100%. The compressive strength was tested at the age of 7 days with a concrete quality of fc' 24 MPa. The results of 0% concrete compressive strength (19,55 MPa), 25% (26,19 MPa), 50% (27,3 MPa), 75% (26,92 MPa), and 100% (16,97 MPa) [20]. Concrete compressive strength test using marble powder waste as a substitute for cement tested at the age of 7 and 14 days, at 28 days compressive strength value obtained from the conversion of test objects. The compressive strength at each variation of 0%, 5%, 10%, and 15% is 25,41 MPa, 26,46 MPa, 22,63 MPa, and 19,32 MPa [21].

3.2.2 Compressive Strength Testing Results Age 28 Days

The detailed 28-day compressive strength test results can be seen in the following table:

Table 3. Compressive Strength Testing Results Age 28 Days

No. Object Test	Waste Marble Powder	Weight (kg)	Dimension T (mm)	Dimension D (mm)	Field Area (mm²)	Load Press (N)	Compressive Strength (7 days) (MPA)	Average (MPa)
BU 1	0%	12,94	300	150	17662,5	354800	20,09	22,00
BU 2		13,08	300	150	17662,5	422600	23,93	
BU 3		12,78	300	150	17662,5	388100	21,97	
BU 1	15%	12,58	300	150	17662,5	430500	24,37	23,79
BU 2		12,78	300	150	17662,5	369900	20,94	

BU 3		12,65	300	150	17662,5	460100	26,05	
BU 1		12,37	300	150	17662,5	307600	17,42	
BU 2	25%	12,48	300	150	17662,5	328400	18,59	16,97
BU 3		12,48	300	150	17662,5	263000	14,89	
BU 1		12,40	300	150	17662,5	312900	17,72	
BU 2	35%	12,28	300	150	17662,5	222800	12,61	15,67
BU 3		12,27	300	150	17662,5	294700	16,69	

Based on Table 3, the compressive strength test using marble powder waste as a substitute for fine aggregate in rigid pavement with variations of 0%, 15%, 25%, and 35%. The compressive strength was tested at 7 days and 28 days, with a planned concrete quality of fc' 21,7 MPa. The test specimens were 15x30cm in size. The results of the compressive strength test at the age of 28 days are 0% (22,00 MPa), 15% (23,79 MPa), 25% (16,97 MPa) and 35% (15,67 MPa).

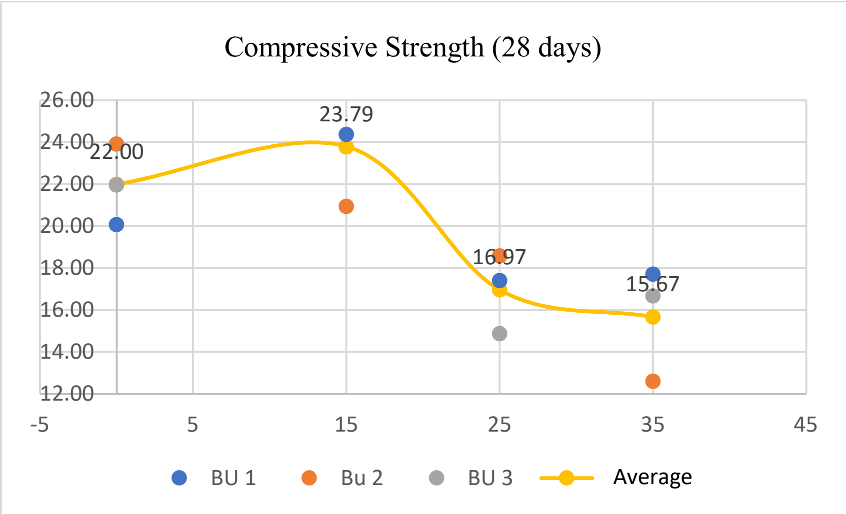


Figure 3. Compressive Strength Chart (28 Days)

In previous research with a review of the compressive strength value of concrete mixtures with the use of marble waste as a substitute for cement with variations of 3%, 8%, and 12%. The compressive strength test results were 3% (9,88 MPa), 8% (14,44 MPa), and 12% (15,43 MPa). This shows that the greater the amount of marble powder used, the less density and pores [22]. Compressive strength test with the utilization of marble waste as a partial replacement of coarse aggregate with variations of 0%, 15%, 25%, and 35% tested at the age of 28 days. The results of the compressive strength test, namely the 0% variation is 31,94 MPa, in concrete with 15% variation is 32,77 MPa, and in concrete with 25% variation is 33,22 MPa, and 35% is 32,64 MPa [23].

Based on the results of the compressive strength test using marble powder waste as a substitute for fine aggregate in rigid pavement with variations of 0%, 15%, 25%, and 35%. The compressive strength was tested at the age of 7 days and 28 days, with a planned concrete quality of fc' 21,7 MPa. The test specimens were 15x30cm in size. The results of the compressive strength test at the age of 28 days are 0% (22,00 MPa), 15% (23,79 MPa), 25% (16,97 MPa), and 35% (15,67 MPa).

It can be concluded that the compressive strength value of compressive concrete utilizing marble waste as a substitute for cement with variations of 3%, 8%, and 12% has the maximum value at a percentage of 12%, namely 15,43 MPa and the minimum at a percentage of 3%, namely 9,88 MPa. Meanwhile, when looking at the compressive strength value with the use of marble waste as a partial substitute for coarse aggregates with variations of 0%, 15%, 25%, and 35%, the maximum value is at 25% percentage of 33,22 MPa and the minimum at 0% percentage of 31,94 MPa. This test uses

SNI 1947-2011 regulations on how to test the compressive strength of concrete with cylindrical test objects. And with the addition of marble powder waste as a fine aggregate substitution, the highest compressive strength value is at a percentage of 15% (23,79 MPa) and the lowest at a percentage of 35% (15,67 MPa). From these results it can be seen that the higher the percentage of waste, the compressive strength of concrete decreases.

3.3 Flexural Strength Testing Results

Flexural strength testing using reinforced concrete plates is carried out to determine deflection and compressive load with marble powder waste as a fine aggregate substitution. The test object used is a reinforced concrete plate with a size of 12 cm x 50 cm x 120 cm with 1 test object for each variation. The following are the results of testing the relationship between load and deflection that occurs in each variation of reinforced concrete plate specimens. Table of combined load and deflection test results with 0%, 15%, 15%, and 35% waste variations.

Table 4. Deflection Test Results of reinforced concrete slab

No	Load	Variation of Powder Waste Deflection (mm)				Average
		0%	15%	25%	35%	
1	0	0.00	0.00	0.00	0.00	0.00
2	100	0.02	0.02	0.04	0.01	0.02
3	200	0.12	0.04	0.07	0.02	0.06
4	300	0.16	0.07	0.11	0.05	0.10
5	400	0.24	0.08	0.13	0.08	0.13
6	500	0.25	0.09	0.17	0.11	0.16
7	600	0.32	0.11	0.21	0.13	0.19
8	700	0.39	0.13	0.29	0.17	0.25
9	800	0.41	0.14	0.33	0.21	0.27
10	900	0.42	0.16	0.47	0.28	0.33
11	1000	0.46	0.18	0.53	0.34	0.38
12	1100	0.52	0.21	0.55	0.36	0.41
13	1200	0.58	0.23	0.59	0.44	0.46
14	1300	0.64	0.24	0.64	0.86	0.60
15	1400	0.67	0.26	0.67	0.94	0.64
16	1500	0.69	0.29	0.71	1.02	0.68
17	1600	0.71	0.31	0.75	1.12	0.72
18	1700	0.76	0.33	0.81	1.29	0.80
19	1800	0.77	0.35	0.85	1.39	0.84
20	1900	0.81	0.39	0.93	1.66	0.95
21	2000	0.87	0.54	0.97	2.15	1.13
22	2100	0.95	1.15	1.02	2.36	1.37
23	2200	0.97	1.27	1.11	2.63	1.50
24	2300	0.99	1.36	1.15	3.13	1.66
25	2400	1.03	1.39	1.25	3.49	1.79
26	2500	1.06	1.48	1.56	5.37	2.37
27	2600	1.08	1.59	1.65		1.44
28	2700	1.12	2.15	1.74		1.67
29	2800	1.24	2.22	1.85		1.77
30	2900	1.43	2.31	1.93		1.89
31	3000	1.79	2.65	2.11		2.18
32	3100	1.89	3.34	2.21		2.48

33	3200	2.04	3.49	2.28		2.60
34	3300	2.12		2.39		2.26
35	3400	2.13		2.49		2.31
36	3500	2.14		2.64		2.39
37	3600	2.16		2.84		2.50
38	3700	2.18		3.21		2.70
39	3800	2.22		3.55		2.89
40	3900	2.24		5.37		3.81
41	4000	2.31		6.21		4.26
42	4100	2.43				2.43
43	4200	2.66				2.66
44	4300	3.93				3.93

Based on the results of the flexural strength test using marble powder waste as a substitute for fine aggregate in rigid pavement with variations of 0%, 15%, 25%, and 35%. Flexural strength was tested at 28 days of age, with a planned concrete quality of fc' 21,7 MPa. The test specimens were 12x50x120cm in size. From the test results, the maximum load on each specimen was 0% (4300 kg), 15% (3200 kg), 25% (4000 kg), and 35% (2500 kg). The deflection that occurs in each test specimen with variations of 0% (3,93 mm), 15% (3,49 mm), 25% (6,21 mm), 35% (5,37mm).

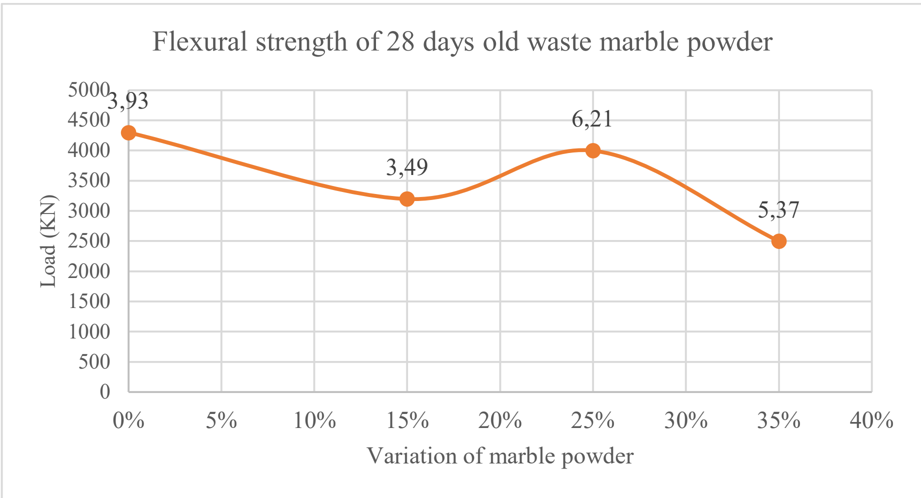


Figure 4. Flexural Strength Chart

In this description, it can be explained that when viewed from the results of the flexural strength value of concrete using marble waste as a substitute for binders where the limit load which is the maximum load that can be received by the beam and dial indicator does not increase anymore. The maximum deflection is reached when the load no longer increases. It is known that the 20% beam has the smallest deflection of the others. This means that the more powder content causes the concrete to be more brittle and quickly broken. At a deflection of 3,61mm the beam was no longer able to accept additional load. This is due to the increasing amount of lime content in the concrete mix. Meanwhile, the maximum value for the flexural strength of concrete with the addition of marble fractions and silica fume as a substitute material in the concrete mixture for the flexural strength value of concrete with variations of 0%, 10%, 12.5%, and 15% is 2,66 at a percentage of 10%. And with the addition of marble powder waste, the largest deflection occurs at a percentage of 25%, namely 6,21mm and the minimum at a percentage of 15% (3,49mm). And at 25% the concrete plate is able to withstand a high load of 4000 kg. While at 35% the concrete plate is only able to withstand a load limit of 2500 kg, this shows that the more the use of marble powder in the mixture on the implementation of its specific gravity, it has the ability to withstand increasingly smaller loads.

In previous research with a review of the flexural strength value of concrete using marble waste as a substitute for binders with variations of 0%, 5%, 10%, 15%, and 20%. Flexural strength was tested at the age of 28 days, with the concrete quality used fc' 8,3 MPa. The test specimens used were 10x15x120cm in size. From the test results, the maximum limit load was obtained for each behavior of 0% (2300 kg), 5% (2125 kg), 10% (2042 kg), 15% (1875 kg) and 20% (1750 kg). The deflection that occurs in each test specimen with variations of 0% (5,88 mm), 5% (5,10 mm), 10% (4,31 mm), 15% (3,86 mm), and 20% (3,61 mm) [24]. From the results of research with the addition of marble fractions and silica fume as a substitute material in the concrete mixture for the value of the flexural strength of concrete with variations of 0%, 10%, 12.5%, and 15% tested at the age of 28 days. The results of the flexural strength test 0% (2,61), 10% (2,66), 12,5% (2,54) and 15% (2,44) [25].

4. CONCLUSION

The maximum compressive strength of concrete using marble powder waste as a substitute for fine aggregate in rigid pavements with variations of 0%, 15%, 25%, and 35% tested at age 7 is at a percentage of 25%, namely 15,99 MPa and the minimum at a percentage of 0%, namely 13,06 MPa. And the maximum compressive strength value of concrete at the age of 28 is 15% percentage (23,79 MPa) and the minimum at 35% percentage (15.67Mpa).

The flexural strength value by using marble powder waste as a substitute for fine aggregate in rigid pavement with variations of 0%, 15%, 25%, and 35% and tested at the age of 28 days, with the quality of test specimens measuring 12x50x120cm with the maximum compressive load is at 0% normal concrete (4300 kg) while the maximum deflection occurs in the 25% variation which is 6,21mm.

ACKNOWLEDGEMENT

From the results of this study there are several suggestions to be used as guidelines / to be used as reference material for further researchers. The suggestions are as follows:
1. Conduct soaking with concrete age more than 7 days to get the optimum compressive strength value of concrete.
2. For further researchers it is advisable to correct or observe the shortcomings or advantages of this paper, so that it is used as a guideline for future researchers.

REFERENCES

[1] A. S. Andreani, T. H. V R., B. F. Seki, And N. Farrah, "The Impact Of Waste Marble Powder As A Partial Alternative Material For Cement," *J. Sains Mater. Indones.*, Vol. 26, No. 1, Pp. 81–91, 2024, Doi: 10.55981/Jsmi.2024.4569.

[2] F. Juwita, D. Nurafni, S. Subekti, C. Sujatmiko, And M. A. Silova, "Evaluasi Tebal Perkerasan Kaku Pada Jalan Provinsi Berdasarkan Manual Desain Perkerasan (Mdp) 2017 (Studi Kasus : Ruas Jalan Padang Ratu - Kalirejo)," *Tek. Sains J. Ilmu Tek.*, Vol. 8, No. 1, Pp. 30–43, 2023, Doi: Https://Doi.Org/10.24967/Teksis.V8i1.2137.

[3] R. Ardiansyah And T. Sudibyo, "Analisis Perencanaan Tebal Perkerasan Kaku Lajur Pengganti Pada Proyek Pembangunan Jalan Tol Jakarta-Cikampek Ii Elevated," *J. Tek. Sipil Dan Lingkung.*, Vol. 5, No. 1, Pp. 17–30, 2020, Doi: Https://Doi.Org/10.29244/Jsil.5.1.17-30.

[4] E. A. Khan *Et Al.*, "Utilization Of Waste Marble Powder As Partial Replacement Of Cement In Engineered Cementitious Composite," *Cogent Eng.*, Vol. 10, No. 1, P. 2243749, 2023, Doi: 10.1080/23311916.2023.2243749.

[5] Y. O. Özkılıç *Et Al.*, "Optimum Usage Of Waste Marble Powder To Reduce Use Of Cement Toward Eco-Friendly Concrete," *J. Mater. Res. Technol.*, Vol. 25, Pp. 4799–4819, 2023, Doi: Https://Doi.Org/10.1016/J.Jmrt.2023.06.126.

[6] B. Oktaviastuti, G. D. Pandulu, And E. Lusyana, "Kuat Tekan Beton Geopolymer Berbahan

Dasar Abu Terbang (Fly Ash) Sebagai Alternatif Perkerasan Kaku Di Daerah Pesisir," *Reka Buana J. Ilm. Tek. Sipil Dan Tek. Kim.*, Vol. 6, No. 1, Pp. 78–87, 2021, Doi: Https://Doi.Org/10.33366/Rekabua Na.V6i1.2271.
[7] B. Oktaviastuti, A. Leliana, And P. D. Rahma, "Beton Geopolimer Sebagai Alternatif Perkerasan Kaku (Rigid Pavement) Ramah Lingkungan," Vol. 2, No. 1999, Pp. 1–5, 2019, [Online]. Available: Https://Pro.Unitri.Ac.Id/Index.Php/Sentikuin/Article/View/151.
[8] B. Oktaviastuti And Yurnalisdel, "Studi Kuat Tekan Beton Geopolymer Dengan Fly Ash Sebagai Perkerasan Kaku Di Pesisir Pantai," *J. Fondasi*, Vol. 9, No. 2, Pp. 201–214, 2020, [Online]. Available: Https://Jurnal.Untirta.Ac.Id/Index.Php/Jft/Article/View/8515/6509.
[9] Y. Rusdianto And M. Munir, "Penggunaan Limbah Marmer Sebagai Filler Terhadap Absorbsi, Kuat Tekan Dan Modulus Elastisitaas Pada Beton," *Media Tek. Sipil*, Vol. 13, No. 1, Pp. 99–108, 2015, Doi: Https://Doi.Org/10.22219/Jmts.V13i1.2549.
[10] A. Gecong, B. Dharmawan, And A. Novraji, "Pengaruh Limbah Marmer Sebagai Filler Pada Campuran Beton Aspal Terhadap Pengujian Modulus Resilien," *J. Tek. Sipil Macca*, Vol. 4, Pp. 125–137, 2019, Doi: 10.33096/Jtsm.V4i2.368.
[11] A. Amal And W. Saputra, "Pemanfaatan Limbah Abu Marmer Sebagai Filler Terhadap Karakteristik Marshall Pada Campuran Lapis Tipis Aspal Pasir (Latasir) B," *J. Media Tek. Sipil*, Vol. 16, 2019, Doi: 10.22219/Jmts.V16i2.6744.
[12] N. M. Sugita, "Tentang Desa Besole Yang Bikin Tulungagung Dijuluki Kota Marmer," *Detikjatim.Com*, Nov. 2023.
[13] R. Nastalia, A. Naibaho, And S. Riyanto, "Analisis Kuat Tekan Dan Tarik Beton Normal Menggunakan Serbuk Limbah Gergaji Marmer Sebagai Substitusi Semen," *J. Online Skripsi Manaj. Rekayasa Konstr.*, Vol. 4, No. 1, Pp. 160–165, 2023, Doi: Https://Doi.Org/10.33795/Josmrk.V4i1.1202.
[14] L. Asif And W. Malik, "Effect Of Marble Powder On Concrete: A Review," In *2nd International Conference On Engineering, Natural And Social Sciences (Icensos)*, 2023, Pp. 166–171, [Online]. Available: Https://Www.Icensos.Com/.
[15] C. Aditya, D. Irawan, And S. Silviana, "Implementation Of Marble Waste As Aggregate Material Rigid Pavement," *Eureka Phys. Eng.*, No. 4, Pp. 76–88, 2021, Doi: 10.21303/2461-4262.2021.001932.
[16] Sugiyono, *Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif, Dan R&D*. Bandung, 2019.
[17] J. W. Creswell, *Research Design: Pendekatan Metode Kualitatif, Kuantitatif, Dan Campuran*. Yogyakarta: Pustaka Pelajar, 2016.
[18] M. Y. E. S. Hartanto Dwi, Hasanuddin Akhmad, "Pemanfaatan Limbah Batu Marmer Sebagai Agregat Kasar Pada Campuran Beton Perkerasan Kaku Yang Menggunakan Bahan Tambah Abu Sekam Padi," *Reka Buana*, Vol. 7, Pp. 1–16, 2022.
[19] D. D. K. Wijayanti And A. Wardhono, "Pengaruh Subtitusi Limbah Marmer Terhadap Nilai Kuat Tekan Dry Geopolymer Mortar Metode Wet Mixing Berbahan Dasar Abu Terbang Dan Naoh 12 M," *Rekats Rekayasa Tek. Sipil Univ. Negeri Surabaya*, Vol. 9, No. 2, 2021, [Online]. Https://Ejournal.Unesa.Ac.Id/Index.Php/Rekayasa-Teknik-Sipil/Article/View/39021.
[20] D. Fitriani, R. D. Kusdian, And B. A. Bakar, "Kajian Kuat Tekan Beton Substitusi Agregat Halus Dari Limbah Pemotongan Batu Marmer Dan Agregat Kasar Dari Limbah Pemotongan Batu Kapur," *Simteks Sist. Infrastruktur Tek. Sipil*, Vol. 1, No. 1, Pp. 89–98, 2021, Doi: Https://Doi.Org/10.32897/Simteks.V1i1.808.
[21] A. Safari And A. A. Setiawan, "Pemanfaatan Limbah Batu Marmer Sebagai Substitusi Parsial Agregat Kasar Pada Campuran Beton Terhadap Kuat Tekan Beton," *J. Ilm. Din. Rekayasa*, Vol. 19, No. 2, Pp. 141–146, 2023, Doi: Http://Dx.Doi.Org/10.20884/1.Dr.2023.19.2.1498.
[22] Budianto, Dedi Cahyono, And Johan, "Pengaruh Pemanfaatan Limbah Marmer Sebagai Subtitusi Semen The Effect Of Utilization Of Marble Waste As Subtitution Of Cement In Mixed Paving Block With 3 %, 8 % And 12 % Percentage," Pp. 3–5.
[23] A. D. Lestari, "Pengujian Kuat Tekan Pada Beton Dengan Limbah Marmer Sebagai Subtitusi

Agregat Kasar," *Reka Buana J. Ilm. Tek. Sipil Dan Tek. Kim.*, Vol. 6, No. 1, Pp. 61–69, 2021, Doi: Https://Doi.Org/10.33366/Rekabuana.V6i1.2263.

[24] A. Abrori And D. B. Fariadi, "Studi Penelitian Pengaruh Penggunaan Limbah Marble Sebagai Pengganti Bahan Pengikat Terhadap Kuat Lentur Beton," *Semin. Keinsinyuran Progr. Stud. Progr. Profesi Ins.*, Pp. 681–689, 2021, Doi: 10.22219/Skpsppi.V2i1.4374.

[25] J. E. Mercy, F. Phengkarsa, And S. R. Tonapa, "Pengaruh Silica Fume Dan Pecahan Batu Marmer Sebagai Bahan Subtitusi Pada Campuran Beton," *Paulus Civ. Eng. J.*, Vol. 5, No. 1, Pp. 29–39, 2024, [Online]. Https://Ojs.Ukipaulus.Ac.Id/Index.Php/Pcej/Article/View/67.