International Journal of Multidisciplinary Research and Publications
ISSN (Online): 2581-6187

Addition of Eggshell Powder and Silica Fume to the Compressive Strength of Normal Concrete

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Abstract— *Nowadays, the need for concrete as a construction material is increasing rapidly. This requires innovation in the materials that make up concrete to reduce negative environmental impacts, including by using waste as concrete mixtures. In this research, compressive strength testing was carried out on concrete with a planned f'c of 25 MPa which was added with eggshell powder and silica fume. The addition of eggshell was 2%, 4%, 6%, and 8% of the weight of cement and the addition of silica fume was 5%, 10%, and 15% of the weight of cement. The results of the research show that concrete with the addition of 2% eggshell produces a maximum compressive strength of 24,168 MPa. Meanwhile, concrete with the addition of 2% eggshell and 5% silica fume produces a maximum compressive strength of 14,624 MPa. The higher the percentage of added eggshells and silica fume, the lower the compressive strength of the concrete.*

Keywords— *Concrete compressive strength, Eggshell, Silica Fume*

I. INTRODUCTION

According to data from the Indonesian Central Statistics Agency in 2022, egg production from laying hens in Indonesia is increasing every year. In 2020 egg production was 5,141,870 tons, in 2021 it was 5,155,997.65 tons and in 2022 it was 5,566,339.44 tons. Chicken eggshells that wrap eggs generally weigh 9-12% of the total egg weight, meaning that almost 600 thousand tons of eggshell waste are produced every year in Indonesia. This large amount of eggshell waste constitutes pollution and has a bad impact on the environment, causes an unpleasant odor and can attract pests and diseases. For this reason, efforts are needed to utilize eggshell, especially for concrete mixtures.

Research on the use of eggshell as a concrete mixture has been widely carried out. One of them is research by Klau, A. S, et al (2021) regarding the use of eggshell waste as a substitute for cement in 25 MPa quality concrete. By varying the eggshell percentage of 0%, 4%, 6%, and 8% of the cement weight, the concrete compressive strength values were respectively 27,351 MPa, 25,842 MPa, 23,201 MPa, and 21,504 MPa. Thus, it was found that eggshell cause the quality of concrete to decrease and the higher the percentage of eggshell, the lower the quality of the concrete produced.

In order to improve the quality, silica fume can be added to the mixture of concrete and eggshell. Parthasarathi, N. et al (2017) conducted research by substituting 5%, 10% and 15% eggshell powder and 2.5%, 5% and 7.5% silica fume of the cement weight. The results obtained showed that the strength of concrete increased with the addition of eggshell powder and silica fume.

Based on this, in this research, concrete was tested with a mixture of eggshell and silica fume, but not by substitution but by adding eggshell and silica fume based on the percentage of cement weight.

II. LITERATURE REVIEW

Concrete is a mixture of Portland cement or other hydraulic cement, fine aggregate, coarse aggregate and water, with or without additives to form a solid mass (SNI 03-2834-2000). Concrete is a construction material that is commonly used for buildings, bridges, roads, and so on.

Making concrete is actually not just about mixing the basic ingredients to form a plastic mixture as is often seen in making simple buildings. However, if good concrete is about to make, for the context of meeting stricter requirements because of higher demands, one of the things that need to be considered carefully is ways to obtain a good fresh concrete mix and produce good hard concrete too. Good hard concrete is concrete that is strong, durable, waterproof, wear-resistant, and has small swelling and shrinkage (Tjokrodimulyo K, 1995).

Concrete Composing Material

a. Aggregate

According to SNI 03-2847-2002, the definition of aggregate is granular material, for example sand, gravel, crushed stone, and dry crust, which is used together with a binding medium to form concrete or hydraulic cement mortar.

b. Cement

The function of cement is to bind the aggregate grains to form a solid mass and fill the air spaces between the aggregate grains. The basic ingredients of Portland cement consist of ingredients containing lime, silica, aluminum and iron oxidation.

c. Water

According to SNI 03-2847-2002, water that can be used in the concrete mixing process is mentioned as follows:

1. The water used in the concrete mixture must be clean and free from damaging materials containing oil, acid, alkali, salt, organic materials, or other materials that are detrimental to the concrete or reinforcement.
2. Mixing water used in prestressed concrete or concrete embedded in aluminum metal, including free water contained in aggregates, must not contain dangerous amounts of chloride ions.
3. Non-potable water should not be used on concrete mixture.

d. Eggshell

The chicken eggshell that encloses the egg generally weighs 9-12% of the total egg weight. Eggshell powder is a powder produced from the process of pounding shells that

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pass sieve No. 200. Eggshell powder contains several of the same compounds as Portland cement. These compounds are magnesium, iron and calcium carbonate.

e. Silica Fume

According to the standard "Specification for Silica fume for Use in Hydraulic Cement Concrete and Mortar" (ASTM.C.1240,1995: 637-642), silica fume is a fine pozzolan material, where the composition is mostly produced from blast furnaces or silicon production waste or silicon iron alloy (known as a combination of micro silica and silica fume). The use of silica fume in concrete mixtures is used to produce concrete with high strength.

Concrete Mix Design

The concrete mix design refers to SNI 03-2834-2000 concerning procedures for making normal concrete mix plans. Normal concrete is concrete that has a bulk density of (2200 – 2500) kg/m3 using crushed natural aggregates.

Concrete Compressive Strength Testing

Concrete compressive strength is the amount of load per unit area that causes the concrete specimen to crumble when loaded with a certain compressive force produced by a compression testing machine (SNI 03-1974-1920). The concrete compressive strength is obtained by using a cylindrical specimen with a diameter of 10 cm and a height of 20 cm which is pressed on a circular side. The compressive strength of the test object can be calculated using the formula:

$$f'c = P/A$$

Description :

f'c = Concrete compressive strength (MPa)
P = Compressive load (N)
A = Cross-sectional area of the test object (mm^2)

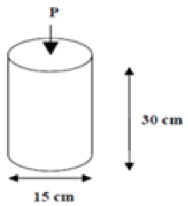

Figure 1. Test object of concrete compressive strength

III. RESEARCH METHODOLOGY

The materials used in this research were Tiga Roda brand PCC cement, aggregate from Palu, crushed chicken eggshell (passed sieve no. 200) and silica fume from PT. Sika Indonesia. The test object used a concrete cylinder with a diameter of 10 cm and a height of 10 cm and was tested at the age of 28 days.

The aggregate will be tested first to find out whether it complies with the SNI requirements. Aggregate testing includes measuring air content, sieve analysis, specific gravity and aggregate absorption as well as testing bulk density and air voids in aggregate. If it is appropriate, then we proceed with making concrete test specimens, curing the concrete and testing the compressive strength of the concrete.

Making test objects is carried out in 2 stages. Stage 1 makes normal concrete (0% eggshell) and concrete with the addition of eggshell as much as 2%, 4%, 6% and 8% of the cement weight. After obtaining the percentage of eggshell that produces maximum compressive strength, a test object is made by adding eggshell and silica fume. The addition of silica fume is 5%, 10% and 15% of the cement weight.

TABLE 1. Number of Phase 1 Test Objects

Test	Eggshell Powder (%)	Test Object (amount)
Compressive strength	0	5
	2	5
	4	5
	6	5
	8	5
Total		25

TABLE 2. Number of Phase 2 Test Objects

Test	Eggshell Powder (%)	Silica Fume (%)	Test Object (amount)
Compressive Strength	x	5%	5
	x	10%	5
	x	15%	5
Total			15

IV. RESEARCH RESULTS AND EXPLANATION

Compressive strength testing was carried out in 28 days of concrete. The results of testing the concrete compressive strength with the addition of eggshells are as follows:

TABLE 3. Results of concrete compressive strength with the addition of eggshell

Concrete	Age	Diameter	Height	Cross-sectional area	Volume	Weight	Bacaan Dial	Compressive strength	Correction factor	Conversion		Average compressive strength		(x̄-x)²		(x̄-x)³		Standard deviation	Skewness	fc' (Mpa)
	Days	(cm)	(cm)	cm²	(cm)³	Kg	KN	Mpa		Shape	Days	Mpa	Average		Total		Total			
SCT0%	28	10	20	78.5	1570.80	4.2	170	21.656	1.04	0.83	1	27.135	26.178	0.917	3.057	-0.878	-0.976	0.874	0.472526	25.76446
		10	20	78.5	1570.80	4.2	170	21.656	1.04	0.83	1	27.135		0.917		-0.878				
		10	20	78.5	1570.80	4.2	160	20.382	1.04	0.83	1	25.539		0.408		0.260				
		10	20	78.5	1570.80	4.2	160	20.382	1.04	0.83	1	25.539		0.408		0.260				
		10	20	78.5	1570.80	4.2	160	20.382	1.04	0.83	1	25.539		0.408		0.260				
SCT2%	28	10	20	78.5	1570.80	4.2	160	20.382	1.04	0.83	1	25.539	24.581	0.917	3.057	-0.878	-0.976	0.874	0.472526	24.16827
		10	20	78.5	1570.80	4.2	160	20.382	1.04	0.83	1	25.539		0.917		-0.878				
		10	20	78.5	1570.80	4.2	150	19.108	1.04	0.83	1	23.943		0.408		0.260				
		10	20	78.5	1570.80	4.2	150	19.108	1.04	0.83	1	23.943		0.408		0.260				
		10	20	78.5	1570.80	4.2	150	19.108	1.04	0.83	1	23.943		0.408		0.260				
SCT4%	28	10	20	78.5	1570.80	4.2	150	19.108	1.04	0.83	1	23.943	22.985	0.917	3.057	-0.878	-0.976	0.874	0.472526	22.57207
		10	20	78.5	1570.80	4.2	140	17.834	1.04	0.83	1	22.347		0.408		0.260				
		10	20	78.5	1570.80	4.2	150	19.108	1.04	0.83	1	23.943		0.917		-0.878				
		10	20	78.5	1570.80	4.2	140	17.834	1.04	0.83	1	22.347		0.408		0.260				
		10	20	78.5	1570.80	4.2	140	17.834	1.04	0.83	1	22.347		0.408		0.260				
SCT6%	28	10	20	78.5	1570.80	4.1	130	16.561	1.04	0.83	1	20.751	21.070	0.102	7.134	0.033	2.928	1.335	0.66220	20.1854
		10	20	78.5	1570.80	4.1	140	17.834	1.04	0.83	1	22.347		1.631		-2.082				
		10	20	78.5	1570.80	4.1	130	16.561	1.04	0.83	1	20.751		0.102		0.033				
		10	20	78.5	1570.80	4.1	120	15.287	1.04	0.83	1	19.154		3.669		7.027				
		10	20	78.5	1570.80	4.1	140	17.834	1.04	0.83	1	22.347		1.631		-2.082				
SCT8%	28	10	20	78.5	1570.80	4.1	130	16.561	1.04	0.83	1	20.751	18.197	6.522	18.344	-16.658	3.904	2.142	0.603835	16.90348
		10	20	78.5	1570.80	4.1	120	15.287	1.04	0.83	1	19.154		0.917		-0.878				
		10	20	78.5	1570.80	4.1	100	12.739	1.04	0.83	1	15.962		4.994		11.159				
		10	20	78.5	1570.80	4.1	120	15.287	1.04	0.83	1	19.154		0.917		-0.878				
		10	20	78.5	1570.80	4.1	100	12.739	1.04	0.83	1	15.962		4.994		11.159				

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Based on Table 3 above, the following graph shows the optimal concrete compressive strength at the age of 28 days:

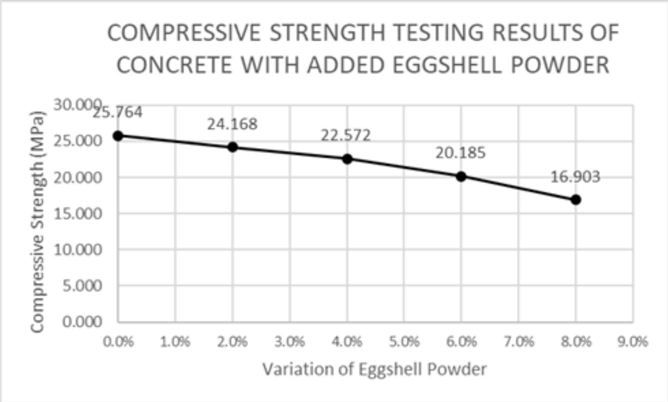

Figure 2. Graph of concrete compressive strength aged 28 days

Based on the graph above, it can be seen that the more eggshell added, the more the compressive strength of the concrete decreases. The addition of 2% eggshell produces the highest compressive strength, namely 24,168 MPa, but the value is still below the planned compressive strength of 25 MPa.

The results of testing the concrete compressive strength with the addition of eggshell and silica fume are as follows:

Based on the Table 4, a graph of the optimal concrete compressive strength at 28 days can be seen in the following graph:

Based on the graph above, it is found that the optimum concrete compressive strength value is 13,242 MPa, namely for concrete with the addition of 2% eggshell and 5% silica fume. From this graph it is also known that as the silica fume content increases in the concrete mixture, the compressive strength value of the concrete decreases. The optimum compressive strength is still far below the design compressive strength of 25 MPa.

TABLE 4. Results of concrete compressive strength with the addition of eggshell + silica fume

Concrete	Age	Diameter	Height	Cross-sectional area	Volume	Weight	Dial reading	Compressive strength	Correction factor	Conversion		Average compressive	
	Days	(cm)	(cm)	cm²	(cm)³	Kg	KN	Mpa		Shape	Days	Mpa	Average
SCT2% & SF5%	28	10	20	78.5	1570.80	4.2	80	10.186	1.04	0.83	1	12.763	13.242
		10	20	78.5	1570.80	4.2	86	10.950	1.04	0.83	1	13.720	
		10	20	78.5	1570.80	4.2	83	10.568	1.04	0.83	1	13.242	
		10	20	78.5	1570.80	4.2	91	11.586	1.04	0.83	1	14.518	
		10	20	78.5	1570.80	4.2	75	9.549	1.04	0.83	1	11.965	
SCT2% & SF10%	28	10	20	78.5	1570.80	4.2	70	8.913	1.04	0.83	1	11.168	12.891
		10	20	78.5	1570.80	4.2	83	10.568	1.04	0.83	1	13.242	
		10	20	78.5	1570.80	4.2	90	11.459	1.04	0.83	1	14.358	
		10	20	78.5	1570.80	4.2	75	9.549	1.04	0.83	1	11.965	
		10	20	78.5	1570.80	4.2	86	10.950	1.04	0.83	1	13.720	
SCT2% & SF15%	28	10	20	78.5	1570.80	4.35	45	5.730	1.04	0.83	1	7.179	4.627
		10	20	78.5	1570.80	4.32	30	3.820	1.04	0.83	1	4.786	
		10	20	78.5	1570.80	4.25	25	3.183	1.04	0.83	1	3.988	
		10	20	78.5	1570.80	4.25	20	2.546	1.04	0.83	1	3.191	
		10	20	78.5	1570.80	4.27	25	3.183	1.04	0.83	1	3.988	

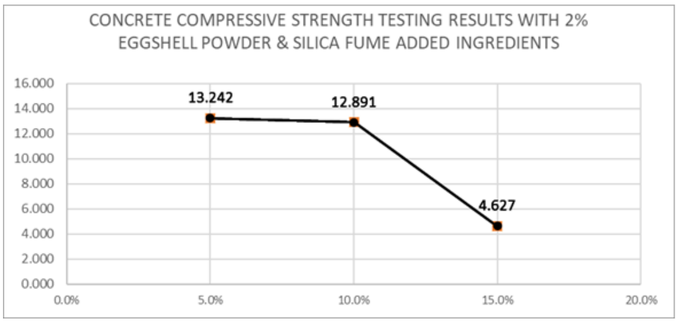

Figure 3. Graph of concrete compressive strength aged 28 days

V. Conclusion And Recommendations

A. *Conclusion*

From this research of concrete with the addition of eggshell powder and silica fume, it can be concluded that:

1. The addition of eggshell and silica fume to the concrete mixture cannot increase the concrete compressive strength. The concrete compressive strength with a mixture of eggshell and silica fume does not exceed the design concrete compressive strength f'c = 25 MPa.
2. The addition of 2% eggshell to concrete produces a maximum compressive strength of 24,168 MPa. The addition of 2% eggshell and 5% silica fume produces a maximum compressive strength of 13,242 MPa.
3. The more eggshell and silica fume added to the concrete mixture, the more the concrete compressive strength value decreases. This is because the cement water factor (f.a.s) in the mixture decreases. If the f.a.s value is less in mixing the concrete is difficult to compact. The density of the concrete mix greatly influences the compressive strength of the concrete after it hardens. Having air pores of 5 percent reduces the concrete compressive strength by up to 35 percent, and pores of 10 percent, reduce the concrete

compressive strength by up to 60 percent (Tjokrodimulyo K, 1995).

B. *Recommendations*

Based on the research that has been carried out, suggestions can be made, including:

1. Eggshell powder and silica fume can be added to the concrete mixture used for light construction, this can have an impact on the waste around us.
2. Further research can be carried out by adding eggshell powder below 2% & silica fume below 5%.
3. It is best to use eggshell and silica fume in concrete as a cement substitute so that the f.a.s. in the concrete mixture can be more controlled.

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