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Effect of Cement Substitution with Corn Stalk Ash and Addition of Snail Shell Powder on Concrete Compressive Strength

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ABSTRACT

As the height of a structure supported by concrete increases, it demands a higher quality of concrete. However, increasing the use of concrete structures makes the materials that compose the concrete more expensive. In this study, corn stalk ash, which contains silica and has pozzolanic properties, was used to partially replace cement. Meanwhile, powdered snail shell can be assumed to act as a filler to fill the voids between aggregate particles. The study was conducted by replacing 7% of the cement weight with corn stalk ash and adding varying amounts of snail shell powder at 0.3%, 0.5%, 0.7%, and 0.9% of the cement content in the concrete mix for ages of 7 days, 14 days, and 28 days. The goal was to determine its effect on the concrete's density, compressive strength, and water absorption.The results of the study concluded that substituting 7% corn stalk ash and 0.3% snail shell powder after 28 days could increase compressive strength by +10.8%, reduce the density by -2.8%, indicating that the concrete becomes lighter, and reduce water absorption by -0.4%, indicating that the concrete becomes denser, which is beneficial for reinforced concrete as it protects the reinforcement from water and harmful substances. However, this substitution and addition led to a decrease in the slump value, affecting workability and making the concrete more difficult to mold.

INTRODUCTION

Construction projects in Indonesia are increasing. This is due to the rapid population growth in certain areas, driven by natural growth, urbanization, or transmigration. In addition to limited land, which is causing the rising cost of housing, the demand for building materials also contributes to the high cost of the construction process. The construction process itself is closely related to the use of concrete structures. According to (Mulyono, 2021), the higher the strength of the structure, the better the concrete compressive strength needed. For this purpose, high-quality concrete is required, but with affordable materials.

Concrete quality is a term based on concrete compressive strength. According to (SNI 2834 2000), concrete consists of Portland cement, aggregates, and water, which then form a solid mass. According to (Irianto *et al.*, 2024), cement reacts with water to form paste that serves as a binder, while aggregates are merely fillers; however, the proportion of aggregates, which make up about 70%-80% of the mixture, contributes to the concrete's strength. According to (Wijaya dan Roberto, 2022), increasing concrete quality can be done by adding cement content, but doing so makes cement use in concrete environmentally unfriendly and makes concrete expensive. According to (Zulkarnain, 2021), it would be cheaper if as much aggregate as possible is used, as long as it is

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technically feasible, in order to minimize the cement content. In light of this issue, it is necessary to find innovations that are expected to provide savings by increasing the proportion of aggregates and reducing cement content, while potentially improving concrete strength. One way is by incorporating substitute and additional materials into the concrete mix. The function of these materials is to modify concrete ingredients with more environmentally friendly materials, reduce costs, yet have the potential to improve the characteristics of concrete. One approach is to substitute or add waste materials available in the environment (Kurniawan *et al.*, 2019).

Indonesia is an agrarian country with vast agricultural land, as a large portion of its population are farmers. One type of agricultural crop that can be found is corn, from which farmers utilize the corn kernels for sale, the corn leaves for animal feed, and the stalks for firewood, though the latter is increasingly abandoned due to the shift to gas stoves. The large production of corn has the potential to create corn plant waste (Aswin, Iqlima dan Alfarizy, 2023). Snails are land mollusks classified under the class Gastropoda and belong to the family Achatinidae. In Indonesia, snails are considered pests for crops. The meat of snails can be consumed by humans or animals, but snail shells produce waste that is not suitable for human consumption. The shells of Gastropoda animals can be made into fine powder (Rahmadi, Abdi dan Haryanto, 2017). The utilization of corn stalk waste and snail shells has not been fully optimized. The remaining waste has the potential to cause pollution and contaminate the environment, which may affect the health of nearby communities. The initial idea of this writing is based on the thought of using corn stalk ash, which contains high silica and has pozzolanic properties, as a partial substitute for cement. Meanwhile, grinding snail shells into powder can be assumed as a filler, which functions as a void filler in fine aggregates, thereby improving the properties of the aggregates so that they can bond and fill each other. Thus, in this case, the author uses it as an additive for filling voids in aggregates without replacing or reducing the aggregate volume.

Referring to the research conducted by (M.Dzaky, 2020), the use of corn stalk ash with variations of 0%, 3%, 5%, 7%, and 9% of the cement weight substitution was studied. According to the results of this research, the optimum substitution of cement with corn stalk ash was at 7%. Similarly, research by (Riantoko, 2021) investigated the use of snail shell powder with variations of 0%, 0.1%, 0.3%, and 0.5% of cement content. The results indicated that the optimal use of snail shell powder as a cement additive was at 0.5%. The researchers reported that during sample preparation, there were inaccuracies in the compaction process, which caused a reduction in concrete compressive strength as the concrete aged. Building on the research done by (M.Dzaky, 2020) and (Riantoko, 2021), the author is interested in further developing the research from these two studies to determine the maximum limit of snail shell powder content by adding variations of 0.7% and 0.9%, increasing by 0.2% to follow the variation interval of the previous studies. Meanwhile, 0.3% and 0.5% will remain part of the study, with the aim to ensure the compressive strength tests remain linear from the previous research. This is because previous research was limited by samples that were not compact enough. Additionally, 7% corn stalk ash will be added as a cement weight substitution to examine compressive strength, density, and water absorption.

Corn Stalk Ash

The large production of corn has the potential to create corn plant waste (Aswin, Iqlima, & Alfarizy, 2023). About 37% of the total corn production is waste. This makes corn plants one of the largest waste suppliers in Indonesia (M.Dzaky, 2020). The following is the composition of corn stalk ash:

Tabel 1. Compounds of Corn Stalk Ash.

Compounds of Corn Stalk Ash (CSA)	
Components	**Composition (%)**
SiO2	52.30
Al2O3	16.29
Fe2O3	2.42
CaO	5.40
MgO	3.70
SO3	1.65
Loss of ignition	9.10

Source: (Salem *et al.*, 2022)

Snail Shell Powder

Snail shells are waste products from processed snail meat that are not utilized. One way to transform shell waste into a useful material and also reduce environmental pollution is by using it as an additive in concrete production (Ketebu dan Farrow, 2017). Snail shells contain calcium carbonate, which is a basic chemical compound in cement, although calcium carbonate is difficult to dissolve in water (Udjiana, Hadiantoro dan Azkiya, 2021). The following is the composition of snail shell powder:

Tabel 2. Compounds of Snail Shell Powder.

Compounds of Snail Shell Powder (SSP)	
Components	**Composition (%)**
Ca	99.10
S	16.29
Cr	2.42
Fe	5.40
Co	3.70
Cu	1.65
Sr	9.10
Lu	0.15

Source: (Pangestu *et al.*, 2021)

RESEARCH METHODS

The method used is a quasi-experimental method, where the researcher uses independent variables to affect the dependent variables. This study was conducted to provide results regarding the effect of substituting part of the cement with corn stalk ash and adding a portion of snail shell powder. The experimental results are then processed to be compared with normal concrete as a reference to the experimental concrete.

Research Flowchart

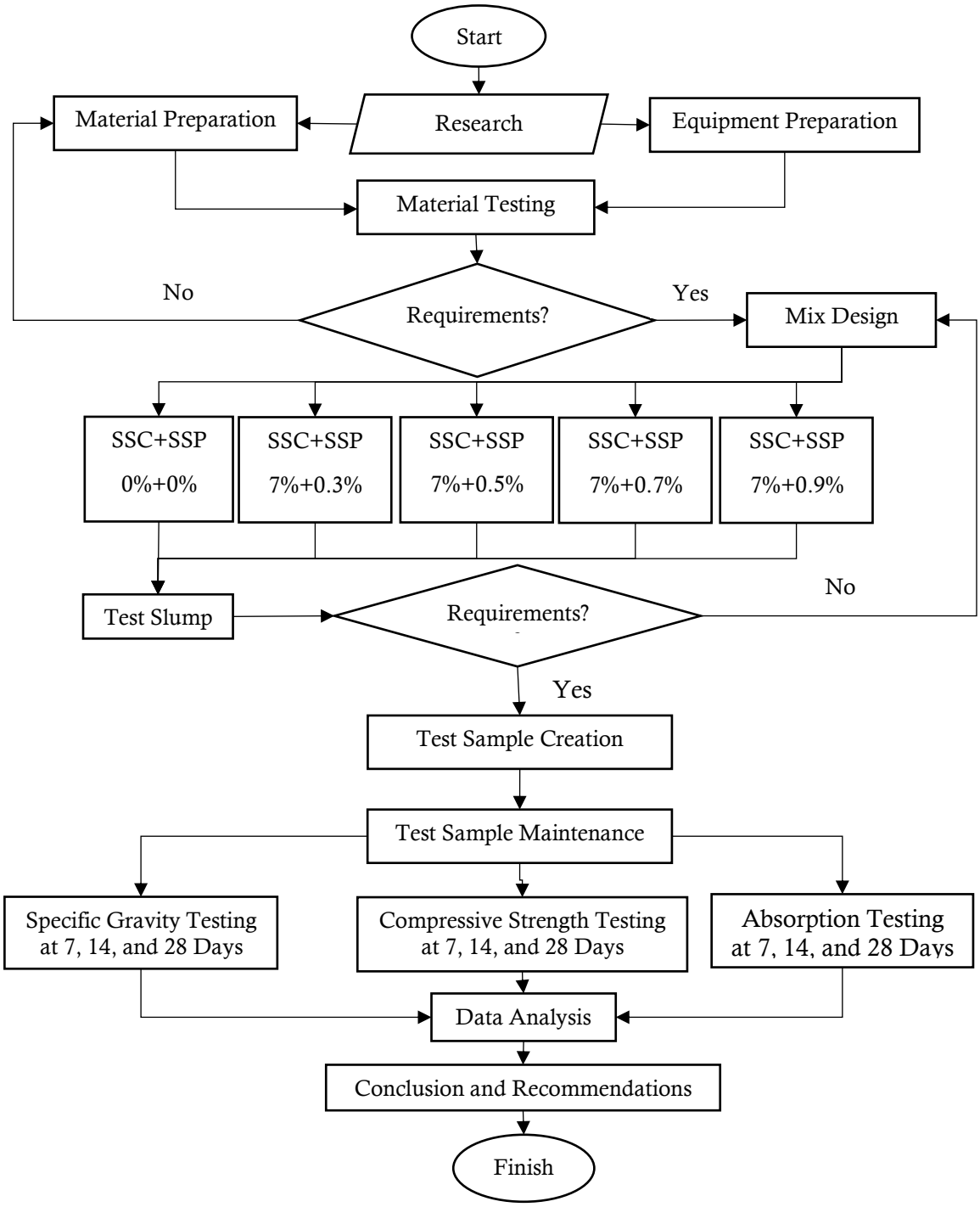


Figure 1. Research Flow Diagram

Based on the research conducted by (M.Dzaky, 2020) and (Riantoko, 2021) the author is developing the study further to find the maximum limit of snail shell powder content by adding variations of 0.7% and 0.9%, which the author increased by 0.2%, following the variation range in the previous studies. Meanwhile, 0.3% and 0.5% will remain under investigation to ensure that the compressive strength testing remains linear with the previous research, as the previous studies were limited to less dense samples. Additionally, 7% corn stalk ash was added as a substitution for cement weight to examine density and water absorption. The variation of corn stalk ash substitution is 7% of the cement weight, and the variations of snail shell powder addition are 0.3%, 0.5%, 0.7%, and 0.9% of the cement weight, and the compressive strength tests were conducted at 7, 14, and 28 days.

Tabel 3. Mix Composition (Trial Mix).

Mixing for 2 cylindrical samples and 2 cubic samples (kg).							
No	**Sample Name.**	**Cement**	**Water**	**Fine aggregate**	**Coarse aggregate**	**CSA**	**SSP**
1	AB0SC0	7,35	2,87	10,04	23,05	0	0
2	AB7SC3	6,84	2,87	10,04	23,05	0,51	0,02
3	AB7SC5	6,84	2,87	10,04	23,05	0,51	0,04
4	AB7SC7	6,84	2,87	10,04	23,05	0,51	0,05
5	AB7SC9	6,84	2,87	10,04	23,05	0,51	0,07

The number of samples for each variation is planned to be 4 samples, with 3 samples used for compressive strength and density testing, and 1 sample for water absorption testing. The research was conducted at the Mercu Buana Meruya Material Laboratory. From the conclusion, it was found that the sample AB7SC3, with 7% corn stalk ash substitution and 0.3% snail shell powder, had the most significant effect.

RESULTS AND DISCUSSION

The purpose of this discussion stage is to understand the variation in material compatibility for concrete mixtures and present the results obtained from this research

Slump Test Results

Tabel 4. Slump Test.

No.	**Sample**	**Average Slump (cm)**	**Target Slump (cm)**	**W/C Ratio**
1	AB0SC0	11	6-18	0,48
2	AB7SC3	8.5		
3	AB7SC5	8.3		
4	AB7SC7	8.1		
5	AB7SC9	8.0		

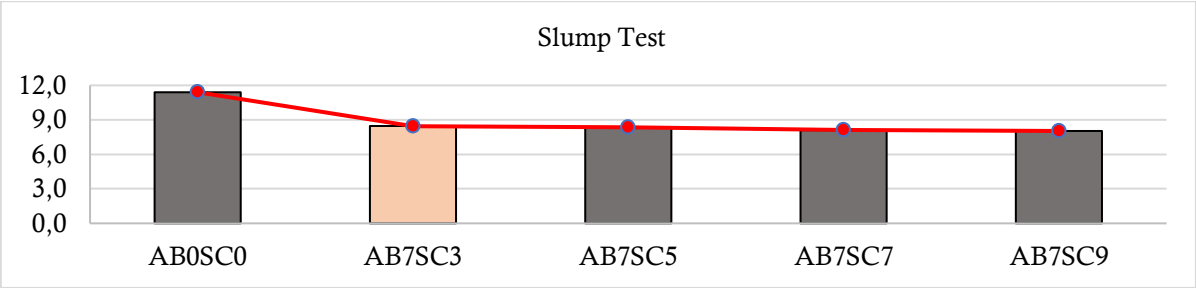


Figure 2. Slump Test Graph

It can be concluded that there was a significant decrease between normal concrete and concrete with corn stalk ash substitution, with an average slump reduction of 3~4 cm for each sample variation. Meanwhile, the addition of snail shell powder, with an increased concentration, only reduced the slump value by a small amount, around 0.5 cm. From the conclusion, it was found that sample AB7SC3, with 7% corn stalk ash substitution and 0.3% snail shell powder, was the closest to normal concrete, with a difference of 2.5 cm. This conclusion is in line with previous research by (M.Dzaky, 2020), which concluded that the use of corn stalk ash would make the paste thicker and reduce the slump value. This may happen because the corn stalk ash material absorbs more water than cement. This is consistent with research by (Riantoko, 2021), which concluded that an increase in the percentage of snail shell powder would lead to a decrease in the slump value. Another study by (Luthfi, Daniaty dan Priastiwi, 2017) found that the slump value is influenced by the Water-Cement Ratio (W/C) and sand particles, where finer sand particles result in a smaller slump value. This occurs because the voids between the coarse aggregate particles, which should be filled with paste, are replaced by fine aggregate, making the concrete mix thicker (Mulyono, 2024).

Specific Gravity Test Results

Tabel 5. Specific Gravity Test (kg).

No.	Sample	7 Days	14 Days	28 Days
1	AB0SC0	2199	2261	2325
2	AB7SC3	2212	2252	2259
3	AB7SC5	2160	2270	2223
4	AB7SC7	2117	2220	2218
5	AB7SC9	2122	2176	2218

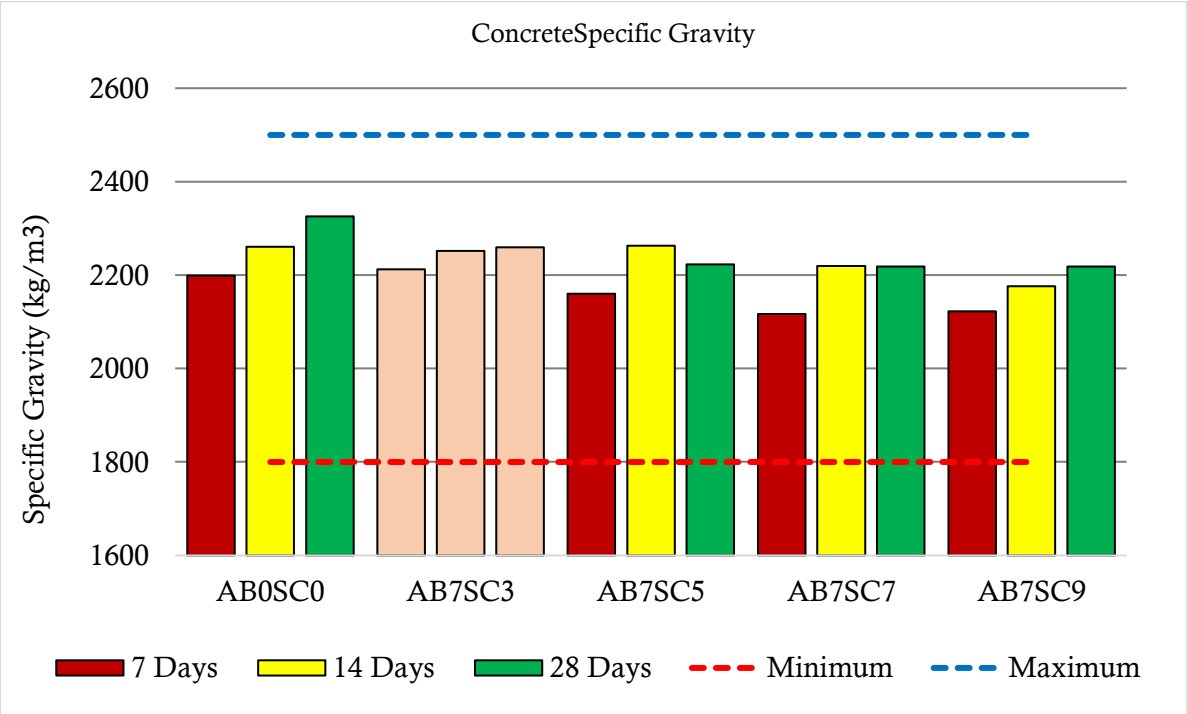


Figure 3. Graph of Specific Gravity Test Results

Based on the research results, normal concrete at 7 days has a weight of 2199 kg/m³, while the concrete with the mix materials in sample AB7SC3 is heavier by +0.6%, whereas samples AB7SC5, AB7SC7, and AB7SC9 are lighter by -1.8%, -3.8%, and -3.5%, respectively. Normal concrete at 14 days weighs 2261 kg/m³, and the concrete with the mix materials in sample AB7SC5

is heavier by +0.4%, while samples AB7SC3, AB7SC7, and AB7SC9 are lighter by -0.4%, -1.8%, and -3.8%, respectively. Normal concrete at 28 days has a weight of 2325 kg/m³, and the concrete with the mix materials in all variations—AB7SC3, AB7SC5, AB7SC7, and AB7SC9—are lighter by -2.8%, -4.4%, -4.6%, and -4.6%, respectively. From the conclusion, it was found that sample AB7SC3, with 7% corn stalk ash substitution and 0.3% snail shell powder, is the heaviest among all variations. However, this value is still below normal concrete, with a difference of -2.8% at 28 days. This may occur because the materials of corn stalk ash and snail shell powder are lighter than cement. Therefore, it can be concluded that the substitution of corn stalk ash and the addition of snail shell powder at higher concentrations can reduce the density of concrete after 28 days while still maintaining the normal density specifications for structural concrete.

Compressive Strength Test Results

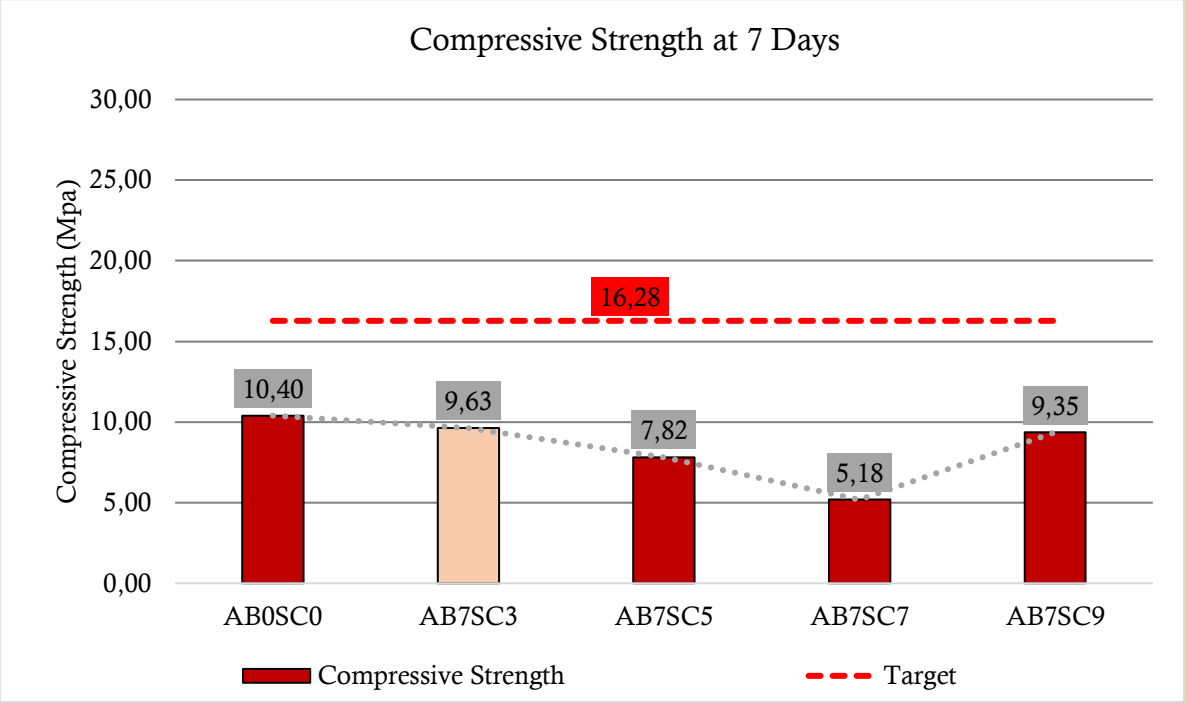


Figure 4. Graph of 7-Day Compressive Strength Test Results

It can be seen that the 7-day normal concrete has a compressive strength of 10.40 MPa, which is 36% lower than the target of 16.28 MPa. This is likely caused by the increased water content in the aggregates due to rain at the seller's location, which affected the water-cement ratio and impacted the concrete's quality. Meanwhile, all the concrete mix variations (AB7SC3, AB7SC5, AB7SC7, and AB7SC9) tend to decrease progressively by -7.4%, -24.8%, and -50%, then increase by -10% compared to the normal concrete with a compressive strength of 10.40 MPa. From the conclusion, it was found that sample AB7SC3, with 7% corn stalk ash substitution and 0.3% snail shell powder, is the closest to normal concrete, with a value difference of -7.4%. This is likely due to the powder particles affecting the fineness modulus of fine aggregates. In optimal amounts, the powder helps bind the aggregate particles together, but in excess, the binder paste between the aggregate particles is reduced and replaced by shell powder, which has a lower crushing strength than fine aggregates.

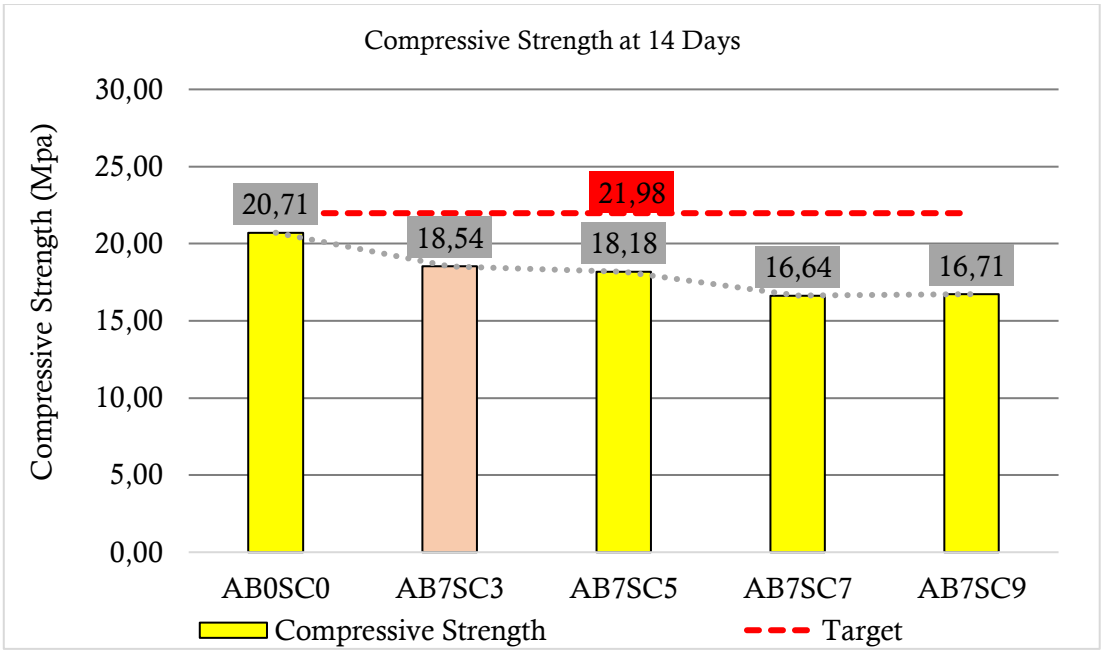


Figure 5. Graph of 14-Day Compressive Strength Test Results

It can be seen that the 14-day normal concrete has a compressive strength of 20.71 MPa, which is slightly lower by 5.8% than the target of 21.98 MPa. This is likely caused by the increased water-cement ratio (FAS), which results in a longer hydration process for the paste. Meanwhile, all the concrete mix variations (AB7SC3, AB7SC5, AB7SC7, and AB7SC9) tend to decrease progressively by -10.5%, -12.2%, and -19.7%, then increase slightly to -19.3% compared to the normal concrete with a compressive strength of 20.71 MPa. From the conclusion, it was found that sample AB7SC3, with 7% corn stalk ash substitution and 0.3% snail shell powder, is the closest to normal concrete, with a value difference of -10.5%. This is likely because the cement and corn stalk ash hydrate with water to form more Dicalcium Silicate (C2S), which determines the final compressive strength of concrete but causes a lower early compressive strength.

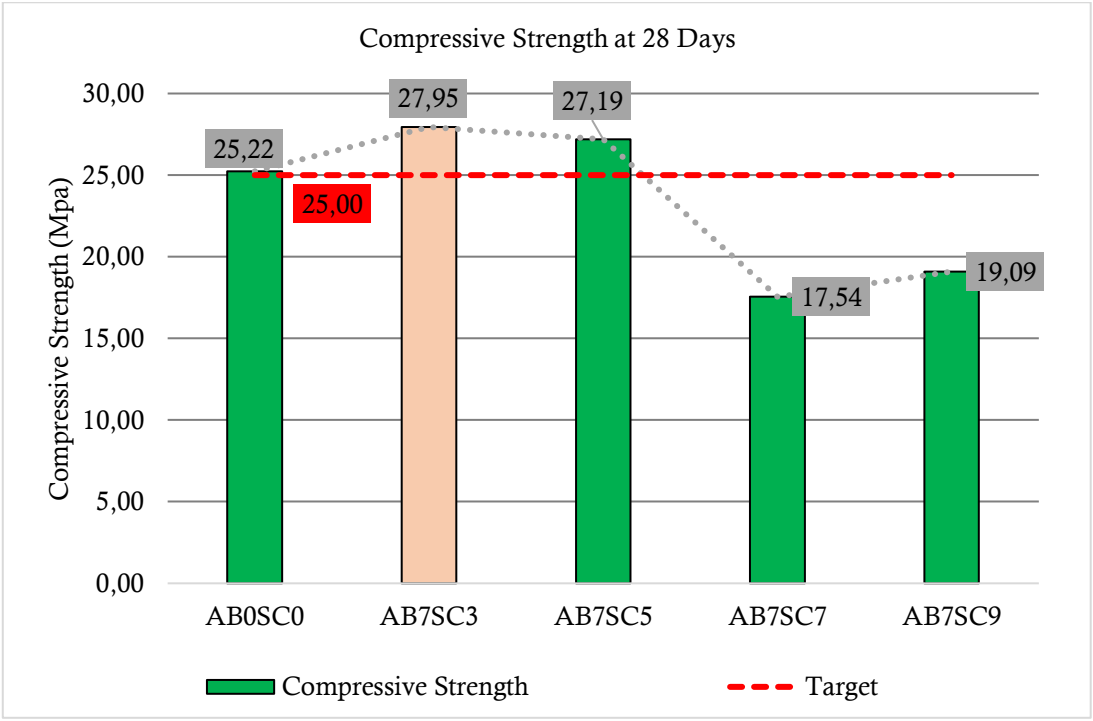
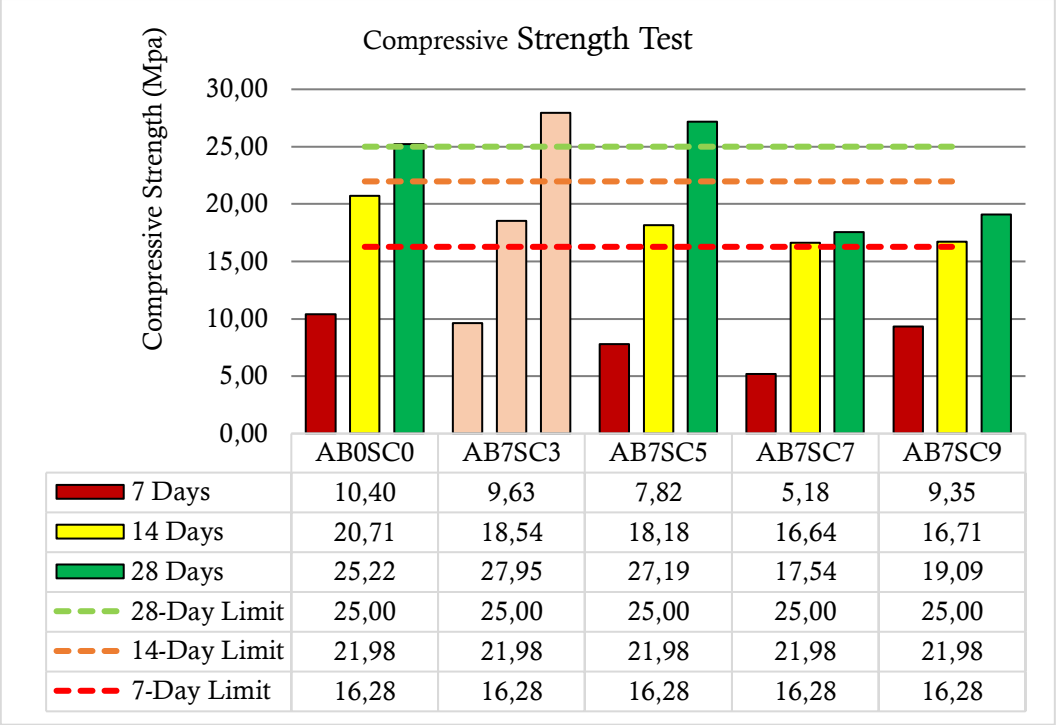


Figure 6. Graph of 28-Day Compressive Strength Test Results



	AB0SC0	AB7SC3	AB7SC5	AB7SC7	AB7SC9
7 Days	10,40	9,63	7,82	5,18	9,35
14 Days	20,71	18,54	18,18	16,64	16,71
28 Days	25,22	27,95	27,19	17,54	19,09
28-Day Limit	25,00	25,00	25,00	25,00	25,00
14-Day Limit	21,98	21,98	21,98	21,98	21,98
7-Day Limit	16,28	16,28	16,28	16,28	16,28

Figure 6. Compressive Strength Test Recap Graph

It can be seen that the 28-day normal concrete has a compressive strength of 25.22 MPa, which is slightly higher by 0.9% than the target of 25 MPa. Meanwhile, the concrete mix variations (AB7SC3 and AB7SC5) tend to increase by +10.8% and +7.8% compared to the normal concrete with 25.22 MPa. From the conclusion, it was found that sample AB7SC3, with 7% corn stalk ash substitution and 0.3% snail shell powder, has the highest value with a difference of +10.8%, making it higher than normal concrete.This is likely due to the positive relationship between Dicalcium Silicate (C2S) and concrete compressive strength (Setiyadi, Muin, & Sukamdo, 2023), which increases the compressive strength at 28 days, and the optimal mixture of powder allows the aggregate particles to bind together. However, the concrete mix variations (AB7SC7 and AB7SC9) tend to decrease by -17.54% and -19.09% compared to the normal concrete with 25.22 MPa. This is likely because the powder particles exceed the optimal amount, reducing the binder paste and being replaced by shell powder, which has a lower crushing strength than fine aggregates. The conclusion of this study is supported by the research of M. Dzaky (2020), which states that corn stalk ash increases compressive strength at 28 days. It is also supported by the research of Riantoko (2021), which found that snail shell powder increases concrete compressive strength at a 0.3% mixture at 28 days. Other research by Hariyanto, Ashad, & Alifuddin (2021) indicates that the fineness modulus of sand affects concrete compressive strength, where a lower fineness modulus results in lower compressive strength. This occurs because the voids between coarse aggregate particles that should be filled with paste are replaced by fine aggregate particles (Mulyono, 2024), reducing the bond between aggregates.

Absorption Test Results

Tabel 6. Absorption Test (%).

No.	Sample	7 Days	14 Days	28 Days
1	AB0SC0	1.3	4.8	3.0
2	AB7SC3	5.5	4.9	2.6
3	AB7SC5	7.7	4.2	6.3
4	AB7SC7	9.3	0.9	5.9
5	AB7SC9	10.1	0.8	5.7

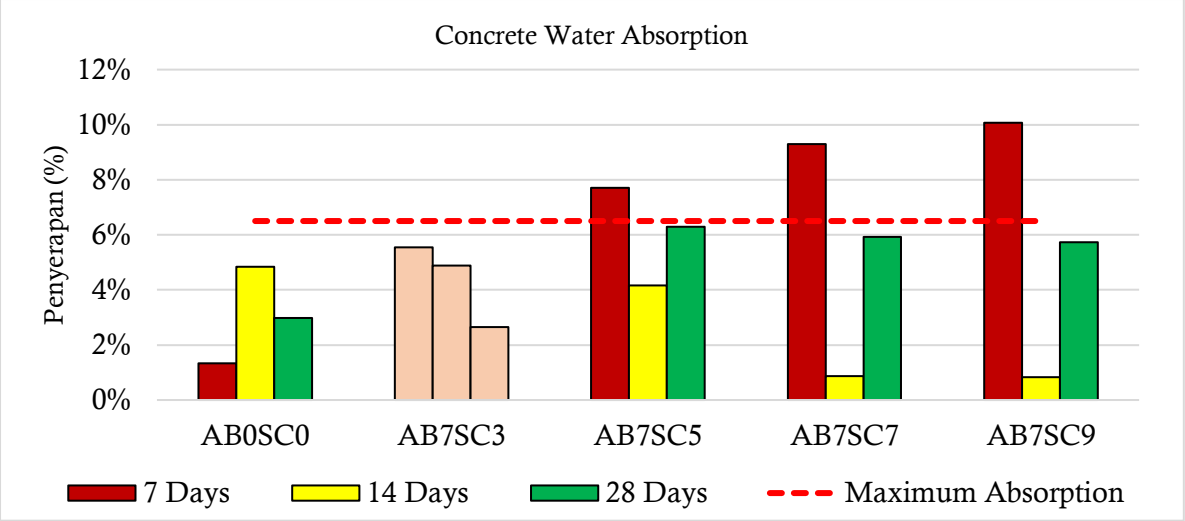


Figure 8. Absorption Test Results Graph

From the research results, the 7-day normal concrete has an absorption of 1.3%, which is far below the maximum value of 6.5% based on (SNI 03 2914 1992). Meanwhile, the concrete mix in the AB7SC3 sample has an absorption of 5.5%, which is higher than the normal concrete but still meets the standard. The absorption of the AB7SC5, AB7SC7, and AB7SC9 samples progressively increases to 7.7%, 9.3%, and 10.1%, respectively, which do not meet the standard because they exceed the maximum limit. This is likely due to the corn stalk ash, which absorbs a lot of water and creates voids in the concrete. The 14-day normal concrete has an absorption of 4.8%, which still meets the standard. Meanwhile, the concrete mixes in the AB7SC3, AB7SC5, AB7SC7, and AB7SC9 samples progressively decrease to 4.8%, 4.2%, 0.9%, and 0.8%. This is likely because the corn stalk ash mixture begins to compact and bind with the snail shell powder, reducing the voids in the concrete. The 28-day normal concrete has an absorption of 3%, which still meets the standard. Meanwhile, the concrete mix in the AB7SC3 sample has an absorption of 2.6%, slightly lower than the normal concrete. However, the samples AB7SC5, AB7SC7, and AB7SC9 show progressively higher absorptions of 6.3%, 5.9%, and 5.7%. This is likely because the corn stalk ash mixture begins to dry out, creating voids that are filled with snail shell powder. From the conclusion, it was found that sample AB7SC3, with 7% corn stalk ash substitution and 0.3% snail shell powder, has the lowest value compared to normal concrete at 28 days, with a difference of 0.4% from normal concrete. At 7 days and 14 days, its value is still below the standard by 6.5%.

CONCLUSION

From the research, it can be concluded that: The highest density value at 28 days is found in the normal concrete sample, which is 2325 kg/m³. Meanwhile, the lowest density value at 28 days is found in the sample with 7% corn stalk ash and 0.9% snail shell powder, which is 2218 kg/m³, a decrease of -4.6% compared to normal concrete. It can be concluded that with the substitution of 7% corn stalk ash and the addition of 0.3% snail shell powder, the density of the concrete decreases by -2.8%, although this value is the highest among all variations. The highest compressive strength value at 28 days is found in the sample with 7% corn stalk ash and 0.3% snail shell powder, which is 27.95 MPa, an increase of +10.8% compared to normal concrete (25 MPa). Meanwhile, the lowest compressive strength value at 28 days is found in the sample with 7% corn stalk ash and 0.7% snail shell powder, which is 17.54 MPa, a decrease of -30.4% compared to normal concrete (25 MPa). It can be concluded that with the substitution of 7% corn stalk ash and the addition of 0.3% snail shell powder, the compressive strength increases by +10.8% at 28 days. The highest water absorption value at 28 days is found in the sample with 7% corn stalk ash and 0.5% snail shell powder, which is 6.3%, an increase of +111.45% compared to the water absorption of normal concrete. Meanwhile, the lowest water absorption value at 28 days is found in the

sample with 7% corn stalk ash and 0.3% snail shell powder, which is 2.6%, a decrease of -0.4% from the water absorption of normal concrete. From the conclusion, it was found that sample AB7SC3, with 7% corn stalk ash substitution and 0.3% snail shell powder, has the lowest value compared to normal concrete at 28 days. However, at 7 days and 14 days, its value is still below the standard by 6.5%."

Here are some suggestions that can be taken as steps for future research. It is hoped that further research will be conducted on snail shell powder with different methods or treatments, such as burning it into ash, or further studies on snail shell powder with percentages less than or more than 0.3%, such as 0.2% and 0.4%, as an additional material. Additionally, there may be future research on substituting snail shell powder into fine aggregates.

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