

## **Application of Eggshell Powder as an Additive Cement on Increasing the Compressive Strength of Papercrete**

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### **ABSTRACT**

Papercrete is a lightweight concrete variant primarily composed of paper, which is characterized by its low compressive strength. This study aims to enhance the compressive strength of papercrete through the incorporation of eggshell powder (ESP) as a partial cement replacement. Given the significant volume of eggshell waste generated in households, this research explores its potential as a sustainable additive in concrete formulation. The experimental design involved the preparation of control concrete mixtures without ESP, incorporating 2.5% and 5% paper by weight of sand. Additionally, concrete mixtures with ESP were formulated at 5% and 7% by weight. A total of 35 cylindrical specimens (15 cm x 30 cm) were cast for testing. Compressive strength evaluations were conducted at 7 days of curing. The findings indicate that the addition of eggshell powder significantly improves the compressive strength of papercrete, with an optimal enhancement observed at a 5% ESP substitution level, yielding a compressive strength of 9.06 MPa in conjunction with a 2.5% paper mix.

**Keywords:** lightweight concrete, papercrete, compressive strength, egg shell, cylindrical test object

### **INTRODUCTION**

Concrete is a mixture of portland cement or hydraulic cement, sand, split, and water, without or with additional materials (admixtures). Along with the development of the times, the world of construction also continues to develop. Many innovations have been developed in the manufacture of concrete, one of which is Papercrete as one of the lightweight concrete-that can be used in non-structural building construction [1].

According to Universal Eco, paper waste is a waste material from the production / usage process that contains components such as cellulose, hemicellulose, lignin, extractive materials, Cl2 solution, hydrogen peroxide, paracetamol and so on with characteristics of blackish or cloudy color, distinctive odor, high COD content. In this case, paper waste can be an alternative as a mixture for making concrete which is commonly called papercrete concrete. This can reduce the amount of paper waste with this alternative besides that it can also help in construction work, especially in reducing construction costs. The definition of papercrete is the result of a combination of concrete with paper so that it has a strong but lightweight material, the components of papercrete are cement, sand and paper. In making papercrete concrete, of course, there are advantages and disadvantages. The advantage of papercrete concrete is that it has a light unit weight with a disadvantage that is not good in compressive strength testing because it has a composition of paper. Previous research from [2] examined the compressive strength and split tensile strength of the addition of paper pulp. Researched the study of compressive strength and tensile strength of concrete with additional paper (Papercrete). In this study, papercrete variations of 2.5% and 5% were used [3].

In overcoming the weaknesses of papercrete concrete, eggshell waste can increase the compressive strength value because eggshells contain the same content as cement formers, namely calcium carbonate. In previous research, [4] researched by making a concrete mixture using eggshell powder (SCT) with the results experiencing an increase in compressive strength. Examined the variation of adding Eggshell-Bamboo Leaf Ash to the weight of cement. The results showed that concrete with

these additions could increase the strength of the concrete. Based on previous research, the study will use eggshell powder for cement additives of 5% & 7% [5], [6].

The purpose of the study was to determine the increase in compressive strength of papercrete with eggshell powder for cement additives of 5% and 7%. In the study, 35 cylindrical concrete test objects will be used, with details of 20 papercrete concrete with eggshells, 10 papercrete concrete without eggshells, and 5 normal-concrete [7]-[9].

Concrete can be made significantly stronger and more durable than conventional mixes by incorporating specialized supplementary materials and chemical admixtures. These enhanced concretes are often referred to as high-strength or high-performance concrete [15]. One of the most widely used additions is silica fume, a by-product of silicon metal production. Silica fume contains extremely fine particles that fill microscopic voids between cement grains. This “micro-filling” effect reduces porosity and increases compressive strength [16], [17]. Concrete containing silica fume can achieve strengths well above 80 MPa, compared to 20–40 MPa for normal structural concrete. Another common additive is fly ash, a by-product from coal-fired power plants. Fly ash reacts chemically with calcium hydroxide in cement through a pozzolanic reaction, forming additional calcium silicate hydrate (C-S-H), which is the primary compound responsible for strength in concrete. This reaction improves long-term strength, reduces permeability, and enhances durability against sulfate attack and alkali–silica reaction [18].

Ground granulated blast furnace slag (GGBS) is also widely used. Slag improves workability and long-term strength while lowering heat of hydration. It enhances resistance to chemical corrosion and improves durability in marine and aggressive environments [19]. Chemical admixtures such as superplasticizers (high-range water reducers) allow a lower water-cement ratio without sacrificing workability. Since strength increases as the water-cement ratio decreases, superplasticizers enable the production of dense, high-strength concrete. Other admixtures, such as air-entraining agents, improve freeze–thaw resistance in cold climates [20].

**RESEARCH METHODS**

The research was conducted using an experimental method conducted at the Laboratory of PT. Triyagan Harnet Perkasa, Triyagan RT03/RW04, Mojolaban, Sukoharjo. In general, the stages of this research were carried out by testing material materials (specific gravity, mud content, volume weight, zone gradation) and making test objects in the form of cylinders, the immersion stage in the form of curing and conducting tests in the form of concrete compressive strength. In this study, literacy was also carried out in the form of books and previous research journals as a reference for the initial study.

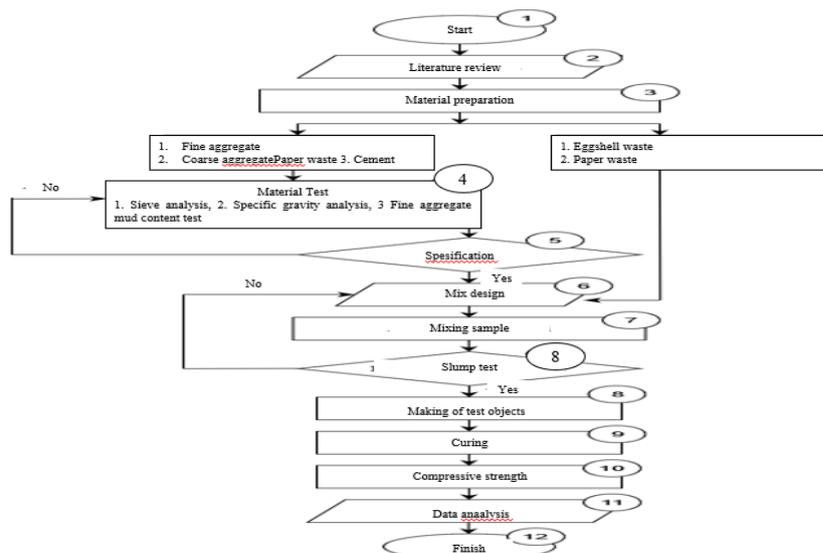


Figure 1. Flow Chart [10]-[13]

## RESULT AND DISCUSSION

### Material Testing

Material testing needs to be done before the concrete making stage, because this process is important to know and ensure the quality, safety and cost efficiency of the materials that will be used in mixing concrete.

### Mud Content

In 03:4142:1996, mud content testing on fine aggregates is max. 5% and for coarse aggregates max. 1%. Excessive mud content in aggregates will affect the quality of the material and construction which will make the quality of the construction material low. Mud content testing is carried out to obtain results in accordance with the applicable SNI specifications. Coarse aggregate testing in Table 1 and fine in Table 2.

**Table 1.** Test Coarse Aggregate Sludge Content

Testing	Testing	Weight	Spesifications
Weight before washing	Weight before washing	501,8	-
Dry weight after washing	Dry weight after washing	497,6	-
Sludge Content	Mud content	0,83	1%

**Table 2.** Test Fine Aggregate Sludge Content

Testing	Weight	Spesifications
Weight before washing	500	-
Dry weight after washing	479,6	-
Sludge Content	4,08	5%

Based on the calculation of the mud content above, it can be concluded that gravel (split) has a mud content of 0.83%, sand has a mud content of 4.08%, gravel and sand meet the specifications according to the SNI standard used, so the aggregate can be used for mixtures in making

### Specific Gravity

Specific Gravity is the ratio of a volume of material at temperature to the weight of water. Aggregate specific gravity is important for aggregate mixing plans, identifying changes in material properties and as a determinant of the number of pores. The results of the fine aggregate specific gravity test with Merapi sand samples in Table 3 and coarse aggregates using Boyolali split samples in Table 4 as well as egg shell testing in Table 5 and paper in Table 6 using the test method [10].

**Table 3.** Specific Gravity and Absorption Fine Agregagate

Calculation	Calculation	Test 1	Test 2	Recapitulation
Bulk Specific Gravity	Bulk Density	2,52	2,49	2,51 gr/cm
Surface Dry Saturated Specific Gravity	Saturated Surface Dry Density	2,61	2,59	2,60 gr/cm
Apparent Specific Gravity	Apparent Density	2,77	2,76	2,77 gr/cm
Absorption	Absorption	3,51	3,95	3,73 %

Based on calculations and testing, it was concluded that the fine aggregate has a specific gravity of 2.60 gr/cm with an absorption of 3.73%.

**Table 4.** Specific Gravity and Absorption Coarse Agregagate

Calculation	Test 1	Test 2	Recapitulations
Bulk Specific Gravity	2,61	2,61	2,61 gr/cm
Surface Dry Saturated Specific Gravity	2,67	2,67	2,67 gr/cm
Apparent Specific Gravity	2,77	2,79	2,78 gr/cm
Absorption	2,30	2,43	2,36 %

Based on table 4, calculations and testing concluded that the coarse aggregate has a specific gravity of 2.67 gr/cm with water absorption of 2.36%.

**Table 5.** Specific Gravity Egg Shell

Testing	Test	Unit
Eggshell Weight	50	gram
Weight of pycnometer + kerosene	293,4	gram
Weight of pycnometer + kerosene + eggshell	327,2	gram
Specific gravity of kerosene	0,8	
Specific gravity	2,47	gr/cm

**Tabel 6.** Specific Gravity Paper

Testing	Test	Unit
Paper Volume	5,30	cm
Paper Weight	5,39	gram
Specific Gravity	1,02	gr/cm

### Volume Weight

The test is conducted to determine the volume weight of fine and coarse aggregates for loose and dense conditions. The procedure in this test includes weighing the container, then filling it with a sample of material and leveling it by shaking the container, reweighing to determine the volume weight, use the weighing results to determine the calculation of the concrete mixture [12]. The results of the coarse aggregate volume weight test are in Table 7 and fine aggregate in Table 8.

**Tabel 7.** Volume Weight Coarse Agregate

Testing	Loose	Dense	Unit
Container Volume	0,00533	0,00533	ltr
Container Weight	1,54	1,54	kg
Container + Sample Weight	9,78	10,08	kg
Sample Weight	8,24	8,54	kg
Volume Weight	1546,59	1602,87	kg/ltr

**Tabel 8.** Volume Weight Fine Agregate

Testing	Loose	Dense	Unit
Container Volume	5,33	5,33	ltr
Container Weight	1,5367	1,54	kg
Container + Sample Weight	9,33	9,66	kg
Sample Weight	7,7933	8,12	kg
Volume Weight	1462,16	1524,07	kg/ltr

### Zone Gradation

Zone Gradation is a division of aggregate size, variations in aggregate are divided into 3, interspersed, continuous, and uniform gradation. In determining the gradation of the aggregate grains, testing is carried out through a sieve or sieve according which is used as a reference in the study [14]. The results of the coarse aggregate zone gradation test are in Table 9 and fine in Table 10.

**Tabel 9.** Sieve Analysis Coarse Agregate

Filter	Zone 1		Zone 2		Zone 3		Test Data
4,8	10	0	10	0	5	0	0,22
9,6	85	50	50	30	40	10	13,55
12,8	100	100	100	95	70	35	37,12
19,1	100	100	100	100	100	95	91,59

Filter	Zone 1		Zone 2		Zone 3		Test Data
25,4	100	100	100	100	100	100	100

The size of the coarse aggregate itself has different grain particles or is divided into several zones, namely zone 1 particle size 4.75mm - 20mm, zone 2 particle size 20mm - 40mm and zone 3 particle size 40mm - 60mm. According to the table above, the test data is included in zone 3 with the graphic image below.

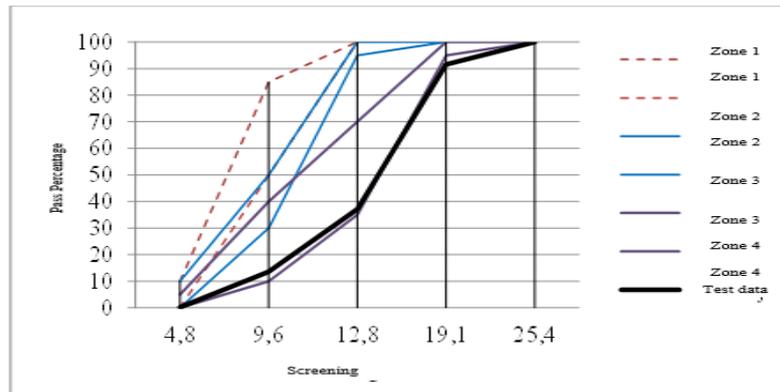


Figure 2. Gravel Zone Gradation Graph

Figure 2 above can be concluded that the gravel (split) used in the study using Boyolali split is included in zone 3. Because most of the test data is included in zone 3. With a grain size of 40mm - 60mm.

Table 10. Sieve Analysis Fine Aggregate

Filter	Zone 1		Zone 2		Zone 3		Zone 4		Test Data
0,15	10	0	10	0	10	0	15	0	0,15
0,3	20	5	30	8	40	12	50	15	6,52
0,6	34	15	59	35	79	60	100	80	21,54
1,2	70	30	90	55	100	75	100	90	61,48
2,4	95	60	100	75	100	85	100	96	70,55
4,8	100	90	100	90	100	90	100	95	88,60
9,6	100	100	100	100	100	100	100	100	94,63
									99,48

The size of fine aggregate has different grain particles or is divided into several zones, namely zone 1 particle size <0.075 mm, zone 2 particle size 0.075 mm - 0.3 mm, zone 3 particle size 0.3 mm - 2 mm and zone > 2 mm. According to the table above, the test data is included in zone 1 with the graphic image below:

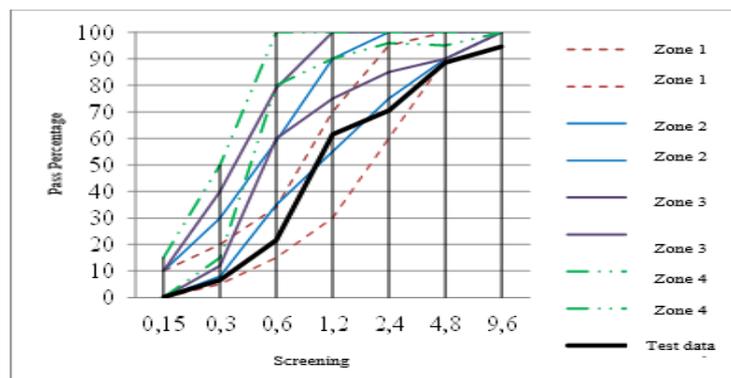


Figure 3. Sand Zone Gradation Graph

Figure 3 above can be concluded that the sand used in the study using Merapi sand is included in zone 1. Because most of the test data is included in zone 1. With very fine particle grains <0.075 mm.

**Material Preparation**

The reference in determining material requirements [13]. The summary of material requirements is converted in 1 mold with the formula:

$$"π" "r" ^2 "t"$$

The results of the calculation of material requirements with the 1 mold conversion formula get the results of material requirements according to Table 11.

**Table 11.** Recapitulation of Material Requirements for 1 Concrete Mold

Materials	BN	BK	BK	BK2,5%	BK2,5%	BK5%	BK5%	Total
		2,5%	5%	CT5%	CT7%	CT5%	CT7%	
Water	1,20	1,20	1,20	1,20	1,20	1,20	1,20	8,37
Cement	2,39	2,39	2,39	2,51	2,56	2,51	2,56	17,31
Agree.smooth	4,20	3,78	3,57	3,78	3,78	3,57	3,57	26,24
Agree.coarse	5,92	5,92	5,92	5,92	5,92	5,92	5,92	41,43
Paper	0,00	0,42	0,63	0,42	0,42	0,63	0,63	3,15
Eggshell	0,00	0,00	0,00	0,12	0,17	0,12	0,17	0,57

Table 11 is the material requirements or mix design that will be used in the research of making test objects in 1 concrete mold measuring 15 x 30 cm. With BN being normal concrete, BK (paper concrete) and CT (egg shell).

**Making Test Objects**

**Slump Testing**

Recapitulation of slump testing with 5 test object samples each in Table 12:

**Table 12.** Recapitulation of Slump Cone Test

Description	Description	Normal	BK	BK	BK2,5%	BK2,5%	BK5%	BK5%	Unit
			2,5%	5%	CT5%	CT7%	CT5%	CT7%	
Sample 1	Sampel 1	17	6,3	3,6	6,2	5,1	3,5	3	cm
Sample 2	Sampel 2	17,3	6,2	3,3	6	5,2	3,7	3,1	cm
Sample 3	Sampel 3	18	6,3	3,4	6,2	5,1	3,6	3,1	cm
Sample 4	Sampel 4	17,4	6,2	3,6	6,1	5,3	3,6	3	cm
Sample 5	Sampel 5	17,7	6,1	3,5	6,3	5,4	3,7	3	cm
<b>Average</b>	<b>Average</b>	<b>17,48</b>	<b>6,2</b>	<b>3,5</b>	<b>6,2</b>	<b>5,2</b>	<b>3,6</b>	<b>3</b>	<b>cm</b>



**Figure 4.** Sample of Normal Concrete Slump Value, BK2.5%, BK5%, BK2.5%CT5%, BK2.5%CT7%, BK5%CT5% and BK5%CT7% in Order from Left

### Concrete Making & Curing

After conducting a slump test on fresh concrete, then put the fresh concrete into the mold and compact it with a rammer to remove air bubbles and let it sit for approximately 6 hours for the concrete to harden. Remove the mold and put it in a curing tank for concrete maintenance during the design life before the testing stage.



Figure 5. Concrete Curing

### 3. Compressive Strength Testing

The testing was carried out when the concrete was 7 days old, where the compressive strength test was carried out at the PT. Triyagan Harmet Perkasa Laboratory with a DCM (Digital Compression Machine) tester. Recapitulation of test results with a mixture of 2.5% BK and 5% and 7% CT additives in Table 13.

Table 13. Recapitulation of 2.5% Papercrete Compressive Strength

Description	Normal	BK 2,5%	BK2,5% CT5%	BK2,5% CT 7%
Sample 1	15,74	5,27	9,40	6,17
Sample 2	20,27	5,94	8,72	6,68
Sample 3	16,19	5,44	9,17	6,85
Sample 4	20,10	5,27	8,89	6,62
Sample 5	17,72	6,57	9,12	6,34
Average	18	5,7	9,06	6,53

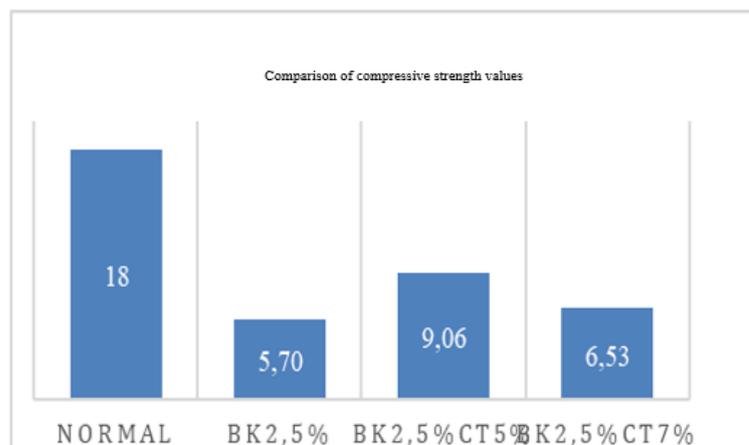


Figure 6. Comparison Chart

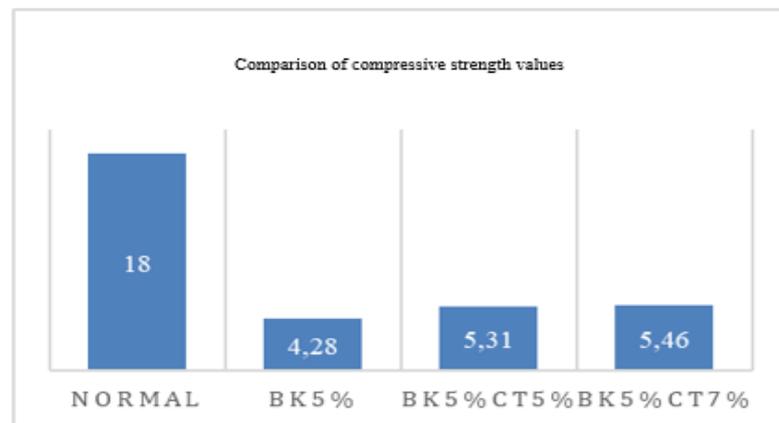
From the recapitulation results according to table 13 and figure 6 comparison above, it can be concluded that normal concrete has a compressive strength of 18 MPa, the addition of paper pulp as much as 2.5% of the weight of sand, the concrete decreases due to the influence of water absorption on the paper, excessive water absorption will cause a decrease in the quality of the concrete itself,

the decrease in the quality of the concrete will affect changes in volume, density and compressive strength. The addition of 5% eggshells (CT) can increase the compressive strength of concrete by 3.36 MPa, but the addition of 7% eggshells causes the compressive strength of papercrete concrete to decrease when adding 5% CT because the eggshell contains a skin that affects water absorption and bond strength of cement with aggregate.

The results of the recapitulation of the compressive strength test with a mixture of 5% BK and additional materials CT 5% and 7% in table 14:

**Table 14.** Recapitulation of 5% Papercrete Compressive Strength

Description	Normal	BK 5%	BK5% CT5%	BK5% CT7%
Sample 1	15,74	4,59	5,04	5,21
Sample 2	20,27	4,98	5,21	5,44
Sample 3	16,19	3,79	5,38	5,72
Sample 4	20,10	4,25	5,66	5,32
Sample 5	17,72	3,79	5,27	5,61
<b>Average</b>	18	4,28	5,31	5,46



**Figure 7.** Comparison Chart

From the recapitulation results according to table 14 and figure 7 comparison above normal concrete reaches a compressive strength of 18 MPa according to what is required in making JMD, the addition of 5% paper concrete reduces the compressive strength to 4.28 MPa. This happens when the addition of quite a lot of paper and there is a decrease in the bond strength of cement with aggregate seen visually. The addition of 5% eggshells can increase the compressive strength by 1.03 MPa and the addition of 7% eggshells can increase the compressive strength by 1.18 MPa from papercrete without additional SCT.

## CONCLUSION

The compressive strength test of normal concrete according to the mix design plan while the addition of 2.5% paper decreased the compressive strength to 5.70 MPa, the addition of 5% paper further reduced the compressive strength value to 4.28 MPa. The addition of eggshells as an additional cement material can increase the compressive strength value, both from a mixture of 2.5% and 5% papercrete. This can be proven according to Figures 6 and 7 in the comparison of concrete compressive strength values in MPa units. The application of eggshells as an additional cement material in making paper concrete in a mixture of BK5% has not reached the optimum value and further research is needed with a mixture of different percentages of eggshells and still paying attention to the proportion of the eggshells.

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**REFERENCES**

- [1] SNI 2847:2013.
- [2] Shaleh, A. M., & Johari, G. J. (2023). *Dengan Campuran Bubur Kertas Abstrak yang ramah lingkungan , salah satu inovasi yang dikembangkan adalah daur ulang limbah kertas. 19(02), 171–175.*
- [3] Pratama, E., & Hisyam, E. S. (2016). Kajian Kuat Tekan Dan Kuat Tarik Belah Beton Kertas (Papercrete) Dengan Bahan Tambah Serat Nylon Study of Compressive Strength Concrete and Strong Pull Shopping Paper ( Papercrete ) With Added Fiber Materials Nylon. *Jurnal, 4, 27.*
- [4] Ashariyanto, Y., Diana, A. I. N., & Deshariyanto, D. (2022). Pengaplikasian Serbuk Cangkang Telur sebagai Bahan Pengganti Sebagian Semen terhadap Kuat Tekan Beton. *Publikasi Riset Orientasi Teknik Sipil (Proteksi), 4(2), 114–119.*
- [5] Anto, A. F. (2020). Pelatihan Teknologi Limbah Cangkang Telur Pada Kuat Tekan Beton. *Jurnal Pengabdian Teknologi Tepat Guna, 1(2), 46–53.* <https://doi.org/10.47942/jpttg.v1i2.708>
- [6] Novianti, D., & Tilik, L. F. (2019). *520843-Pengaruh-Cangkang-Telur-Ayam-Sebagai-Sub-Aecc1831. 14(02), 1–6.*
- [7] Nababan, T. W. (2016). Analisis Hubungan Kompetensi Project Manager Dan Kinerja Proyek Konstruksi Jalan. 5–11.
- [8] Purwanto, & Priastiwi, Y. A. (2017). Pengaruh Kadar Lumpur Pada Agregat Halus Dalam Mutu Beton Purwanto, Yulita Arni Priastiwi \*). Pengaruh Kadar Lumpur Pada Agregat Halus Dalam Mutu Beton, 33, 46–52. P Purwanto, YA Priastiwi - Teknik, 2012 - [ejournal.undip.ac.id](http://ejournal.undip.ac.id)
- [9] Safarizki, H. A., & Ristanto, I. (2019). Kajian Kuat Tekan Papercrete Mutu Tinggi Dengan Bahan Tambah Limbah Keramik. *Jurnal Ilmiah Teknosains, 4(2), 69–75.* <https://doi.org/10.26877/jitek.v4i2.2947>
- [10] Badan Standardisasi Nasional. (20 C.E.). SNI 1969:2008 Pengujian Berat Jenis Agregat Kasar. *1970 Sni.*
- [11] Badan Standardisasi Nasional. (1974). Cara uji kuat tekan beton dengan benda uji silinder. *Badan Standardisasi Nasional, Jakarta.* <https://www.academia.edu/download/57886647/SNI-1974-2011-.pdf>
- [12] Badan Standardisasi Nasional Indonesia. (2008). SNI 1973:2008 Cara uji berat isi, volume produksi campuran dan kadar udara beton. *Badan Standardisasi Nasional, 1–13.* <https://www.universaleco.id/blog/detail/limbah-kertas/7>
- [13] SNI 03-2834-2000. (2000). SNI 03-2834-2000: Tata cara pembuatan rencana campuran beton normal. *Sni 03-2834-2000, 1–34.*
- [14] ASTM C. 136: 2012 standard
- [15] Sutarno, S., Rahmawati, D., & Masvika, H. (2021). EFFECT OF CHICKEN FEATHER WASTE ON CONCRETE MIXING ON COMPRESSIVE STRENGTH AND FLEXURAL STRENGTH. *ASTONJADRO, 10(1), 162–172.* <https://doi.org/10.32832/astonjadro.v10i1.4330>
- [16] Iswady, I., Gusti, S., & Chaerul, M. (2025). Analysis of the Use of Palm Shells as a Substitute for Fine Aggregate on the Water Absorption of Concrete. *ASTONJADRO, 14(4), 1122–1131.* <https://doi.org/10.32832/astonjadro.v14i4.19091>
- [17] Lubab, L., Antonius, A., & Sumirin, S. (2025). Innovation in the Use of Rigid Pavement Waste in Recycled Concrete: Challenges and Solutions to Improve Mechanical Performance. *ASTONJADRO, 14(3), 791–804.* <https://doi.org/10.32832/astonjadro.v14i3.17956>
- [18] Widodo, S., Aski Safarizki, H., & Marwahyudi, M. (2022). Durability of Concrete Based on

- the Remaining Life of the Building Case Study: Reinforced Concrete in Klaten District. ASTONJADRO, 11(3), 713–720. <https://doi.org/10.32832/astonjadro.v11i3.7848>
- [19] Lutfi, M., Chayati, N., Suali, M., Khaerul Insan, M., Syaiful, S., & Muktadir, R. (2024). Structural Analysis of One Block Compartment Building in Sentul Indah Residence Housing. ASTONJADRO, 13(3), 665–674. <https://doi.org/10.32832/astonjadro.v13i3.14978>
- [20] Amar, T. I. K., Magfirona, A., Rosadi, D., & Putri, N. F. (2025). Optimizing the Use of Recycled Materials in Environmentally Friendly Concrete Block Production. ASTONJADRO, 14(2), 474–483. <https://doi.org/10.32832/astonjadro.v14i2.17348>.