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THE EFFECT OF CERAMIC ROOF TILE WASTE POWDER SUBSTITUTION ON PROPERTIES OF CONCRETE

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ABSTRACT: This study aims to investigate the effect of finer roof tile waste powder (CRTWP) on cement performance in concrete as a cement substitute. The compressive strength of concrete utilized in the study is 25 MPa. Dosages of CRTWP as cementitious material in the study are 0.0, 2.5, 5.0, 7.5, and 10.0 % by cement weight used in the concrete. The physical and mechanical properties studied in the research include the setting time, compressive strength, and accelerated corrosion. The specimen dimensions are a cube with 15 cm of sides, a cylinder with 15 cm of diameter and 30 cm of height, and a beam with 10x10x20 cm^3 for setting time, compressive strength, and accelerated corrosion test in sequence. The results show that the cement substitution using CRTWP affects the concrete hydration process with a tendency to slower setting time. The final setting time of 10% addition of CRTWP is longer, around 25 minutes, compared to the specimen without CRTWP. Moreover, other results present that the usage of CRTWP in the concrete mixture increases the development of compressive strength of concrete from 3 days to 28 days. Those increasing of the compressive strength development of the specimen with 10% and without CRTWP is 17.54%. The results of accelerated corrosion indicate that the addition of CRTWP reduces the corrosion attack on the reinforcement by around 7% in concrete with 10% CRTWP compared to concrete without CRTWP.

Keywords: Waste; Ceramic; Roof Tile; Setting Time; Accelerated Corrosion

1. INTRODUCTION

Concrete, as a building material, is applied to many types of construction structures in the world. They have advantages in terms of compressive strength, durability, and ease of forming various types of structural elements, such as plate decks, columns, and beams. Concrete is composed of a mixture of fine aggregate, coarse aggregate, cement, water, and other materials. Over time, cement and water react, and hydration processes occur in the concrete mixture to form Calcium Silicate Hydrate (CSH). The CSH has a function as an adhesive to unite the composite material of concrete. The usage of concrete in building structures will escalate the usage of non-renewable natural resources like limestone, rock, and sand.

The challenge of sustainable materials usage on concrete makes researchers undertake to find recycled materials that can be used in concrete. The usage of recycled material in the concrete has double advantages. Firstly, the recycling of waste material can be conducted at low cost and reduce environmental pollution, such as carbon emissions. Secondly, the usage of waste materials in concrete is expected to increase the physical, mechanical, and chemical properties of concrete. Various recycled materials like bottom ash, fly ash, nylon, red brick, slag [1], rice husk [2,3], ceramic rooftile, and marble [4] have been investigated to replace partially or completely in coarse aggregate and fine aggregate of concrete or in civil work such as subgrade and asphalt [5] in pavement roads.

Green concrete with coarse aggregate from ceramic tile waste was investigated by Huseien et al., 2025, and Tawfik et al., 2024 [6,7] in order to find its effect on mechanical strength, durability, and microstructure property. The results show that both compressive strength and tensile strength of concrete decrease due to increasing of ceramic tile waste as coarse aggregate usage. This tendency is caused by the smooth surface of the ceramic tile waste. In addition, research on replacement coarse aggregate using recycled concrete aggregate (RCA) was conducted by Monika et al. 2025, Hassan et al. 2023, and Mahdi et al. 2024 [8,9,10]. The result of RCA in concrete by Monika et al. indicates that workability is reduced and the slump loss increases faster than concrete without RCA, and the compressive strength is decreased significantly. On the other hand, in the Hassan et al., and Mahdi et al. the compressive strength increase of concrete due to the usage of RCA. Another study on rice husk ash and fly ash to replace cement content on concrete shows that the compressive strength of concrete increases due to the addition 22.5% of fly ash and 7.5% of rice husk ash as cementitious material. Furthermore, research on the utilization of ceramic waste as a material substitution 28% in the production of composite cement [11] shows that the flexural and compressive strength of concrete was intensified. Sikhonde et al., 2022 [12] investigated the usage of powder from red brick on the physical and mechanical properties of cement paste. The study results show that powder from red brick with a content of 5% by cement weight scales down the compressive strength of cement paste. The interesting finding of the research by using an electron microscope is that the chemical content of powder from red brick have alike chemical content to that of pozzolanic material.

Maryoto et al., 2020 [13] state that the higher the concrete quality, the lower the corrosion rate. This is because it is influenced by the water-cement ratio in the concrete mix. Cement requires approximately 25% water by weight to form Calcium Silicate Hydrate. The remaining water in the concrete, due to a water-cement ratio greater than 0.25, is used for workability and eventually evaporates. During the evaporation process, millions of capillary pores form in the concrete. The higher the water-cement ratio, the greater the number of capillary pores. Concrete with a high water-cement ratio increases its permeability. As a result, water and chloride ions easily penetrate the concrete. As a result, the corrosion rate in concrete also increases.

Another study on accelerated corrosion test of recycled ceramic gradient concrete in a soil environment [14], they conclude that regenerated ceramic gradient concrete of the N-60 group had the best resistance to corrosion and expansion. Based on the analysis of each specimen group, it was found that, compared to recycled concrete, recycled ceramic gradient concrete made with the functional gradient material concept could effectively withstand the expansion forces of steel reinforcement and delay crack opening.

The newest study was done by Wibowo et al., 2026 [15] and Maharani et al., 2025 [16] on CRTWP as a substitution material for cement in concrete in order to know the effect of concrete slump loss. It shows that CRTWP on concrete behave slump loss like a concrete without CRTWP. Unfortunately, the influence of concrete with CRTWP on compressive strength and other properties of concrete has not been studied yet. Based on the background, this research aims to investigate the influence of CRTWP usage on setting time, compressive strength, and corrosion attack of concrete. Those parameters are observed due to the importance of concrete properties in the short, medium, and long term. Setting time correlates with the fresh concrete quality, especially for the workability of concrete. Then, the compressive strength is the main mechanical property of concrete that should be analyzed on the reinforced concrete structure. The corrosion ressistance is corresponded to the durability of the reinforced concrete.

This article consists of five parts. The first part is an introduction which is discussed about the background and objective of the research. The second part discusses the research significance. The material and method are presented in the third part. The third part also discusses the material used, the procedure of specimen making, and the sequences of testing. The fourth section contains the results and discussion. Finally, in the last part, the fifth sections, the summary of the results is presented.

2. RESEARCH SIGNIFICANCE

This study is related to Sustainable Development Goals (SDGs), especially SDG 11, in order to reduce the negative effects of waste material. This research is conducted to utilize Sokka ceramic roof tile waste in concrete. Sokka is a name of small village in the Kebumen region where the first roof tile factory was established in this village. It later became one of the most well-known ceramic roof tile brands in Kebumen. The amount of Sokka ceramic roof tile waste in Kebumen Regency, Indonesia, is approximately 503 tons per year. Its use as a cement substitute serves two purposes. The significant contributions of the study are: first, it can effectively and safely dispose of the waste materials. Second, its use in concrete can improve its physical properties and reduce cement use. This, in turn, can reduce carbon emissions in cement production.

3. MATERIALS AND METHOD

3.1 Materials

Materials used in the experiment are Portland composite cement with fineness size 4677 cm^2/g, coarse aggregate, fine aggregate, water, ceramic roof tile waste powder (CRTWP), and sodium chloride (NaCl) solution 3%. The fine aggregate used in the research comprises of 2 type, which are silica and optima sand. The physical [17] and chemical properties of the CRTWP used are presented in Table 1. Figure 1 shows the ceramic roof tile waste, and after being ground to fine powder, it can be seen in Fig. 2. The finish mill, as shown in Fig. 3, with hundreds of solid steel balls inside, is used to blend the ceramic roof tile waste to fine powder around the fineness size of Portland composite cement. The fineness of CRTWP is measured using Automatic Blaine equipment, as shown in Fig. 4.

Table 1. Physical and chemical properties of CRTWP

Item	Size and percentage
Fineness size	4871 cm^2/g
Specific gravity	2.72
SiO_2	52.51%
Al_2O_3	17.78%
Fe_2O_3	14.91%
CaO	8.26%
K_2O	2.04%
Na_2O	0.25%
MgO	1.58%
SO_3	0.22%
Others	2.44%

Fig.1 Ceramic roof tile waste

Fig. 2 Fine powder of ceramic roof tile waste

Fig. 3 Finish mill

Fig. 4 Automatic Blaine

Other equipments which are used in the research are concrete mixer, a concrete siever for concrete, a penetrometer to measure the setting time of concrete, a cube mould with a 15 x 15 x 15 cm^3, a cylinder mould with a 15 cm diameter and 30 cm of height, a beam mould with dimensions 10 x 10 x 20 cm^3, a direct current of power supply, buckets, cables, copper plate, and packer.

Table 2 shows the number of specimens and mix design of concrete 25 MP is presented in Table 3.

Table 2. Number of specimens

Testing type	Code of specimens				
	A	B	C	D	E
Setting time	1	1	1	1	1
Compressive strength	9	9	9	9	9
Accelerated corrosion	3	3	3	3	3

Table 3. Mix design of concrete 25 MPa

Code	Materials (kg)				
	PCC	Crushed stone	Sand	water	CRTWP
A	345	1090	695	185	0
B	336	1090	695	185	9
C	328	1090	695	185	17
D	319	1090	695	185	26
E	310	1090	695	185	35

In Tables 2 and 3, Codes A, B, C, D, and E represent specimens with CRTWP content of 0.0, 2.5, 5.0, 7.5, and 10.0 % by weight of cement.

3.2 Method

All of the processes of the research are conducted in the laboratory, a closed room, with a temperature of 25°C and a humidity of 77.7%.

3.2.1 Setting time of concrete

The setting time of concrete is investigated based on SNI ASTM C403/C403M:1012 [18]. In order to find mortar mix from fresh concrete, the fresh concrete from the concrete mixture is then refined using a concrete siever to separate the mortar matrix and coarse aggregate. Figure 5 shows the concrete sieve. Setting time of mortar is conducted by using a penetrometer, as shown in Fig. 6. Penetrometers are equipped with some needles. The largest diameter of the needle is applied to the young concrete. By the time the concrete will to be harden and should be tested with the smallest diameter of the needle.

After the mortar is obtained from separation processes on concrete, the mortar is remixed manually to get a homogeneous condition. The homogenized mortar is poured into the cube mould 15 x 15 x 15 cm^3 and compacted using a vibrating table as shown in Fig. 7. Next step is to place the mortar with the moulding specimen in a comfortable ambient temperature around 25°C. The test is applied at an interval of 30 minutes for 3-4 hours. Penetration test on the mortar, using a penetrometer with the smallest to the largest diameter of needle, is continuously applied until the penetration resistance reaches 27.6 MPa. Figure 8 shows one step of the penetration processes on the mortar in the mould.


Fig.5 Concrete siever


Fig. 6 Penetrometer


Fig. 7 Vibrating table


Fig. 8 Testing on mortar

3.2.2 Compressive strength of concrete

The compressive strength tests are conducted according to SNI 1974:2011 [19] on how to test the compressive strength of concrete with a cylindrical test object. Concrete compressive strength testing was carried out when the test specimens were 3, 7, and 28 days old. Each parameter of the mix design of concrete and the age of the object test is represented by 3 specimens.

The fresh concrete is cast in the cylinder moulding with a diameter of 15 cm and height 30 cm, as shown in Fig. 9. To obtain the solid of the hard concrete, the fresh concrete conrete in the moulding is compacted by tamping with a steel rod with a diameter of 16 mm as many as 25 times for 3 layers. The specimens are removed from the mould after specimens have 1 day of age in the mould. Then the hard concrete is cured in the water, as like Fig. 10. The curing of the hardened concrete is conducted for 28 days. The temperature of the water for curing the specimens is around 25 °C. The specimens are lifted up from the water on the days of 28. Before compression testing is applied, the specimens should be placed in the ambient air for around 1 hour in order to remove the water content on the surface of the specimens.


Fig.9 Casting of fresh concrete


Fig. 10 Curing of hard concrete in the water

Then the hard concrete is lifted from the water immersion and placed at room temperature. After the specimen has already been in the saturated surface dry condition, a compression test is carried out. Sulfur capping sulfur (Fig. 11) on the cylinder specimen is applied before conducting the compression test using Universal Testing Machine/ UTM (Fig. 12). The UTM was turned on at a speed of 2 to 4 kg/cm^2 per second. The maximum load applied when the test specimen broke was recorded. The compressive strength can be calculated by dividing the maximum force by the area of the test specimen and can be calculated using Eq. 1.

$$\sigma = \frac{P}{A} \text{ MPa} \quad (1)$$

In Equation 1, σ is the compressive strength (MPa), P is the maximum compression load (Newton), and A is the surface area of the concrete (mm^2).

Fig. 11 Capping of concrete using sulfur

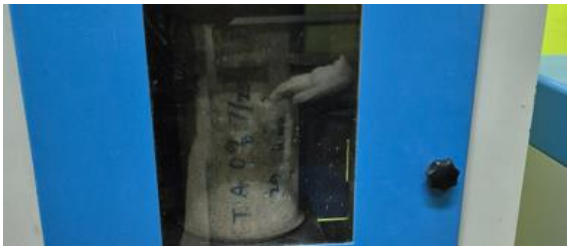

Fig. 12 Compression test

3.2.3 Accelerated corrosion

The accelerated corrosion specimen dimensions were a cube with sides of 100 x 100 x 200 mm. A plain steel bar with a diameter of 12 mm and a length of 100 mm was inserted into the concrete cube specimen. The plain steel bar was covered by approximately 50 mm of concrete on all sides. The accelerated corrosion testing procedure was carried out using the following steps. The first step involved connecting the 12 mm diameter plain steel bar with a cable using a welded joint. This joint was protected with duct tape to prevent direct contact with the concrete. The 12 mm diameter plain steel reinforcing bar with the cable was then installed in the beam mold. The plain steel bar was suspended using a string to place the plain steel bar at the center of the beam. Once the plain steel bar was stable, fresh concrete was placed into the beam mold. After one day, the beam mold was removed to take out the specimen, and the concrete specimens were cured for 28 days. Figure 13 shows the scheme of the accelerated corrosion test [13].

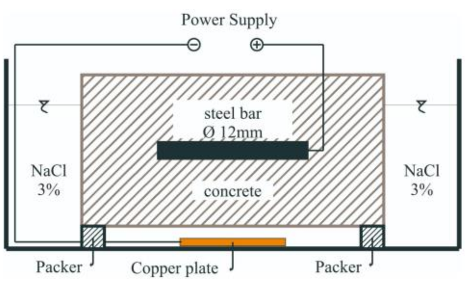

Fig. 13 Scheme of accelerated corrosion

The concrete block was immersed in a NaCl solution. A cable on the specimen block was connected to a direct current power source, followed by another cable connected to a copper plate. The copper plate was located beneath the specimen. A single direct current power supply resulted in accelerated corrosion for four specimens. The duration of accelerated corrosion was determined to be 14 days. The voltage was set at approximately 10 V. After the accelerated corrosion process reached 14 days, the electrical current connection was terminated [20]. Figure 14 shows the process of accelerated corrosion on the specimen at 1st day. The figure also shows the single direct current power sources. After accelerated corrosion conducted for 14 days old, the corrosion product appear on the concrete specimen as shown in Fig. 15. The concrete beam of the corrosion specimen is broken to remove the reinforcing steel bars as shown in Fig. 16. The wires are removed from the reinforcing steel bars before the rust on the plain steel bars is cleaned using a wire brush and then soaked in a 10% ammonium citrate solution until all rust is removed [20]. After the corrosion was removed, the reinforcing steel bars were weighed as shown in Fig. 17, and the corrosion percentage was calculated using Eq. 2.

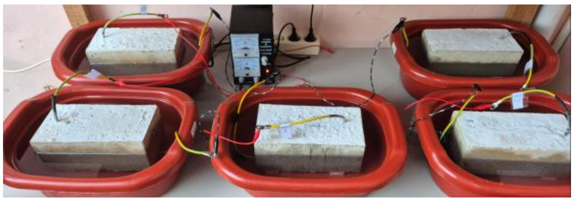

Fig. 14 Corrosion processes at 1st day

Fig. 15 Corrosion processes at 14th days

Fig. 16 Beam specimen after breaking

Fig. 17 Weighing of rust free steel bar

Percentage of corrosion (%) = $\frac{A-B}{A}\ x\ 100\%$ (2)

In Equation 2, A is the initial weight of the steel bar before the application of accelerated corrosion (grams), B is the final weight of the steel bar after the application of accelerated corrosion, and the rust on the surface of the steel bar has already been removed.

4. RESULTS AND DISCUSSION

4.1 Setting Time of Concrete

The setting time of the mortar matrix in the concrete can be found in Fig. 18. In the Figure show that the horizontal axes represent the time in minutes and the vertical axis expresses penetration resistance in pounds per square inch. Initial and final setting time can be specified using the relationship between time and penetration resistance. The colour line in the graph reflects the mortar matrix with various contents of CRTWP. According to SNI ASTM C403/C403M:2012 [21], the initial and final setting times are specified when the penetration resistance reaches 3.45 MPa and 27.60 MPa.

Figure 18 shows that the fastest initial and final setting time is reached by the mortar matrix without CRTWP.

The addition of CRTWP in the mortar matrix in concrete increases the initial and final setting time longer than the mortar matrix without CRTWP. The tendency caused by some SiO_2 in the CRTWP reacts with Ca(OH)2 as a result of the hydration reaction of cement and water. The steps of the hydration reaction of cement are as follows.

$2C3S + 6H_2O \rightarrow C3S2H3 + 3Ca(OH)_2$

In the reaction C3S and C3S2H3 : C = CaO, S = SiO2, H = H_2O.

Then, the continuous reaction of CRTWP and calcium hydroxide, called the pozzolanic reaction, to form calcium silicate hydrate (C-S-H), tobermorite, which is the mineral, caused the concrete to be hard, as follows :

$SiO2 + Ca(OH)_2 \rightarrow$ C-S-H

According to the steps of pozzolanic reaction, it show that to form the C-S-H, more time is needed.

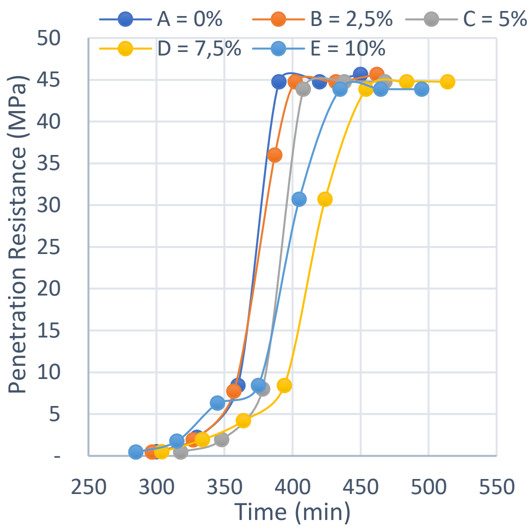

Fig. 18 Setting time of mortar matrix

The higher the content of CRTWP in the mortar matrix, the longer the initial and final setting times. This phenomenon has the same tendency on the initial setting time of cement paste that was investigated by Oktaviani et al., 2026 [17] and Sinkhonde et al., 2022 [12].

4.2 Compressive Strength

Compressive strength of concrete is shown in Fig. 19.

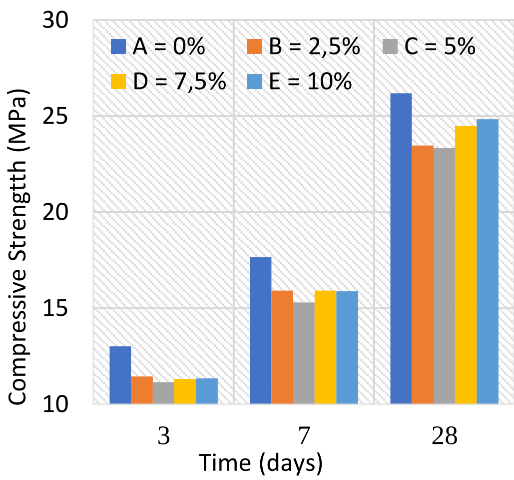

Fig. 19 Compressive strength

It shows that the horizontal axes reflect the time of conducting the test in days, and the vertical axes reflect the value of compressive strength in MPa. There are 5 five colours on the bar chart which represent the content of CRTWP in concrete, starting from 0% to 10%.

Figure 19 shows that concrete with CRTWP content has a slow behavior in the initial setting time of cement in concrete. It can be observed from Fig. 19 that the compressive strength of concrete at 3 days old is 13.0, 11.4, 11.2, 11.3, and 11.3 MPa for concrete containing CRTWP of 0.0, 2.5, 5.0, 7.5, and 10.0% consecutively, and also at 28 days old are 26.2, 23.5, 23.3, 24.5, and 24.9 MPa. The tendency of compressive strength of concrete at both ages of 3 days and 28 days is to decrease. According to this data, there is an interesting phenomenon due to the development of compressive strength in percentage.

The increase of compressive strength from 3 days to 28 days in concrete with CRTWP contents is 101, 105, 109, 116, and 119%. Even though the compressive strength of concrete with CRTWP at 28 days old is still lower than that of concrete without CRTWP, the development of compressive strength increases significantly due to the addition of CRTWP in concrete. Table 4 shows the development of compressive strength at 3 to 28 days.

Table 4. Development of compressive strength

CRTWP Content	Average of compressive strength (MPa)		Development compressive strength (%)
	3 days	28 day	
A=0%	13.0	26.2	101
B=2.5%	11.4	23.5	105
C=5%	11.2	23.3	109
D=7.5%	11.3	24.5	116
E=10%	11.3	24.9	119

Based on the above analyses, the conclusion can be made that CRTWP influences the mechanical properties of concrete similar to fly ash. It might be predictable that the compressive strength of concrete with CRTWP at an older time, i.e., 90 days old, will exceed the compressive strength of concrete without CRTWP. The compressive strength of concrete with CRTWP is lower at a young age, and has a higher compressive strength at an older age. It can be explained by the pozzolanic reaction, as stated in the setting time section before. Substitution of CRTWP with high SiO2 content, the more C-S-H is formed in longer time. The enhancement of the content of C-S-H, the higher compressive strength of concrete. This tendency is also similar to Cuong's research, 2024 [22]. The research showed that the addition of 50% fly ash in concrete increases the compressive strength at 90 days of age by around 22.2% to 24.5%. Based on the chemical content in Table 1, the CRTWP is classified as Pozzolan type N as ASTM C-618-08a. Pozzolan type N and Fly Ash have similar properties when used in concrete.

4.3 Accelerated Corrosion

Accelerated corrosion is performed in the study to determine the resistance of concrete containing CRTWT to corrosion attacks in a short time. Fig. 20 shows the relationship between the content of CRTWP in concrete and the percentage of corrosion of the steel bar inside the concrete.

According to Fig. 20, it can be described that increasing the CRTWP content in concrete reduces the corrosion attack on the steel bar in reinforced concrete. The level of corrosion is decreased by around 7% due to the addition of CRTWP 10% in concrete. It is understandable because the grain size of CRTWP in the study is finer than that of cement. In the experiment, the grain size of CRTWP is 4871 cm^2/gram, and cement is 4677 cm^2/gram. The finer of CRTWP grain has an effect on forming and filling in the smaller capillaries [17].

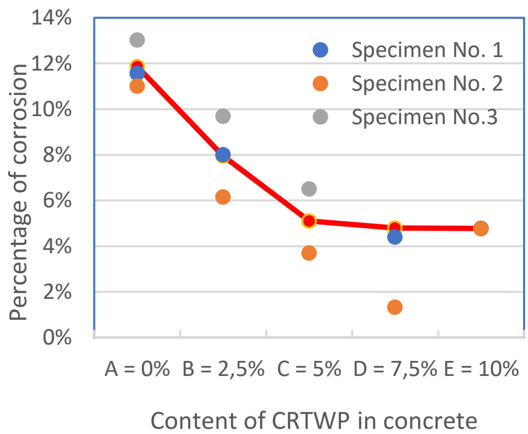

Fig. 20 Percentage of corrosion

Besides that, the content of SiO_2 in the CRTWP will react with $Ca(OH)_2$ in the hydration processes on cement to reform calcium silycate hydrate (CSH), which we usually call it as “tobermorite”. As a result, more CSH is produced in the concrete due to the reaction hydration of cement, CRTWP, and water. CSH is a hard compound found in concrete. A smaller diameter of capillaries formed in the concrete results in more resistance against corrosion attack. It is more difficult for chloride ions to infiltrate into the concrete, which has capillaries with a smaller diameter.

5. CONCLUSION

CRTWP substitution usage in concrete has already been discussed in order to find the effect of setting time, compressive strength, and corrosion in concrete. There are some conclusions of the study on the usage of CRTWP as a cementitious material to partially substitute for cement content in concrete. The conclusions are as follows:

1. The addition of CRTWP as a cement substitute in concrete mixes tends to extend the concrete setting times, especially the final hardening time.
2. The results of the study show that the usage of CRTWP in the concrete mixture increases the compressive strength from 3 days to 28 days. Compared to concrete without CRTWP, the increasing of compressive strength in concrete with CRTWP 2.5, 5.0, 7.5, and 10.0% are 101, 105, 109, 116, and 119%, respectively.
3. The corrosion attack is significantly reduced due to the usage of CRTWP in concrete because the grain size of CRTWP is smaller than that of cement. The reduction of corrosion attack is around 7% in concrete with 10% of CRTWP compared to concrete without CRTWP.

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7. REFERENCES

1. Vighnesh R., and Vaishnavi D. S., Use of slag and hemp for enhancing the strength and durability properties of concrete - A case study, Revista Ingenieria de Construccion, Vol. 40, No. 1, 2025, pp. 1-12. https://doi.org/10.7764/RIC.00139.21
2. Sathawane S. H., Vairagade V. S., and Kene K. S., Combine effect of rice husk ash and fly ash on concrete by 30% cement replacement, Procedia Engineering, Vol. 51, 2013, pp. 35–44. https://doi.org/10.1016/j.proeng.2013.01.009
3. Ratchakrom C., Rodvinij P., Chaiwithee S., and Wattanachai P., Utilization of rice husk ash as a sustainable additive for subbase strength enhancement, International Journal of Geomate, Vol. 30, Issue 138, 2026, pp. 77-84. https://doi.org/10.21660/2026.138.g15127
4. Jassim N.W., Hassan H.A., Mohammed H.A., and Fattah M.Y., Utilization of aste marble powder as sustainable stabilization materials for subgrade layer. Results in Engineering, Vol. 14, 2022, pp. 1-8. https://doi.org/10.1016/j.rineng.2022.100436
5. Akram H.A., Hilal M.M., and Fattah M.Y. Numerical simulation of the effect of repeated load and waste polypropylene on the behavior of asphalt layers. IOP Conf. Series : Earth and Environmental Science 961, Vol. 961. https://doi:10.1088/1755-1315/961/1/012039.
6. Huseien G. F., Joudah Z. H., Baghban M. H., Nur N. H., Faridmehr I., Dong K., Li Y., and Gu X., Sustainability of recycling waste ceramic tiles in the green concrete industry: a comprehensive review. Buildings, Vol. 15, Issue 14, 2025, pp. 1-51. https://doi.org/10.3390/buildings15142406
7. Tawfik T. A., Sičáková A., Kuzielová E., Kušnír Š., Eštoková A., Bálintová M., and Junáková N., Sustainable reuse of waste ceramic tiles powder and waste brick powder as a replacement for cement on green high strength concrete properties. Innovative Infrastructure Solutions, Vol. 9, Issue 166, 2024, pp. 1-22. https://doi.org/10.1007/s41062-024-01498-2
8. Monika F., Prayuda H., Cahyati D.M., Pangestu A., Al Majid R., and Rahmawati K., Engineering properties of concrete panels containing nylon waste fibers and recycled coarse aggregates, Revista Ingenieria de Construccion, Vol. 40, Issue 3, 2025, pp. 1-28. https://doi.org/10.7764/RIC.00156.21
9. Hassan S.S., and Fattah M.Y. Strength properties of polymer reactive powder concrete with waste materials**.** Civil Engineering Journal, Vol 9, No. 08, 2023, pp. 1936-1956. http://dx.doi.org/10.28991/CEJ-2023-09-08-09.
10. Mahdi Z.R., Hasan, S.S, Hamoodi M.N., and Fattah M.Y. Evaluation of the performance of sustainable modified polymer concrete made from various waste materials**.** International Journal of GEOMATE, Vol. 27, Issue 121, 2024, pp. 21-32. https://doi.org/10.21660/2024.121.4430
11. Baylavlı H., and Gödek E., Use of Ceramic Tile Wastes as Raw Substitution Material in the Production of Blended Cement, Buildings, Vol. 14, Issue 9, 2024, pp. 1-13. https://doi.org/10.3390/buildings14092942
12. Sinkhonde D., Onchiri R. O., Oyawa W. O., and Mwero J. N., Effect of Waste Clay Brick Powder on Physical and Mechanical Properties of Cement Paste, The Open Civil Engineering Journal, Vol. 15, 2021, pp. 370–380.

https://doi.org/10.2174/1874149502115010370

13. Maryoto A., Gan B. S., Hermanto N. I. S., and Setijadi R., Effect of calcium stearate in the mechanical and physical properties of concrete with PCC and fly ash as binders, Materials, Vol. 13, 2020, pp. 1-16. https://doi.org/10.3390/ma13061394
14. Peng K., Li H., Li Y., and Zhou M., Accelerated Corrosion Test of Ceramic Recycled Gradient Concrete in Saline Soil Environment, Crystals, Vol. 15, Issue 2, 2025, 2025, pp. 1-11. https://doi.org/10.3390/cryst15020122
15. Wibowo I., Maryoto A., and Hermanto N. I. S., Influence of Ceramic Roof Tile Waste Powder Fineness on Slump Loss and Water Content of Concrete with Cement Substitution. *Jurnal Dinamika Rekayasa*, Vol. 22. No. 1, 2026, pp. 86–93. https://doi.org/10.20884/1.jidr.2026.22.1.103
16. Maharani A. T., Maryoto A., and Hermanto N. I. S., Influence of Ceramic Roof Tile Waste Powder as a Partial Cementitious Material on the Initial and Final Setting Times of Cement Paste, E3S Web of Conferences, Vol. 609, 2025, pp. 1-4. https://doi.org/10.1051/e3sconf/202560903002
17. Oktaviani V., Maryoto A., and Hermanto N.I.S., Influence of ceramic roof tile waste powder as cementitious material on mortar slump flow, *Jurnal Dinamika Rekayasa*, Vol. 22, Issue 1, 2026, pp. 55-62.
18. ASTM C618-08a, Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete, 2009, United States.
19. SNI 1974:2011, Procedure for testing concrete compressive strength with cylindrical test specimens, 2011 Indonesian National Standard, Indonesia.
20. Maryoto A., Gan B. S., Hermanto N. I. S., and Setijadi R., On the water absorption and corrosion rate of concrete using calcium stearate. Journal of Engineering and Applied Sciences, Vol. 12, Issue 20, 2017, pp. 5233–5238. https://doi.org/10.3923/jeasci.2017.5233.5238
21. SNI ASTM C403/C403M:2012, Test method for setting time of concrete mixture with penetration resistance, 2012, Indonesian National Standard, Indonesia.
22. Cuong N.H., Study on compressive strength and chloride ion permeability of high fly ash content self-compacting concrete, International Journal of GEOMATE, Vol. 26, Issue 113, pp. 34-40. https://doi.org/10.21660/2024.113.4164.