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Utilization of Waste Ceramic Powder as a Substitute of Fine Aggregate and Addition of Zinc Fibre to Increase the Split Tensile Strength of Concrete

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Abstract. Almost all buildings and buildings made of concrete have many advantages such as being easy to form, withstanding heavy loads, relatively low cost, and many other advantages concrete. However, there are still many buildings whose columns, walls, and beams still have cracks; the concrete is not strong against tensile forces and because of the overload carried by the concrete. Therefore, the research was conducted to find a solution to this problem. In this study, making concrete by adding additional materials to increase the split tensile strength of the concrete, namely ceramic powder and zinc fibre. Ceramic powder uses percentages of 0%, 20%, 25%, 30% as a substitute for fine aggregate. While the percentage of zinc fibre is 0%, 0.25%, 0.5%, 0.75%, 1%, and 1.5% as a substitute for coarse aggregate. The results of data analysis and sample testing show the value of the tensile strength of mixing ceramic powder and mixing the ceramic powder with zinc fibre. The results of testing concrete with ceramic powder mixing have an average split tensile strength optimum value at the age of 28 days 2.3 MPa, 3.16 MPa, 1.93 MPa. While the optimum value of the test results of the split tensile strength of concrete by mixing 25% ceramic powder and zinc fibre at the age of 28 days was 1.86 MPa, 1.73 MPa, 1.7 MPa, 1.73 MPa, 1.83 MPa, 2 MPa

INTRODUCTION

In the development of the construction world, concrete is often used as a structural and non-structural material. As a structural component of buildings, concrete is used as beams, columns and walls, foundations, and slabs. In building construction, concrete is currently one of the most widely used materials compared to other building materials. As a result of earthquakes that often occur in some areas in Indonesia, several houses and buildings have cracked walls and beams due to a lack of strength against tensile forces in concrete. These cracks occur due to a lack of strength against tensile forces. Concrete as a structural component is combined with steel reinforcement to withstand tensile forces in beams, instead cracks in the walls, which are non-structural components, are a different problem. Therefore, there must be additional materials in the form of fibres, powders, and chemical liquids to increase the strength of non-structural concrete.

Around 35% of waste is generated from raw materials used in construction sites or renovation of houses, such as zinc on the roof or ceramics on the floor. Some of this waste can be utilized on-site, such as for excavation pit refill. Still, most of these waste materials are generally thrown away or let pile up in one place or scattered everywhere to ruin the aesthetics of the whole region. Indispensable for developing environmentally friendly concrete from waste.

The use of zinc roofing is still common today. During zinc installation, the excess zinc will be cut and vainly disposed of on the ground and become a hazardous waste because it is made of thin and sharp metal. The use of zinc waste in the concrete mixture can also function as fibre to increase the tensile strength of the concrete in addition to the compressive strength required for structural concrete. Likewise, ceramic waste on construction sites can be utilized. Ceramic waste can be collected together and crushed into powder form to replace some cement of concrete mixture. The ceramic powder can substitute cement because of the silica content in ceramics found in cement. The high silica content in ceramics (up to 60%) is expected to increase the strength of concrete.

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A previous study on ceramic waste material shows that the compressive strength of concrete increases when the cement replacement with ceramic powder up to 30% by weight of cement, but more than 30% will decrease the compressive strength [1]. The utilization of ceramic waste as aggregate in concrete was also investigated, where the optimization of the use of ceramic waste as a substitute for sand was 25% to 50%. In comparison, its use as coarse aggregate was 10% to 20% [2]. The use of this ceramic waste not only increases the compressive strength but also reduces the specific gravity and reduces the negative effect such as water absorption, the effect of a ceramic electrical insulator, and the durability of concrete [3–6]. However, the use of ceramic waste material as a filler combined with zinc disposal as zinc fibre to increase the split tensile strength of concrete has not been studied. Therefore, zinc fibre was used as a mixed variable material and ceramic waste in this study, which became a binder in the concrete and prevented cracking (Fig. 1). The purpose of this study was to investigate the split tensile strength of concrete using zinc fibre as a mixed variable in the concrete material with a mixture of ceramic powder waste.

(a) (b)

FIGURE 1. (a) Ceramic Powder (b) and Zinc Fibre

METHOD OF RESEARCH

The research method used is an experimental study in the Concrete Materials Technology Laboratory of Civil Engineering Department of the Christian University of Indonesia (UKI). The research variables are the use of ceramic powder waste and zinc fibre to determine its effect on increasing the tensile strength of concrete. The research materials are taken from construction waste, namely ceramic waste powder and zinc fibre. The ceramic powder is a substitute for fine aggregate to improve the quality of concrete, while the addition of zinc fibre increases the split tensile strength of concrete. The zinc fibre of 2mm x 40mm, functions as a mixed variable material that becomes a binder in the concrete and prevents cracks when the concrete is pressed or pulled. So, the concrete is expected to be stronger in receiving split tensile stresses. Concrete samples use a cylindrical concrete mould with a size of (15x30) cm by testing the split tensile strength of the 28 days old.

The method of mixing ceramic powder variable materials in this study replaces 25%, 30%, and 35% of the fine aggregate weight. As for the mixing of zinc fibre, there are five variations of 0.25%, 0.5%, 0.75%, 1%, and 1.5% as a substitute for coarse aggregate weight. The stages to examine the split tensile strength in this research are as follows: (1) Collecting literature studies and data related to research; (2) Prepare waste materials (ceramic powder and zinc fibre); (3) Prepare the necessary tools and other materials; (4) Testing of waste materials properties to be used in this research; (5) Analyzing the feasibility of waste materials availability; (6) Design of concrete mixtures with waste materials; (7) Molding of concrete specimen samples; (8) The curing process of the concrete specimen with the age of 7,14, and 28 days; (9) Split tensile strength testing to obtain the optimum value for the variation of ceramic powder mixture at sample ages of 7, 14, 28 days of normal concrete using ceramic powder; (10) Testing of concrete specimen by mixing ceramic powder with zinc fibre by split tensile strength test at the age of 7, 14, and 28 days; (11) Analyzing the characteristics of concrete due to the effect of adding a variable mixture of powder and zinc fibre to the value of the tensile strength of the concrete. The overall process of the experimental study can be seen in Fig. 2.

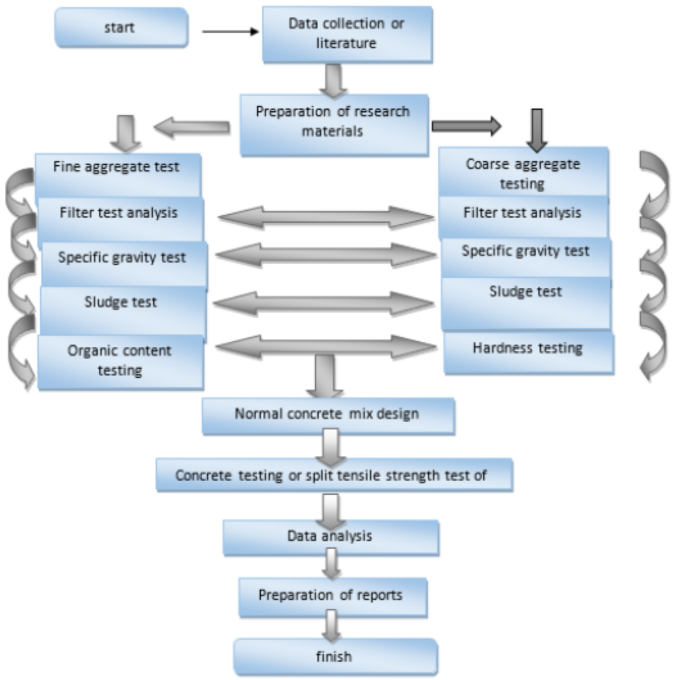

FIGURE 2. Flowchart of Experimental Study

RESULT AND DISCUSSION

The average split tensile strength test of concrete with a mixture of ceramic powder against normal concrete can be seen in Table 1, Table 2, and Table 3. Ceramics powder on concrete specimens as a substitute for fine aggregate is 25%, 30%, 35%, respectively.

TABLE 1. Test Results of 7 Days Split Tensile Strength Concrete with Waste Ceramic

The age of the test object is 7 days	Normal concrete	Variation of ceramic powder		
		25%	30%	35%
Sample 1	2	2.5	2	1.3
Sample 2	1.8	2.1	1.7	1.4
Sample 3	1.8	2.5	2.1	1.7
Average	1.86	2.36	1.93	1.46

In Table 1, the results of the 7-day age test obtained an average value of 2.36 MPa at a percentage of 25% ceramic powder. These results show an increase of 27% from the split tensile strength of normal concrete at 1.86 MPa. Furthermore, if the addition of ceramic powder is more than 25%, the results obtained will reduce the split tensile strength of concrete. Therefore, the addition of ceramic powder is limited to only 25% to increase the split tensile strength of concrete effectively. The same results were also seen in the 14-day and 28-day-old concrete test with 25% ceramic powder (Table 2, Table 3), where the split tensile strength increased by 36% and 70%, respectively, compared to normal concrete. It can be seen that the mixed ceramic powder of about 25% is very significant for increasing the split tensile strength of up to 70% of the concrete because it contains a fairly high SiO2 compound. The use of ceramic powder will certainly reduce the amount of cement used in the concrete mix. The use of ceramic powder will certainly reduce the amount of cement used in the natural concrete mix and minimize polluting the environment by utilizing existing construction waste. Thus, more environmentally friendly concrete can be produced.

TABLE 2. Test Results of 14 Days Split Tensile Strength Concrete with Waste Ceramic

The age of the test object is 14 days	**Normal concrete**	**Variation of ceramic powder**		
		25%	**30%**	**35%**
Sample 1	2	2.6	2	1.4
Sample 2	1.8	2.4	1.6	1.6
Sample 3	1.8	2.6	2.1	1.6
Average	1.86	2.53	1.9	1.53

TABLE 3. Test Results of 28 Days Split Tensile Strength Concrete with Waste Ceramic

The age of the test object is 28 days	**Normal concrete**	**Variation of ceramic powder**		
		25%	**30%**	**35%**
Sample 1	2	3.2	1.8	2.2
Sample 2	1.8	3.3	1.6	1.6
Sample 3	1.8	3	1.8	2
Average	1.86	3.16	1.73	1.93

From the graph of the test results for the split tensile strength of concrete at the age of 7 days, as shown in Fig. 3, the optimum value of the split tensile strength of concrete is the addition of ceramic powder of 16%. Concrete's optimum split tensile strength is about 2.9 MPa, with the optimum percentage of ceramic powder mixture around 16%.

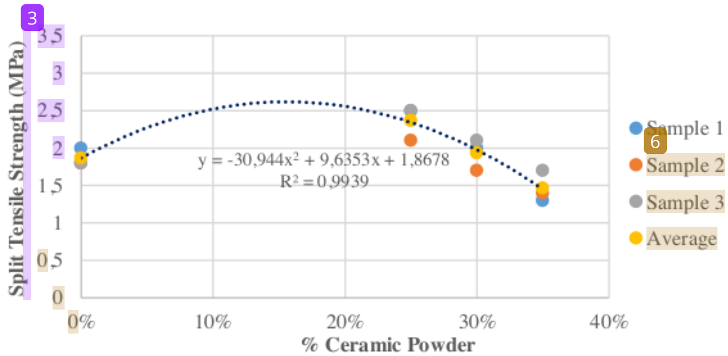

FIGURE 3. Average Tensile Strength of 7 Days Concrete with Waste Ceramic

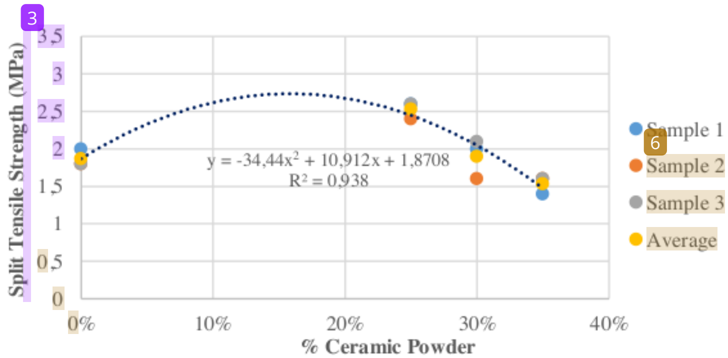

FIGURE 4. Average Tensile Strength of 14 Days Concrete with Waste Ceramic

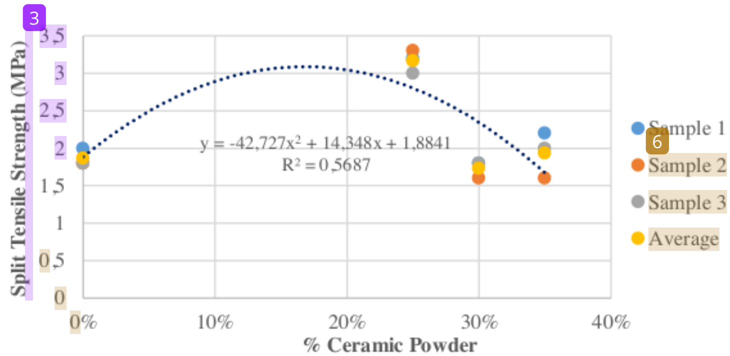

FIGURE 5. Average Tensile Strength of 28 Days Concrete with Waste Ceramic

Moreover, from Fig. 4 and 5, the results obtained of the split tensile strength in 14-days and 28-days testing of concrete reach optimum values at 2.6 MPa and 3.3 MPa, respectively, with the mixed ceramic powder of about 15% to 20%. The split tensile strength of the concrete increased with the use of ceramic powder at each age of the concrete, from 7 days up to 28 days. The highest increase was achieved at the age of 28 days of concrete, as shown in Figure 5 where the split tensile strength was almost 4 MPa with a mixture of 16% ceramic powder.

It can be seen that ceramic powder effectively increases the split tensile strength of concrete with an optimum mixture value of around 16%. The use of ceramic powder waste in large proportions will certainly reduce environmental waste. Still, it must consider the mechanical properties of the concrete, which is split tensile strength. Therefore, ceramic powder is limited to 25% and then combined with zinc fibre in the concrete mix. The experimental results prove that the concrete mixture using 25% ceramic waste combined with zinc fibre with a certain percentage can also increase the split tensile strength of the concrete. The results of testing the split tensile strength of mixed concrete, aged 7, 14, 28 days using 25% ceramic waste combined with zinc fibre with varying percentages of 0.25%, 0.5%, 0.75%, 1%, 1.5 respectively can be seen in Table 4, Table 5, and Table 6 as follows:

TABLE 4. Test Results of 7 Days Split Tensile Strength Mixture Concrete with Waste Ceramic and Zinc Fibre

The age of the test object is 7 days	**Normal concrete**	**Variations of Zinc Fibre**				
		0.25%	**0.5%**	**0.75%**	**1%**	**1.5%**
Sample 1	2.1	1.6	1.5	1.3	1.5	1.4
Sample 2	1.7	1.6	1.5	1.3	1.3	1.3
Sample 3	1.8	1.5	1.4	1.2	1.2	1.4
Average	1.86	1.56	1.46	1.26	1.3	1.36

The addition of 1.5% zinc fibre until the age of 7 days will initially reduce the split tensile strength of the concrete as shown in Table 4. Then with the increasing age of concrete (Fig. 6 and 7) combined with 25% ceramic powder, it can be seen that the split tensile strength of the concrete will increase with 1.5% zinc fibre addition. The increase that occurs in about 5% to 8% of the split tensile strength of concrete is 1.96 MPa in 14-days concrete and 2 MPa in 28-days concrete compared to normal concrete of 1.86 MPa.

TABLE 5. Test Results of 14 Days Split Tensile Strength Mixture Concrete with Waste Ceramic and Zinc Fibre

The age of the test object is 14 days	**Normal concrete**	**Variations of Zinc Fibre**				
		0.25%	**0.5%**	**0.75%**	**1%**	**1.5%**
Sample 1	2	1.67	1.67	1.67	1.5	2.1
Sample 2	1.8	1.6	1.6	1.6	1.4	1.8
Sample 3	1.8	1.7	1.7	1.6	1.4	2
Average	1.86	1.66	1.62	1.62	1.43	1.96

TABLE 6. Test Results of 28 Days Split Tensile Strength Mixture Concrete with Waste Ceramic and Zinc Fibre

The age of the test object is 28 days	**Normal concrete**	**Variations of Zinc Fibre**				
		0.25%	**0.5%**	**0.75%**	**1%**	**1.5%**
Sample 1	2	1.7	1.8	1.8	1.8	2.2
Sample 2	1.8	1.7	1.6	1.7	2.1	1.8
Sample 3	1.8	1.8	1.7	1.7	1.6	2.1
Average	1.86	1.73	1.7	1.73	1.83	2

From the graph of the test results, it can be seen in Fig. 6 to 8 that the split tensile strength of concrete will increase with the addition of 1.5% zinc fibre in concrete with a mixture of 25% ceramic waste.

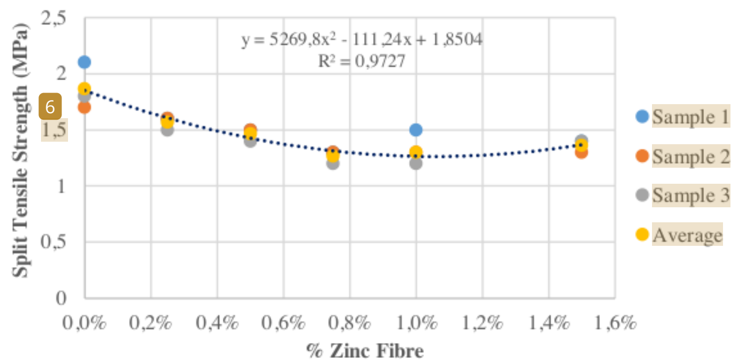

FIGURE 6. Average Tensile Strength of 7 Days Concrete with Waste Ceramic and Zinc Fibre

The pattern of increasing split tensile strength in concrete, aged 14 days (Fig. 7) and 28 days (Fig. 8) shows a similarity where there is an increase in strength with the addition of zinc fibre around 0.6% to 0.8%, while in 7-days concrete (Fig. 6) in around 0.8% to 1.2%. It shows that the age of concrete greatly affects the function of zinc fibre to provide a split tensile strength in concrete.

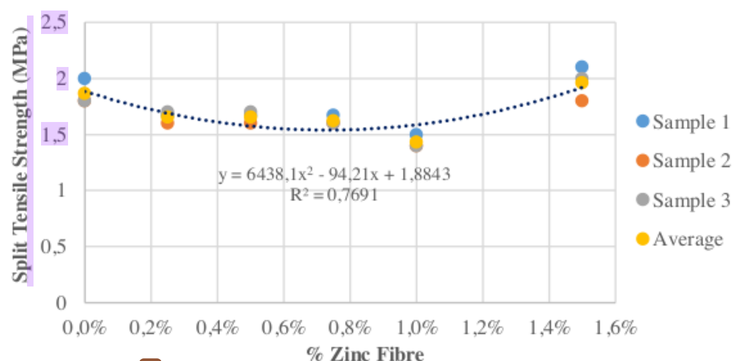

Figure 7. Average Tensile Strength of 14 Days Concrete with Waste Ceramic and Zinc Fibre

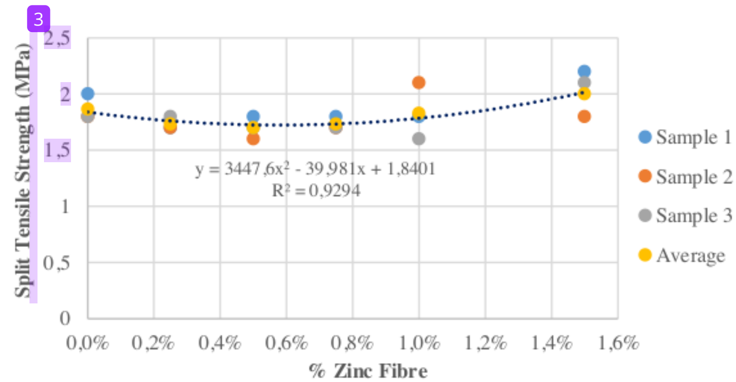

FIGURE 8. Average Tensile Strength of 28 Days Concrete with Waste Ceramic and Zinc Fibre

From the results of the tests carried out, it can be seen in Fig. 7 and 8 that the use of 1.5% zinc fibre with a combination of 25% ceramic powder in concrete can increase the split tensile strength by 13% and 18%, respectively by 2.1 MPa at the age of 14 days of concrete and 2.2 MPa at 28 days of concrete age.

CONCLUSIONS

Based on the research and data analysis results, the conclusions have been described that the addition of ceramic powder of mixed concrete as a substitute for 25% fine aggregate can increase the split tensile strength of the concrete. The mixed ceramic powder of about 25% is significant for increasing the split tensile strength of up to 70% of the concrete because it contains a fairly high SiO2 compound. The results of testing concrete with ceramic powder mixing have an average split tensile strength optimum value at the age of 28 days 2.3 MPa, 3.16 MPa, 1.93 MPa. In contrast, the value of the test results of the split tensile strength of concrete by mixing 25% ceramic powder and zinc fibre at the age of 28 days was 1.86 MPa, 1.73 MPa, 1.7 MPa, 1.73 MPa, 1.83 MPa, 2 MPa. It concluded that the greater the percentage of ceramic powders replacing fine aggregates, the lower the split tensile strength. The average optimum value from the tensile strength test results of the 7, 14, 28-day-old ceramic powder mixing concrete is around 2.9 MPa; 2.9 MPa; 3.9 MPa with an optimum mixture value of ceramic powder of 16%. From the previous research literature studies using ceramic powder with a percentage of 10%, 15%, and 20% as a substitute for fine aggregates, the optimum value for split tensile strength is 20%. However, in this study using ceramic powder with percentages of 25%, 30%, and 35% as a substitute for fine aggregate, the optimum value is around 16%. Meanwhile, the average optimum value from the results of the tensile strength test of 25% ceramic powder combine with zinc fibre vary from 0.25%, 0.5%, 0.75%, 1.0%, 1.25%, 1.5%, mixture concrete in 7,14, 28-day-old are around 1.4 MPa; 2.1 MPa; 2.2 MPa. The optimum value of split tensile strength of concrete by mixing 25% ceramic powder as a substitute for coarse aggregate and 1.5% zinc fibre at the age of 28 days with a split tensile strength of 1.96 MPa can exceed the split tensile strength of normal concrete. In further research, it is recommended to use a mixture of ceramic powder variations below 25% as a substitute for fine aggregate for testing split tensile strength in concrete, considering this result can be applied on porous concrete pavements.

REFERENCES

1. Awoyera PO, Ndambuki JM, Akinmusuru JO, Omole DO. Characterization of ceramic waste aggregate concrete. HBRC J. 2018;14(3):282–7.
2. Halicka A, Ogrodnik P, Zegardlo B. Using ceramic sanitary ware waste as concrete aggregate. Constr Build Mater. 2013;48:295–305.
3. Rashid K, Razzaq A, Ahmad M, Rashid T, Tariq S. Experimental and analytical selection of sustainable recycled concrete with ceramic waste aggregate. Constr Build Mater. 2017;154:829–40.
4. Tavakoli D, Hashempour M, Heidari A. Use of waste materials in concrete: A review. Pertanika J Sci Technol. 2018;26(2):499–522.
5. Pacheco-Torgal F, Jalali S. Compressive strength and durability properties of ceramic wastes based concrete. 2011;

6. Medina C, De Rojas MIS, Frías M. Reuse of sanitary ceramic wastes as coarse aggregate in eco-efficient concretes. Cem Concr Compos. 2012;34(1):48–54.

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