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Comparison of Compressive Strength of Concrete Using White Portland Cement with Gray Cement

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Abstract. White Portland cement (WPC) in Indonesia is generally used for architectural work. WPC is still rarely used in structural concrete because the price is relatively higher than grey cement. This research reviewed the compressive strength of concrete using WPC and compared it with concrete using grey cement. Compressive strength testing of concrete using WPC and grey cement was carried out at ages: 3, 7, 14, 21, and 28 days. From the research, the compressive strength of concrete using WPC was 13.81 MPa (60%) at 3 days, 16.68 MPa (72%) at 7 days, 19.45 MPa (84%) at 14 days, 22.34 MPa (97%) at 21 days, and 23.11 MPa (100%) at 28 days. The compressive strength of concrete using grey cement was 13.03 MPa (63%) at 3 days, 15.11 MPa (74%) at 7 days, 17.22 MPa (84%) at 14 days, 18.78 MPa (91%) at 21 days, and 20.54 MPa (100%) at 28 days. The compressive strength of concrete using WPC is higher than grey cement at all ages. The rate of compressive strength of concrete using WPC is almost the same as grey cement at all ages.

Keywords: white Portland cement, compressive strength, ages of concrete, structural concrete

INTRODUCTION

White Portland Cement (WPC) is widely used in architecture to create aesthetic effects, such as finishing the exposed aggregate and making colored cement with the addition of pigments [1]. The white color of WPC is achieved by eliminating iron and magnesium oxide, which are substances that cause a grey color in cement [2]. WPC has a high C_3A content and without C_4AF. The high cost of raw materials and the manufacturing process, so that white cement is expensive [1]. The difference with grey cement is only in terms of the color [1, 2, 3]. White Portland cement (WPC) is made according to the specifications of ASTM C150 [4]. The most common are according to types I and III, although type II and V are also produced.

WPC has several advantages over grey cement. The impact of high temperatures on mortar using WPC is lower than that of mortar using Ordinary Portland Cement (OPC) [5]. WPC produces concrete that is durable and suitable for aggressive environments to protect the reinforcement from chloride and sulfate attack [6].

WPC has several disadvantages compared to grey cement. WPC is finer than grey cement, so the consistency of WPC cement paste is higher than grey cement [7]. Initial setting time and final setting time of WPC is lower than grey cement [7, 8]. Workability of concrete with WPC is lower than OPC [9]. Permeability of concrete using WPC is comparable to that of the grey cement [10].

Compressive strength is one of the essential properties in concrete. One of the factors that affects the compressive strength of concrete is the type of cement. Compressive strength of concrete using WPC is higher than OPC [8, 9, 11, 12]. The strength of concrete using WPC increases higher than grey cement at the same age [13]. The use of WPC as a substitute for 25% OPC causes cement mortar production to be different in terms of color and specifications being better [14]. SRPC (Sulphate Resisting Portland Cement) substitution with WPC increases the concrete compressive strength and splitting tensile strength [15]. Normal concrete using WPC can be used for frame construction, and lightweight concrete using WPC can be used for reinforced concrete panels [16]. WPC can be used for structural and architectural concrete [3].

WPC in Indonesia is generally used for architectural work, and fiber reinforced precast concrete, panels, terrazzo surfaces, stucco, cement paint, tile grout, and decorative concrete. White cement is still rarely used in structural concrete because the price is relatively higher than grey cement. Information about the use of white cement for structural concrete is also lacking. Based on these reasons, it is necessary to conduct research on the use of Indonesia WPC products for structural concrete. The aim of this research was to determine the comparison of compressive strength of concrete using white Portland cement (WPC) with gray cement.

MATERIAL AND METHODS

This research reviewed the compressive strength of concrete using WPC and compared it with concrete using grey cement. The WPC used in this study is an Indonesian product made in accordance with the Indonesian National Standard SNI 15-0129-2004[17]. The grey cement is Portland Composite Cement (PCC) which is made in accordance with Indonesian National Standard SNI 7064: 2014[18].

Sand is used from the Progo river, Yogyakarta, Indonesia. Sand tests carried out in this study consisted of silt testing according to SNI 03-4142-1996 [19], specific gravity and absorption according to SNI 1970:2016 [20], unit weight according to SNI 03-4804-1998 [21], and fineness modulus according to SNI ASTM C136:2012 [22]. The sand test results are shown in Table 1 and Figure 1.

TABLE 1. Test results of sand

Types of testing	Test results	Unit
Silt content	2.81	%
Specific gravity (SSD)	2.63	-
Unit weight	1.56	g/c m^3
Fineness Modulus (FM)	2.67	-
Absorption	1,92	%

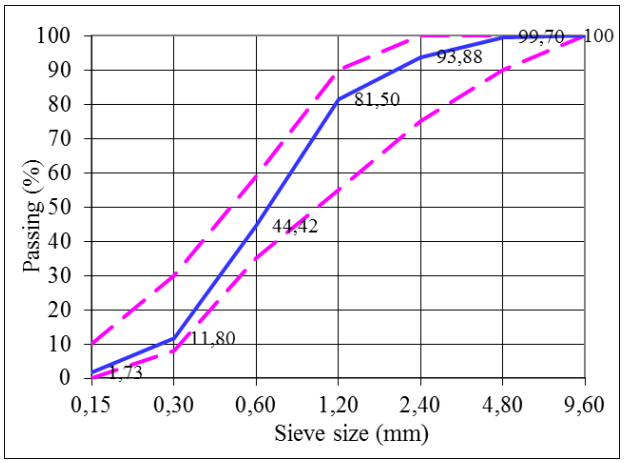

FIGURE 1. Grading of sand

Table 1 and Figure 1 show that the sand used in this study is classified as rather coarse sand because it is in grading zone II, or medium sand because the modulus of fineness between 2.6 - 2.9.

The crushed stone was taken from Kulon Progo, Yogyakarta, Indonesia. The crushed stone has specific gravity and absorption according to SNI 1969:2016 [23], unit weight according to SNI 03-4804-1998 [21], and fineness modulus, according to SNI ASTM C136:2012 [22]. The crushed stone test results are shown on Table 2 and Figure 2.

TABLE 2. Test results of crushed stone

Types of testing	Test results	Unit
Specific gravity (SSD)	2.61	-
Unit weight	1.46	g/cm^3
Fineness Modulus (FM)	6.80	-
Absorption	1.63	%

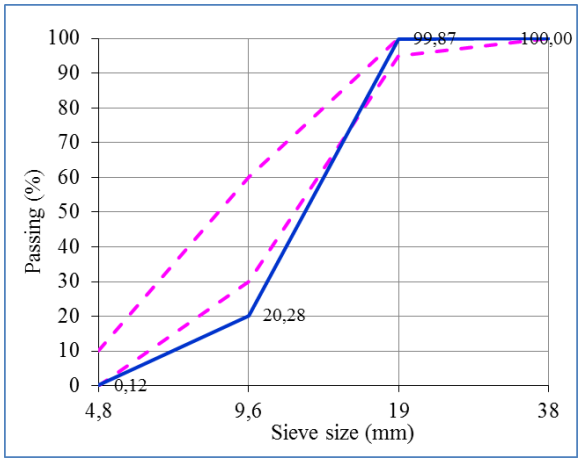

FIGURE 2. Grading of crushed stone

Table 2 and Figure 2 show that the crushed stone has a maximum size of 20 mm and fineness modulus between 6.0 - 6.9.

Concrete mix design, according to SNI 03-2834-2000 [24]. The results of the mix design calculation for 1 m^3 concrete with characteristic compressive strength of 20 MPa are as follows: 205 liters of water, 394 kg of cement, 650 kg of sand, and 1071 kg of crushed stone. Compressive strength testing of concrete using WPC and grey cement was carried out at ages: 3, 7, 14, 21, and 28 days. Compressive strength testing of concrete, according to SNI 1974: 2011 [25]. The specimen of each variation in age and type of cement consists of 3 concrete cylinders, with a total of 30 cylinders. The specimen is shown in Figure 3.

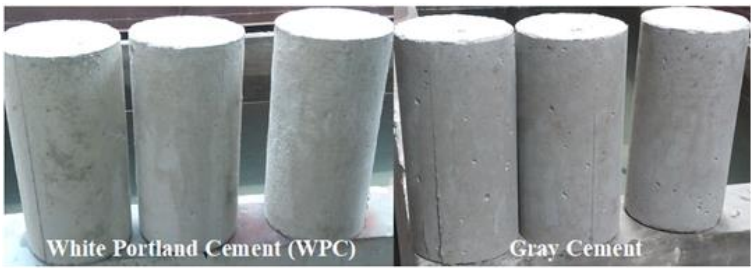

FIGURE 3. Concrete cylinder specimen

RESULTS AND DISCUSSION

The compressive strength of concrete using WPC and grey cement at ages 3, 7, 14, 21, and 28 days are shown in Table 3, Figure 4, and Figure 5.

TABLE 3. Compressive strength of concrete using WPC and gray cement

Age (Days)	Average Compressive Strength			
	WPC		Gray Cement	
	(MPa)	(%)	(MPa)	(%)
3	13,81	60	13,03	63
7	16,68	72	15,11	74
14	19,45	84	17,22	84
21	22,34	97	18,78	91
28	23,11	100	20,54	100

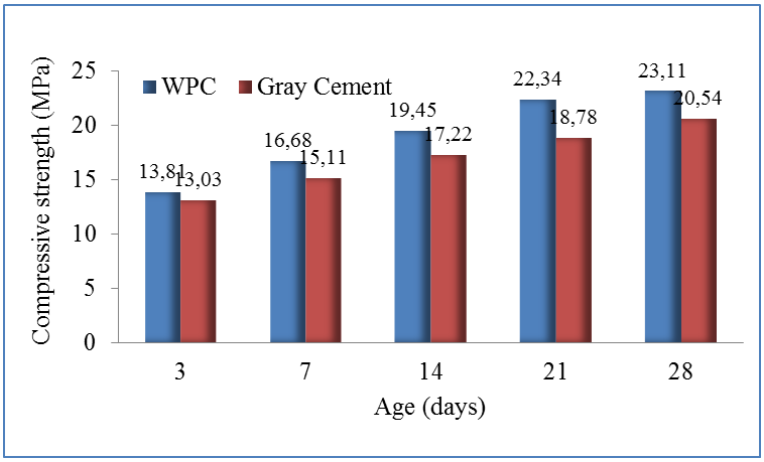

FIGURE 4. Compressive strength of concrete at various ages

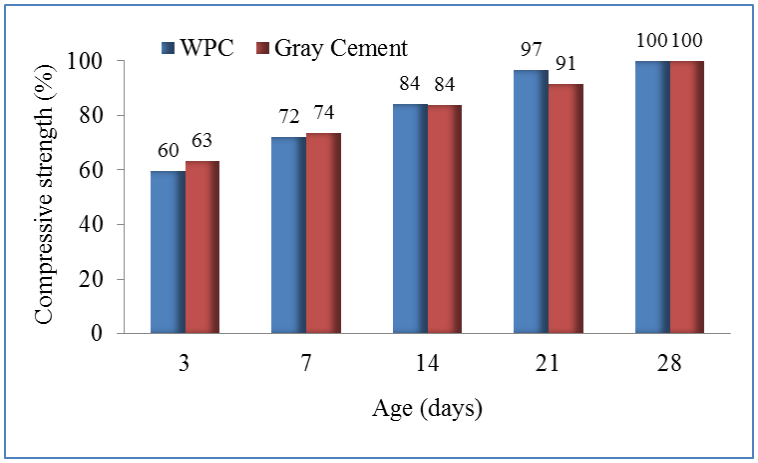

FIGURE 5. Percentage compressive strength of concrete at various ages

From Table 3 and Figure 4, it is shown that the compressive strength of concrete using WPC and grey cement increases with increasing age of concrete. The compressive strength of concrete using WPC is higher than grey cement at all ages. At the age of 28 days, the compressive strength of concrete using WPC is 23.11 MPa, exceeding the characteristic compressive strength of concrete in mix design which is 20 MPa. The compressive strength of concrete using grey cement is 20.54 MPa which is slightly higher than the characteristic compressive strength of concrete, which is 20 MPa. The compressive strength of concrete at the age of 28 days using white cement is greater than grey cement [8, 9, 11, 12].

From Table 3 and Figure 5, it is shown that concrete using WPC gains compressive strength of 60% at three days, 72% at seven days, 84% at 14 days, 97% at 21 days, against concrete strength at the age at 28 days. Concrete using grey cement (PCC) gain compressive strength of 63% at three days, 74% at seven days, 84% at 14 days, 91% at 21 days, against concrete strength at 28 days. Concrete using grey cement (OPC) gain compressive strength of 48% at three days [26], 66% at seven days [27], 68% at seven days [26], 81% at 14 days [27], against concrete strength at 28 days. The percentage of compressive strength concrete using WPC at ages 3, 7, 14, 21, and 28 days is almost the same as the concrete compressive strength using grey cement.

The unit weight of concrete using WPC and grey cement at ages 3, 7, 14, 21, and 28 days are shown in Table 4 and Figure 6.

TABLE 4. Unit weight of concrete using WPC and gray cement

Age (Days)	Unit weight (kg/m^3)	
	WPC	**Gray Cement**
3	2318	2321
7	2345	2346
14	2359	2330
21	2324	2390
28	2323	2357

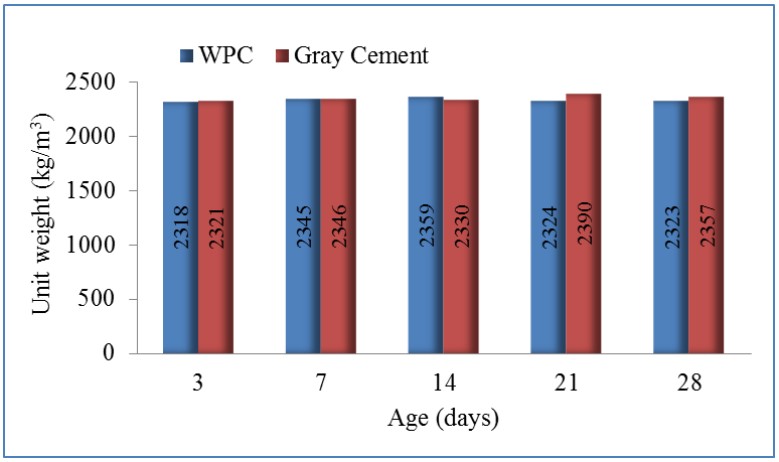

FIGURE 6. Unit weight of concrete at various ages

Table 4 and Figure 6 show that the age of the concrete does not significantly influence the unit weight of the concrete using WPC cement and grey cement. The unit weight of the concrete using WPC is almost the same as concrete using grey cement at all ages [9].

CONCLUSION

From the results of the study, it can be concluded that: the compressive strength of concrete using WPC was 13.81 MPa at 3 days, 16.68 MPa at 7 days, 19.45 MPa at 14 days, 22.34 MPa at 21 days, and 23.11 MPa at 28 days. The compressive strength of concrete using grey cement was 13.03 MPa at 3 days, 15.11 MPa at 7 days, 17.22 MPa at 14 days, 18.78 MPa at 21 days, and 20.54 MPa at 28 days. The compressive strength of concrete using WPC and grey cement increases as the concrete ages. The compressive strength of concrete using WPC is higher than grey cement at all ages. The rate of compressive strength of concrete using WPC was 60% at 3 days, 72% at 7 days, 84% at 14 days, 97% at 21 days, against the compressive strength of concrete at 28 days. The rate of compressive strength of concrete using grey cement was 63% at 3 days, 74% at 7 days, 84% at 14 days, 91% at 21 days, against the compressive strength of concrete at 28 days. The rate of compressive strength of concrete using WPC and grey cement is almost the same at all ages. The unit weight of concrete using WPC is almost the same as grey cement, which is 2318-2390 kg/m^3.

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