Journal of Sustainable Civil Engineering and Technology
Vol 1 Issue 1 (March 2022) 29–41

Influence of wastepaper sludge ash (WPSA) on ultimate flexural and non-destructive test (NDT) results of Ultra-High-Performance Concrete (UHPC)

Wan Mohd Syahidin Wan Sukri[1], Sakhiah Abdul Kudus[1*], Adiza Jamadin[1], Nurkamaliah Mustaffa[1], and Kunimoto Sugiura[2]

[1]School of Civil Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

[2]Department of Civil and Earth Resources Engineering, Graduate School of Engineering, Kyoto University, Kyoto, 615-8540, Japan

* Corresponding author E-mail address: sakhiah@uitm.edu.my

Received: 04 January 2022 / Accepted: 26 February 2022 / Published online: 28 March 2022

Abstract

Nowadays, cement is widely used in the construction industry for the development of this modern era, which causes bad effects on the environment and human health. Besides, waste products such as wastepaper are the other problems facing the environment and land field disposal. In this research, the use of WPSA is not only used as an alternative way to save the environment but also to improve concrete strength in UHPC. WPSA has been added in the range of 5% to 15% of the total weight of cement in UHPC. The prisms with a size of 100 mm x 100 mm x 500 mm with a different percentage of WPSA were tested for flexural tests and non-destructive tests (NDT), which measure ultrasonic pulse velocity and rebound. These tests were carried out to evaluate the flexural strength and mechanical properties of WPSA based on NDT testing. The results show the addition of 5%, 10%, and 15% of WPSA, which are 1.96 N/mm2, 2.26 N/mm2, and 2.11 N/mm2 respectively, in UHPC, which causes the lower flexural strength result. At the same time, the UPV test result shows the concrete is of doubtful quality for all specimens. The average pulse velocity of control UHPC is 2397.38 m/s, which is the highest. This result was also followed by a rebound number that represents low compressive strength as compared to the result of the compressive test. The highest average compressive strength is 38 MPa, which represents the control UHPC. At 5% WPSA addition, the compressive strength started to decrease. The addition of 10% and 15% of WPSA causes a more significant drop in compressive strength.

Keywords: Ultra-high-perfomance-concrete, wastepaper sludge ash, non-destructive testing, flexural test

1. Introduction

Concrete is the most commonly used material in the building industry and is widely used not only in Malaysia but worldwide. As an example, the construction of buildings, bridges, and roads are concrete structures that can be seen in daily life. Concrete mixture generally consists of cement, coarse and fine aggregates, and water. These materials mixture will form hard concrete. Due to the high speed of development, concrete material demand increases because it has good strength, resilience, and resistance while the cost of using concrete is also cheap with a guarantee of low maintenance cost makes it popular in any construction (Kusumawardaningsih et al., 2013). Recently, the high demand for construction materials causes the supplies to rise every day. There are many studies on concrete materials by engineers in order to find the material that can be substituted with other resources that not only improve its strength but also eliminate fully or partially uses of cement to reduce its cost in construction. The addition of cementing material does not only increase the durability of concrete but is also important to cater to environmental problems (Ahmad et al., 2013). Hence, blended cement was introduced by many researchers as an alternative to solve these problems (Abdul Razak et al., 2021; Kamaruddin et al., 2022).

Cement is one of the most extensive materials used in industrial construction widely in the world. It is a very important material in any construction material for the development of building and infrastructure which is a key for a growing economy. Cement is the common material used as a binder that enhances the other material to combine with the presence of water (Devi et al., 2018). Fine aggregate such as sand mixed with cement produces mortar while the combination of fine and coarse aggregate with cement produces concrete. The manufacturing of cement uses a large number of sources that cannot be renewable. This industry contributes to using a huge amount of energy-intensive processes which cause about 5-6% of carbon dioxide production, a potent greenhouse gas. Small particles such as dust and the emission of harmful gas are released to the environment due to the utilization of raw material and energy. A smaller particle that releases into the air may contain organic compounds and heavy metals while harmful gases such as nitrogen oxide, carbon monoxide, fluorides, chlorides, and others are released from the kiln of cement (Devi et al., 2018). The releases of harmful gases cause a reduced amount of oxygen and a large number of small particles fly in the air producing a bad quality of air. These emissions are not only bad for the environment but also affect human health. The impact of these emissions will contribute to global warming, depletion of the ozone layer, acid rain, and others. A study from the past researcher, diseases like asthma attacks, cardio-vascular, bronchitis, and many more are affected by harmful emission of gas and bad air quality.

Ultra-high-performance concrete (UHPC) is an improvement engineering of concrete technology in the last two decades. The excellent innovation of this concrete boost strength, workability, durability, and ductility. UHPC has been attracted by many countries with various use such as in building, bridges, and pavement because of its mechanical properties improvement as compared to normal concrete (Azmee et al., 2018). UHPC become popular in the construction industry which causes the usage demand increases. This is because UHPC has high strength and high resilience where the compressive strength can exceed 150MPa compared to normal concrete (NC) strength (Faizal et al., 2014). The strength and durability of UHPC increases if fiber is added in the content that improves its properties and can withstand for a longer period, more safe and lower cost of maintenance of a building (Kusumawardaningsih et al., 2013). Previously, UHPC is called reactive powder concrete (RPC) (Barbos, 2016). The mixing of material such as cement, cementitious binder, fine aggregate, admixtures, limestone and or quartz flour, steel fibers, and water that combine together produce a very high compressive strength of concrete that exceed 150Mpa. Small or fine material particles are used to enhance the particles to fill the space between the composition of cement and coarser aggregates in order to produce UHPC (Kusumawardaningsih et al., 2013).

One of the waste material products produced by the paper industry is Wastepaper Sludge Ash (WPSA) (Sani et al., 2011). According to Anuar et al. (2011), WPSA is a form of ash produced from paper mill sludge by-product which the paper is de-inked and re-pulped. Oxide materials in WPSA are obtained from the burning of inorganic compounds. In Malaysia, the Malaysian Newsprint Industry (MNI) based in Pahang is one of the largest sources of WPSA where the process of producing the ash as shown in Figure 1.

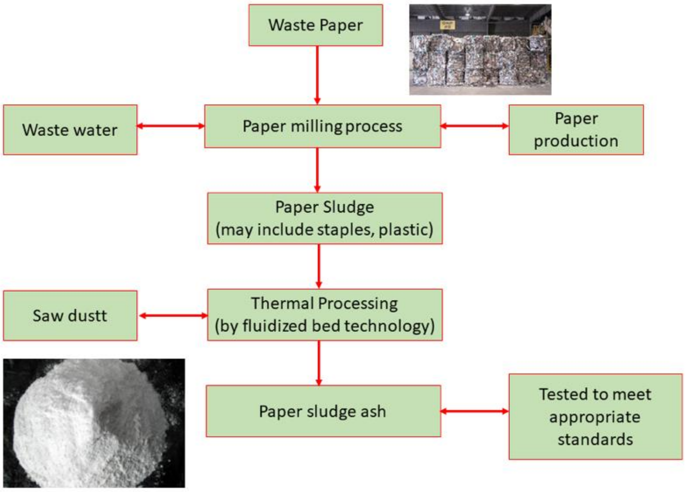

Figure 1: The process of WPSA production (Anuar et al., 2011)

Sani et al. (2011) stated that WPSA can be used as a binder to form paste if it is mixed with water where its behaviour acted same as Ordinary Portland Cement (OPC). Calcium Oxide (CaO) and Silica (SiO2) are the major elements found in WPSA as shown in Table 1. The hydration of pozzolanic material for hardening can occur after an alkaline agent is activated. WPSA is determined by MNI as non-pozzolanic material since it contains less than 50% of the total three combination chemical constituent of silicon dioxide, aluminum oxide, and ferric oxide (Sharipudin & Ridzuan, 2013).

Table 1: Typical chemical composition of WPSA (Sharipudin & Ridzuan, 2013)

Chemical Composition of WPSA	**Percentage (%)**
SiO_2	15.16
Al_2O_3	6.06
Fe_2O_3	1.11
TiO_2	0.45
MgO	2.00
CaO	55.87
Na_2O	0.19
K_2O	0.34
P_2O_5	0.48
MnO	0.05
SiO_3	0.78
Loss of Ignition (LOI)	17.51

2. Methodology

2.1 Materials

2.1.1 Cement

In this study, four (4) series of concrete mixtures of WPSA addition in UHPC which are control, 5%, 10%, and 15% were cast. Ordinary Portland Cement (OPC) type CEM I provided by Tasek Corporation Berhad was used as a binder in the concrete. The properties of OPC are followed according to MS EN 197-1:2014 and BS EN 197-1:2000. The concrete mixture was prepared using OPC while WPSA in UHPC mixes were prepared by adding the WPSA with different amount of WPSA which are 5%, 10%, and 15% from the overall weight of OPC.

2.1.2 Aggregates

The crushed gravel was used to contribute compressive strength of the concrete and also affect the fresh concrete properties from its texture and shape of the aggregate. The coarse aggregate used was crusher run with the maximum size of 10 mm according to BS EN933-1:2012. For fine aggregates, sand was used to bond cement paste and fill in the void between the cement in concrete. The sand that was used must be passed through a 2 mm size sieve pan.

2.1.3 Water

Water was used for this experiment to act as the lubricant with cement particles which affect the workability of fresh concrete mixture and hydration process of hardened concrete. In order to maintain its characteristics, following BS EN 1008:2002, water must be free from any contamination when mixing which will affect the setting time of concrete.

2.1.4 Superplasticizer

In order to develop high strength of concrete, superplasticizer namely Master Glenium ACE 8538 supplied by BASF (M) Sdn. Bhd was used. The other purpose of using this chemical admixture is to decrease water usage as well as decrease the water over cement ratio. The uses of superplasticizer also to increase workability or flow of fresh concrete which was eased for placement of fresh concrete to the formwork.

2.1.5 Wastepaper Sludge Ash (WPSA)

WPSA is a by-product of paper and board industry. It comes from the burning of Wastepaper Sludge (WPS) to form such as white powder color. It contains a very high amount of calcium which is good for fast hardening in concrete. For this study, the WPSA was sieved passing 212 micron (μm) using a sieve pan.

2.2 Mix Proportion

Four (4) set mix proportions of UHPC and WPSA in UHPC were prepared. The UHPC mix was designated as UHPC or control mix (0% WPSA) and the addition of WPSA in UHPC contained a different amount of UHPC which are 5%, 10%, and 15% were designated as UHPC-WPSA5, UHPC-WPSA10, and UHPC-WPSA15 respectively. The mix proportion of the UHPC and UHPC-WPSAs are tabulated in Table 2.

Table 2: Mix proportion of UHPC and UHPC-WPSAs

Materials	**UHPC**	**UHPC-WPSA5**	**UHPC-WPSA10**	**UHPC-WPSA15**	**Unit**
Cement (800 kg/m^3)	13.2	15.6	15.6	15.6	kg
Coarse Aggregate (800 kg/m^3)	13.2	15.6	15.6	15.6	kg
Fine Aggregate (433 kg/m^3)	7.14	8.44	8.44	8.44	kg
Water (160 kg/m^3)	2.64	3.12	3.12	3.12	kg
Glenium (16 kg/m^3)	0.26	0.31	0.31	0.31	kg
WPSA	0	0.78	1.56	2.34	kg

In addition, Ordinary Portland Cement (Type 1) was used with a constant water-cement ratio value which is 0.2. A total of 12 beams were cast which represent three beams for each percentage addition of WPSA into UHPC. The beam dimension is 100 mm x 100 mm x 500 mm. Flexural tests and non-destructive tests were used for testing. The slump test was conducted to show the workability of fresh concrete. Each specimen was cured in water for 28 days. After curing was done, flexural test and non-destructive test conducted using rebound hammer and ultrasonic pulse velocity were tested.

2.3 Test Methods

2.3.1 Flexural Test

The concrete beams that had been cast and cured were tested for the determination of flexural strength. All concrete beams will be tested for their flexural strength after 28 days from casting day. In this study, a four-point test was used and the result of elasticity modulus, rupture modulus, and stress-strain diagram can be determined. This flexural test was tested following standard BS 1881:4 by using Universal Testing Machine (UTM).

2.3.2 Ultrasonic Pulse Velocity Test

Ultrasonic pulse velocity test was conducted to determine the wave velocity of the concrete structure which can determine its homogeneity of concrete such as internal voids or crack. In simple words, this UPV was selected in this experiment in order to check the wave pulse velocity to determine the quality of the concrete specimen without damaging the structure. UPV tests were carried out by following standard BS EN 12504-4:2004. High speed velocity pulse going through the body of concrete showed that the concrete was approximately perfect while slow velocity showed by the pulse represents poor quality of concrete with internal voids and cracks. For this research, all three specimens for every mix were tested by using the indirect method for all four sides of beams.

By using the indirect method, the time taken for the pulse to traverse the path length was recorded. Equation (1) was used to calculate the pulse velocity of the concrete to determine the quality of the concrete.

$$V = L/T \qquad (1)$$

Where V is pulse velocity, L is the length of travel and T is the time taken for the pulse to travel. The aim is to find the pulse velocity, V, therefore the concrete quality or grading can be determined by referring to Table 3.

Table 3: Quality of concrete category based on UPV (Lawson et al., 2011)

UPV (m/s)	**Concrete Quality (Grading)**
Above 4500	Excellent
3500 to 4500	Good
3000 to 3500	Medium
Below 3000	Doubtful

2.3.3 Rebound Hammer Test

Rebound hammer test was used in this experiment is Schmidt Rebound Hammer according to BS EN 12504-2:2001. The aim to conduct a rebound hammer test is to find the compressive strength of the structure without destroying the structure of concrete. The rebound number was taken for every different percentage amount of WPSA added in UHPC. The parameter obtained from this test is Rebound Number (RN). From the rebound number, the values of average compressive strength were determined.

3. Results and Discussion

3.1. Flexural Strength

Based on Table 4 shows the flexural test results on the prism for every percentage of WPSA added in UHPC. Every percentage of WPSA consists of three beams that have been tested, then the average maximum load has been calculated. Figure 2 represents the average maximum load versus percentage of WPSA. It is shown that the highest average maximum load is 309.63 kN where no addition of WPSA is added. The maximum load is then faced a huge drop when 5%, 10%, and 15 % of WPSA added to the concrete which are 309.63 kN, 21.8 kN, 25.08 kN, and 23.43 kN respectively. In Figure 3, the average stress of control UHPC is 92.88 N/mm^2 also the highest compared to others. The average stress for 5%, 10%, and 15% addition of WPSA are 1.96 N/mm^2, 2.26 N/mm^2 and 2.11 N/mm^2 respectively.

Table 4. Flexural test results for prisms at 28 days

Percentage of WPSA (%)	**Maximum Load (kN)**	**Stress (N/mm^2)**	**Average Maximum Load (kN)**	**Average Stress (N/mm^2)**
0	289.40	86.81	309.63	92.88
	318.60	95.57		
	320.90	96.26		
5	21.80	1.96	21.80	1.96
	20.47	1.84		
	23.14	2.08		
10	25.08	2.26	25.08	2.26
	25.88	2.33		
	24.28	2.19		
15	23.43	2.11	23.43	2.11
	19.82	1.78		
	27.04	2.43		

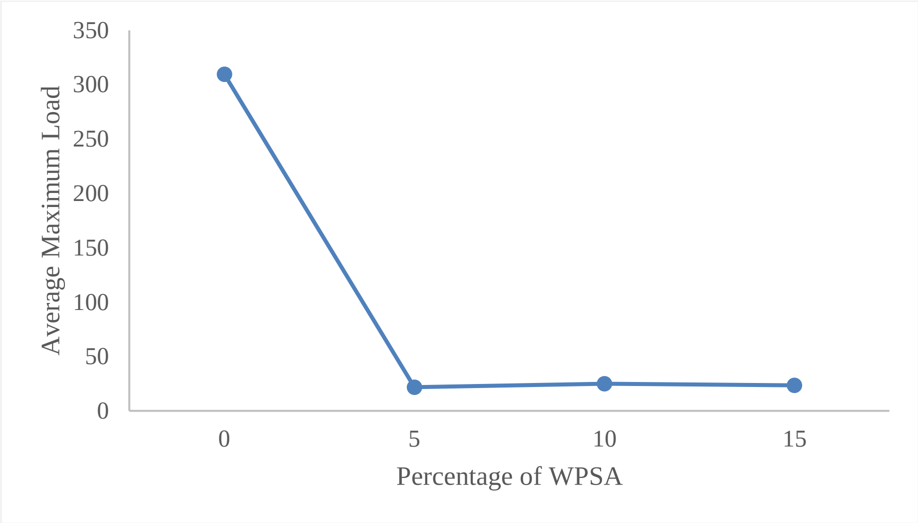

Figure 2. Average maximum load versus percentage of WPSA

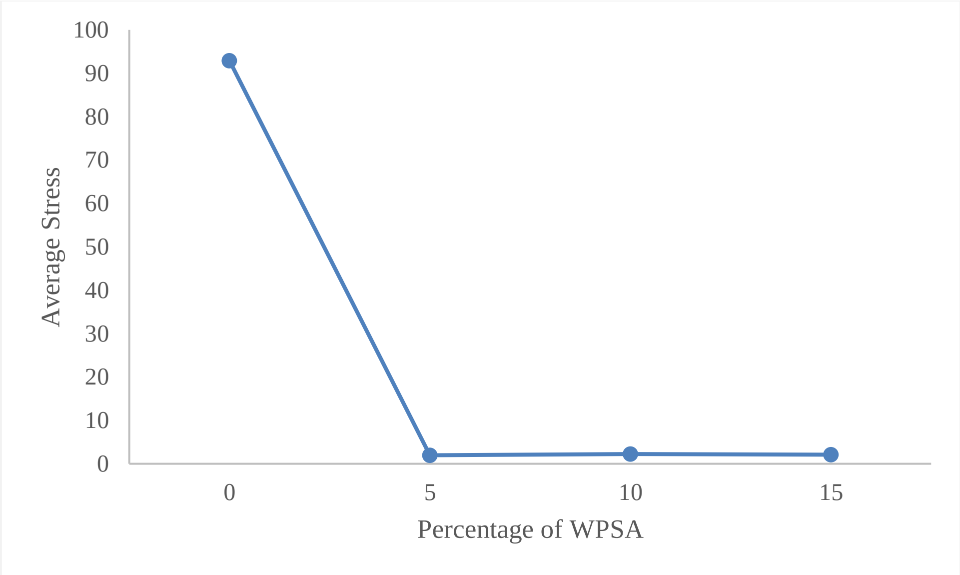

Figure 3: Average Stress versus percentage of WPSA

According to a previous study by Balwaik & Raut (2010), the flexural strength and compressive strength were reduced when the addition of paper pulp in the concrete mixtures as compared to control mixture. This is due to the acceleration of the pozzolanic reaction positively influencing strength development at any age, but the rate of strength to increase it depending on the content of active silica and alumina. Furthermore, the WPSA consists of high carbon content that is shown by an ignition loss (LOI) of 4.5% compared to the cement of 0.64% (Fauzi et al., 2016).

In this study, the content of WPSA may have a small percentage of active silica and alumina that slower the pozzolanic reaction rate. The slow reaction between calcium hydroxide with silica oxide and alumina trioxide from WPSA decreases the production in calcium silica hydrate. Hence, this causes the reduction of the compressive strength as well as flexural strength.

According to Ahmad et al. (2013), the replacement of cement with 5% of WPSA gives the highest strength as compared to control and other 10%, 15%, and 20% of WPSA addition in normal concrete. However, it is reported that the workability of concrete becomes poor because WPSA absorbs more water during mixing. In addition, a study from Alsadey (2015) stated that the fresh property and hardened concrete is depending on the interaction between superplasticizer and cement. This is because it can be said that the superplasticizer effect improved its workability.

In this study, the uses of superplasticizer to make UHPC good in self-compacting concrete. However, the fresh concrete of UHPC becomes poor workability during placing. To relate with this study, the addition of WPSA in UHPC resulted in the high hydration rate of the concrete which cause the concrete to harden faster. The presence of high calcium in WPSA becomes a main role for the concrete to harden as compared to control UHPC. The fineness of WPSA increases the rate of pozzolanic reaction which makes the concrete harden faster and causes the internal concrete to have cracks. The poor flexural strength results in 5% to 15% of addition WPSA is affected by a poor internal concrete structure. This can be proved when all specimen shows poor flexural strength in term of stress and maximum load. There is no optimum percentage to improve concrete strength when adding WPSA in UHPC.

3.2. Ultrasonic Pulse Velocity

Based on ultrasonic pulse velocity (UPV) test results, the concrete quality for all specimens with addition 0%, 5%, 10% and 15% of WPSA in UHPC which are 2397.38 m/s, 2404.76 m/s, 2361.11 m/s, and 2313.12 m/s respectively. All average pulse velocity results were doubtful. This is because the value of velocity pulse for all specimens was below 3000 m/s as referred to Table 5. The average pulse velocity of three prisms is calculated by using the formula in Equation (1) based on the distance between the transducer and the time taken for the pulse to travel is recorded by UPV equipment. Although the results show all the prisms are doubtful, it is recorded that the highest pulse velocity travels is 2404.8 m/s which 5% addition of WPSA added in UHPC.

Table 5: Pulse Velocity and Quality of Concrete Result

Percentage of WPSA (%)	Specimen name	Length (m)	Time Taken (μs)	Pulse Velocity (m/s)	Average Pulse Velocity (m/s)	Concrete Quality (Grading)
Control (0%)	Beam A	0.2	83.70	2389.49	2397.38	Doubtful
	Beam B	0.2	83.15	2405.29		
	Beam C	0.2	83.43	2397.36		
5	Beam A	0.2	83.92	2383.27	2404.76	Doubtful
	Beam B	0.2	82.43	2426.38		
	Beam C	0.2	83.17	2404.63		
10	Beam A	0.2	84.76	2359.74	2361.11	Doubtful
	Beam B	0.2	84.66	2362.49		
	Beam C	0.2	84.71	2361.11		
15	Beam A	0.2	86.20	2320.19	2313.12	Doubtful
	Beam B	0.2	86.82	2303.70		
	Beam C	0.2	86.51	2315.46		

From the results obtained in the experiment, there are many factors that affect the wave velocity of the concrete specimen. A study from Fauzi et al., (2016) stated that reducing water absorption will significantly affect the performance and life service of concrete The discontinuous pores presence due to hydrate cement paste can affect its durability and reduces the strength of concrete. Another experiment conducted by Ahmad et al., (2013) found that the higher presence of WPSA cause a high percentage of water absorption occurred. The percentage of water absorption increased from 1.17% to 1.713% and the amount of WPSA addition to the concrete from 0% to 20%. The increment of water absorption causes the porosity of the concrete which leads to its durability.

According to Gehlot et al., (2016), the uniformity, crack, or defects can be detected using ultrasonic pulse velocity method since it is having high potential for concrete control. Hence, poor pulse velocity propagation might cause when internal concrete structure contained longer cracks or detection of discontinuities. The concrete test result is affected by many factors such as surface smoothness, test specimen geometric properties, test specimen age, concrete surface and internal moisture condition, type of cement and coarse aggregate, type of mold, and surface concrete carbonation (Halal et al., 2015).

However, this study showed slow-wave velocity propagates the concrete specimen which causes the quality of concrete is doubtful for all specimens might cause by admixture effect to produce UHPC. This is because the concrete hardens very quickly when adding a superplasticizer. The addition of WPSA that contains high calcium that absorbs more water which helps the quick hardening in UHPC that may cause a high rate of hydration. This might cause the porosity of the concrete which produces many small internal cracks in the concrete. Besides, the slow pulse velocity produced might cause by many factors such as materials or surrounding effects. Hence, it resulted in the lower quality or grading of the concrete specimen.

3.3. Rebound Hammer Test

Table 6 shows the compressive strength result based on the rebound number. The rebound number recorded is then calculated as the average of rebound number by referring to Schmidt Hammer Graph. Based on the result in Figure 4, the average compressive strength when no addition of WPSA in UHPC is the highest which is 38 MPa. The addition 5% of WPSA shows the average compressive strength which is 32 MPa. Then the average compression strength starts to decrease and constantly drop when addition 10% and 15% of WPSA which are 28 MPa and 23 MPa, respectively.

Table 6. Compressive strength result based on rebound number

Percentage of WPSA (%)	**Specimen Name**	**Observed Average Rebound Number**				**Compressive Strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
		Left	**Middle**	**Right**	**Average**		
0	Beam 1	36	38	35	36	38	38
	Beam 2	38	41	38	39	43	
	Beam 3	33	35	32	33	33	
5	Beam 1	30	35	32	32	32	32
	Beam 2	30	34	31	32	32	
	Beam 3	29	36	32	32	32	
10	Beam 1	29	33	28	30	28	28
	Beam 2	28	29	25	27	24	
	Beam 3	30	36	31	32	31	
15	Beam 1	27	30	25	27	24	23
	Beam 2	25	29	26	27	24	
	Beam 3	25	30	24	26	22	

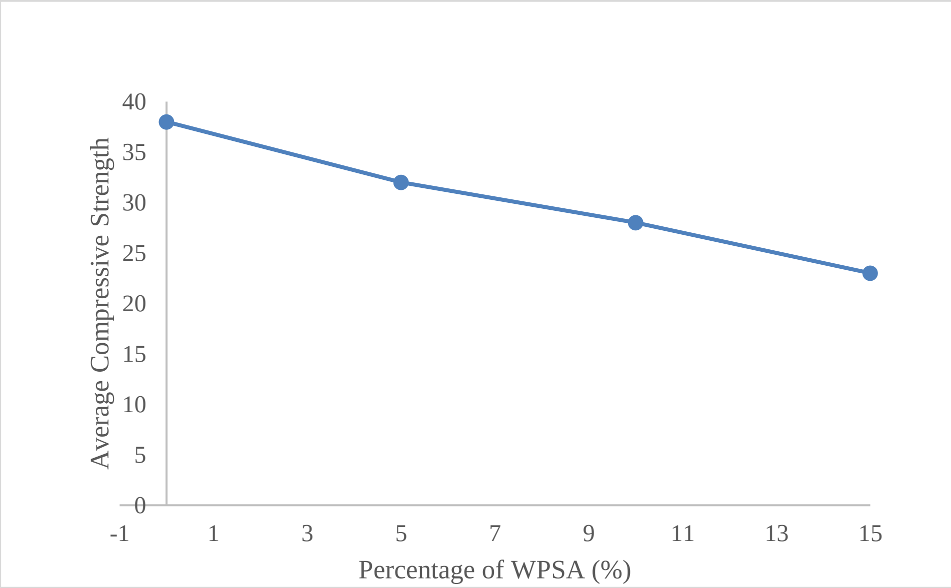

Figure 4: Average compressive strength according to the percentage of WPSA

The purpose of conducting rebound hammer tests commonly used to determine the relationship between compressive strength and hardness of the surface of the body structures (Balakrishna et al., 2017). The results obtained reflect by many factors such as surface smoothness, specimen's shape, and rigidity, specimen's age, materials' type, condition of internal moisture, type of mould, and surface carbonation. They added that the results of rebound number from the Schmidt Rebound test resulting in the value of compressive strength and its hardness. A lower number of rebounds indicates soft concrete surface and weak concrete, while a higher rebound number shows strong and hard concrete strength.

In this experiment results, there are many factors involved that influence the rebound number as well as compressive strength to drop when addition WPSA in the concrete. Since WPSA has a very fine texture, it will contribute to a large surface area in which the concrete evaporates faster than normal concrete. The high amount of calcium with the presence of superplasticizer helps the concrete to harden fast which more water was absorbed during mixing of fresh concrete. During the experiment, the specimens at a hardened state showed cracks and non-uniformity on the surface of the concrete. The higher the addition of WPSA, the more defects occur on the concrete surface. Due to those reasons, the value of average compressive strength showed a fall trend when more amount of WPSA was added.

The results of the rebound hammer enable to obtain the imperfections on the surface of the concrete (Lorenzi et al., 2014). He added that the result of rebound hammed reflects to hardness of the surface and less potential to detect the internal defects. It is important for the surface of the concrete body perpendicular to the hammer body which will affect the rebound number (Jain et al., 2013).

From the results of the rebound hammer, it is shown that high percentage error between theoretical and experimental as shown in Table 7. The difference between experimental and theoretical control UHPC is 457.46%. The addition 5%, 10% and 15% causing the percentage error are -89.95%, -86.13% and -87.27%. The high percentage of error can be related to the bad quality of concrete that is affected by various reasons. High absorption of water and a high amount of calcium by WPSA might result in concrete hydrating faster. These reasons might cause the hardened concrete to have many imperfections of the concrete surface. Thus, lower rebound numbers contribute to low compressive strength and lower surface hardness of the specimen.

Table 7: Percentage error relationship between flexural strength and compressive strength

Percentage of WPSA (%)	Average Compressive Strength (N/mm^2)	Flexural Strength		Percentage Error (%)
		Experimental	Theoretical	
CONTROL	80.32	92.88	16.14	475.46
5	97.08	1.96	19.51	-89.95
10	81.09	2.26	16.3	-86.13
15	82.48	2.11	16.58	-87.27

4. Conclusion

The significant conclusion that can be made from this study are:

- The results obtained from the flexural test demonstrated that the control of UHPC which is 0% of WPSA has highest maximum load and stress applied to the prism.
- However, the flexural strength started to decrease at 5% addition of WPSA in UHPC. The continuation addition of 10% and 15% WPSA showed that flexural strength continues to drop might cause due to high hydration reaction of WPSA in UHPC. There is no optimum percentage to improve concrete strength when adding WPSA in UHPC.
- Control UHPC produced the highest wave velocity of the concrete. The wave velocity started to decrease at 5% of WPSA addition and the dropping trend continues when 10% and 15% of WPSA were added.
- This study also found that the quality of concrete after adding WPSA shows the same output which is slow in pulse velocity resulting in doubtful concrete grade. This shows that the concrete might have high cracks, defects, porosity, or imperfections of internal concrete due to high water absorption.
- For the rebound test, the results of compressive strength from the rebound hammer test cannot achieve as high as the compressive test result. The highest value of the average rebound number is when no WPSA is added in UHPC.
- The study found the rebound test showed decreasing rebound number which shows a decrease in compressive strength and surface hardness when WPSA is added into the concrete. There are many factors involved that affected its rigidity.

Acknowledgments

The authors wish to acknowledge the College of Engineering, Universiti Teknologi MARA, and Ministry of Higher Education Malaysia for supporting this publication process via research grant RACER/1/2019/TK01/UITM/2.

References

Abdul Razak, T. K. A., Kudus, S. A., Jamadin, A., & Suliman, N. H. (2021). Compressive Strength of Ultra High Performance Concrete (UHPC) Containing Palm Oil Mill Effluent (POME). In Materials Science Forum (Vol. 1042, pp. 165-170). Trans Tech Publications Ltd.

Ahmad, S., Malik, M. I., Wani, M. B., & Ahmad, R. (2013). Study of Concrete Involving Use of Waste Paper Sludge Ash as Partial Replacement of Cement. *IOSR Journal of Engineering*, *3*(11), 06–15. https://doi.org/10.9790/3021-031130615

Ahmad Shah, I., Rao, H., & Gupta, V. (2019). An Experimental Research On Partially Replacement Of Cement In M20 Conrete With Rice Husk Ash And Waste Paper Sudge. *International Journal of Engineering Sciences & Research Technology*, *8*(1), 100–110.

Alsadey, S. (2015). Effect of Superplasticizer on Fresh and Hardened Properties of Concrete. *Journal of Agricultural Science and Engineering*, *1*(2), 70–74.

Anuar, K. a, Ridzuan, a R. M., & Ismail, S. (2011). Strength Characteristics of Geopolymer Concrete Containing Recycled Concrete Aggregate. *International Journal of Civil & Environmental Engineering*, *11*(February), 59–62. https://doi.org/119601-2323 IJCEE

Azmee, N. M., & Shafiq, N. (2018). Ultra-High Performance Concrete : From Fundamental to Applications Case Studies in Construction Materials Ultra-high performance concrete : From fundamental to applications. *Case Studies in Construction Materials*, (November), 1–15. https://doi.org/10.1016/j.cscm.2018.e00197

Balakrishna M.N., Fouad Mohammad, R. E. & R. M. M., & School. (2017). INTERPRETATION OF CONCRETE MIX DESIGNS BY SURFACE HARDNESS METHOD. *Malaysian Journal of Civil Engineering*, *29*(2), 227–238.

Balwaik, S. A., & Raut, S. P. (2010). Utilization of Waste Paper Pulp by Partial Replacement of Cement in Concrete. *International Journal of Engineering Research and Applications*, *1*(2), 300–309.

Bărbos, G. – A. (2016). Long-term Behavior of Ultra – High Performance Concrete (UHPC) Bended Beams. *Procedia Technology*, *22*(October 2015), 203–210. https://doi.org/10.1016/j.protcy.2016.01.045

Bin Mohd Sani, M. S. H., Bt Muftah, F., & Ab Rahman, M. (2011). Properties of Waste Paper Sludge Ash (WPSA) as cement replacement in mortar to support green technology material. *3rd ISESEE 2011 - International Symposium and Exhibition in Sustainable Energy and Environment*, (June), 94–99. https://doi.org/10.1109/ISESEE.2011.5977117

Devi, K. S., Lakshmi, V. V., & Alakanandana, A. (2018). Impacts of Cement Industry on Environment - An Overview. *Asia Pacific Journal of Research*, *I*(NOVEMBER 2017), 156–161. https://doi.org/10.3945/ajcn.110.003483

Ekwulo, E. O., & Eme, D. B. (2017). *Flexural Strength and Water Absorption of Concrete made from Uniform Size and Graded Coarse Aggregates American Journal of Engineering Research (AJER)*. (10), 172–177.

Faizal, M. J. M., Hamidah, M. S., & Norhasri, M. S. M. (2014). Strength and Chloride Content of Nanoclayed Ultra-High Performance Concrete. *Proceeding on Structures, Materials and Construction Engineering Conference*, (November), 99–111.

Fauzi, M. A., Sulaiman, H., Ridzuan, A. R. M., & Azmi, A. N. (2016). The effect of recycled aggregate concrete incorporating waste paper sludge ash as partial replacement of cement. AIP Conference Proceedings, 1774(October 2016). https://doi.org/10.1063/1.4965063

Gehlot, T., Sankhla, D. S. S., Gehlot, D. S. S., & Gupta, A. (2016). Study of Concrete Quality Assessment of Structural Elements Using Ultrasonic Pulse Velocity Test. IOSR Journal of Mechanical and Civil Engineering, 13(05), 15–22. https://doi.org/10.9790/1684-1305071522

Helal, J., Sofi, M., & Mendis, P. (2015). Non-Destructive Testing of Concrete : A Review of Methods. Electronic Journal of Structural Engineering, 1(January), 97–105.

Jain, A., Kathuria, A., Kumar, A., Verma, Y., & Murari, K. (2013). Combined Use of Non-Destructive Tests for Assessment of Strength of Concrete in Structure Combined Use of Non-Destructive Tests for Assessment of Strength of Concrete in Structure by Elsevier. Procedia Engineering, 54(December 2014), 241–251. https://doi.org/10.1016/j.proeng.2013.03.022

Kamaruddin, M. N., Jamadin, A., Kudus, S. A., & Mustaffa, N. K. (2022). The Effect of Waste Paper Sludge Ash Addition to the Fresh and Hardened Properties of Ultra-High-Performance Concrete. In Green Infrastructure (pp. 59-73). Springer, Singapore.

Kusumawardaningsih, Y., Susilorini, R. M. I. R., & Aboubakr, A. (2015). Properties of Ultra High Performance Concrete. Proceedings of International Conference on Concrete and Infrastructure 2015, (October), 44–49.

Lawson, I., Danso, K. A., Odoi, H. C., Adjei, C. A., Quashie, F. K., Mumuni, I. I., & Ibrahim, I. S. (2011). Non-destructive evaluation of concrete using ultrasonic pulse velocity. Research Journal of Applied Sciences, Engineering and Technology, 3(6), 499–504.

Lorenzi, A., Caetano, L. F., Chies, J. A., Carlos, L., & Filho, S. (2014). Investigation of the Potential for Evaluation of Concrete Flaws Using Nondestructive Testing Methods. 2014.

Sharipudin, S. S., & Ridzuan, A. R. M. (2013). Influence of waste paper sludge ash (WPSA) and fine recycled concrete aggregate (FRCA) on the compressive strength characteristic of foamed concrete. Advanced Materials Research, 626, 376–380. https://doi.org/10.4028/www.scientific.net/AMR.626.376