American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-11, Issue-04, pp-98-107
www.ajer.org
Research Paper Open Access

The influence of using ceramic polishing waste powder and water glass on properties of concrete

Yasmeen N.Soliman[1], Kamal G. Sharobim[1], Hassan A. Mohamadien[1]&Hussein M.Hassan[1], Omar M. Omar[2].
[1](SCU, Ismailia, Egypt)
[2](SU, Suez, Egypt)
Corresponding Author: Yasmeen N.Soliman

ABSTRACT : *Growing populations generate large amounts of solid waste, needing massive landfill sites for disposing process. Solid waste can be recycled into other resources, reducing the demand on non-renewable resources and helping to solve the landfill problem. Also, cement manufacture pollutes the environment particularly in Suez city in Egypt due to emitting of CO_2 gas from fuel burning. So most studies had a great concern to use waste and low cost materials contributing in concrete industry and improving its properties. The fast increase of ceramic wastes has sparked a huge interest in their sustainable usage in construction field. This work showed the effect of using ceramic polishing waste powder (CPWP) produced during the final polishing process of ceramic tiles as partial replacement of cement with 5, 10 and 15 % by weight of the cement and water glass (WG) as an addition with 0.5 and 1 % on concrete properties. Slump, initial and final setting times and air content tests were performed on fresh concrete and compressive, abrasion resistance, permeability and accelerated corrosion tests were conducted to evaluate the hardened and durability properties of concrete specimens. Experimental results showed that up to 10 % replacement level of CPWP had positive effect on strength properties of concrete. Also the results showed that usage of WG as an addition in mixes incorporating CPWP resulted in improved durability properties compared with control mix. So CPWP and WG could be used in concrete production without causing negative effects on its properties depending on their dosages.*

KEYWORDS *Ceramic polishing waste powder, water glass, Cement replacement, strength, waste*

Date of Submission: 04-04-2022 Date of acceptance: 19-04-2022

I. INTRODUCTION

Concrete is the most used construction materials. Using of supplemental cemented materials (SCMs) could improve the concrete properties and contributing in reducing the environmental effects of concrete production [1]. The long-term goal of minimizing undesired industrial by-products can be achieved through reducing material consumption. One ton of Portland cement, which responsible for 5% of worldwide CO_2 emissions, generates about one ton of CO_2 in the environment [2]. Concrete manufacturing attracts a great attention to recycle wastes in a safe way [3]. Solid waste dumps will continue to receive huge amounts of waste to meet consumer needs [3]. Many types of solid wastes are recycled and utilized in many sectors such as fly ash, silica fume, glass powder and rice straw ash etc. . So most studies try to prevent environmental contamination caused by improper disposal of solid wastes, as well as the detrimental impact on public health and also find additional material for enhancing concrete properties with low costs compared with other alternatives. Ceramic waste (CW) is a popular research topic. Sedimentation settles CW, which is then discharged, polluting the environment and creating health hazards. Ceramic industry is expanding due to growing demand. The pozzolanic activity of CW powder can be employed in concrete production. For concrete grades M20 and M25, Amitkumar D. Raval et al. [4] showed that replacing cement with ceramic waste up to 30% increased compressive strength .Venkata and G V Rama Rao [5] discovered that CW replacement might improve mechanical characteristics of concrete grade 20 up to 30% and concrete grade 40 up to 20%. Amr and Dima [3] discovered that 40% replacement rate was required to increase durability. It is also more durable than plain concrete, according to Dima et al [3]. L.G. Li et al. [6] discovered that utilizing CW as paste alternative boosted mortar strength while reducing cement by 33%. Water glass is a sodium silicate that dissolves easily in water. It is a widely used chemical substance. Water glass impregnating cement products makes them more water resistant and durable [7]. Water glass can be used as a hardening accelerator in cement paste by Shevchenko Viktor and Kotsay Galyna [8]. It can also be used to seal porous natural and man-made building materials [7] and improve concrete surface properties. Giannaros et al. [9] employed sodium silicate microcapsules to heal concrete. Hongru Zhang et al. [10] found that WG improves recycled aggregate concrete. The effects of both ceramic waste and sodium silicate on the fresh and durable qualities of concrete, as well as its effect on reinforced concrete did not have a great concern in most studies. Thus, investigations on local CPWP and WG were required to understand its actual environmental and economic benefits.

II. MATERIAL AND METHODS

CEMENT

The study used EL-Suez cement CEM I grade 42.5 N for normal concrete with specific surface area of 3195 cm^2/kg and having compressive strength of 22.4 MPA, 40.6 MPA after 3, 28 days respectively. Table 1 shows the chemical compositions of used cement.

Chemical properties of used cement Table (1)

Chemical components	Loss of ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO3
CEM I (42.5) percentage by weight (%)	1.4	19.5	7.5	2.65	61.53	3.65	2.4

FINE AGGREGATE

The used fine aggregate was natural sand .Figure 1 shows the grading of the sand according to ECP 203/2018. The physical and chemical properties of the sand are given in Tables 2 and 3 respectively.

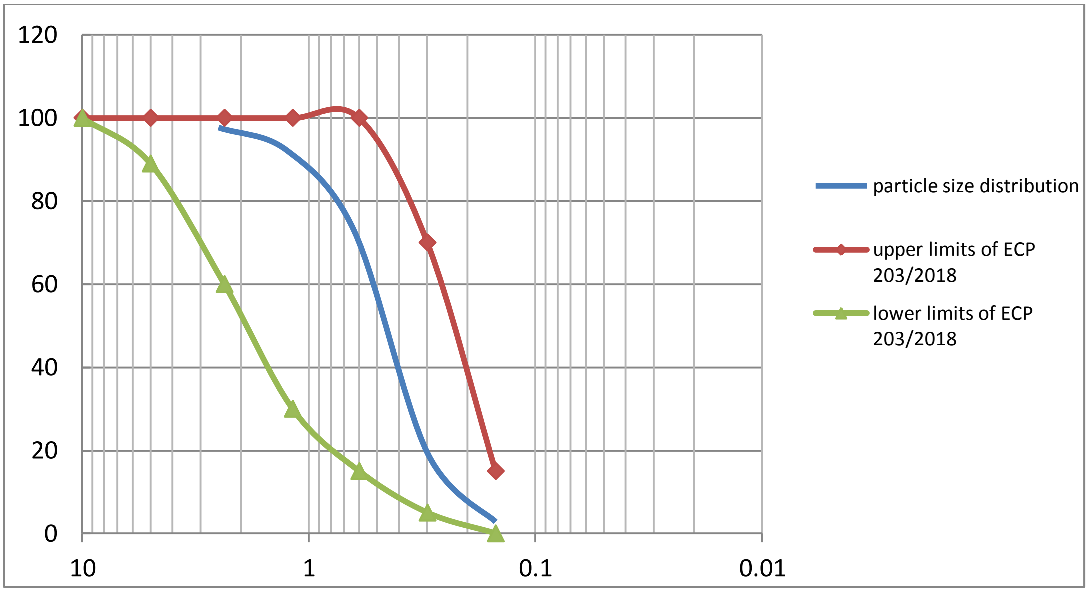

Fig. 1 grading curve of used fine aggregate

Table 2 Physical properties of fine aggregate

Property	Results	Limits of ES (1109/2008) and ECP 203/2018
Specific weight	2.63	2.5 – 2.75
Unit weight (t/m^3)	1.62	-
Clay and Fine Dust Content %	2.68 %	Not more than 3 %

Table 3 chloride and sulfate content in fine aggregate

Property	Results	Limits of ECP 203/2018
Total chlorides	0.035	0.06
Total sulfate	0.020	0.40
PH	7.8	-

COARSE AGGREGATE

This study used crushed dolomite as coarse aggregate. Tables 4 and 5 show the results of testing physical and chemical properties. Figure 2 shows the coarse aggregate grading curve according to ECP 203/2018.

Table 4: Physical properties of coarse aggregate

Property	Results	Limits ECP 203/2018
Specific weight	2.62	2.6 -2.7
Unit weight (t/m^3)	1.33	-
Abrasion index (loss Anglos apparatus)	25.5 %	Not more than 30 %
Clay and fine material content %	1.78 %	Not more than 3 %
Water absorption %	2.42 %	Not more than 2.5 %

Table 5: chloride and sulfate content in coarse aggregate

Property	Results	Limits ECP 203/2018
Total chlorides	0.037	0.04
Total sulfate	0.011	0.4
PH	7.9	-

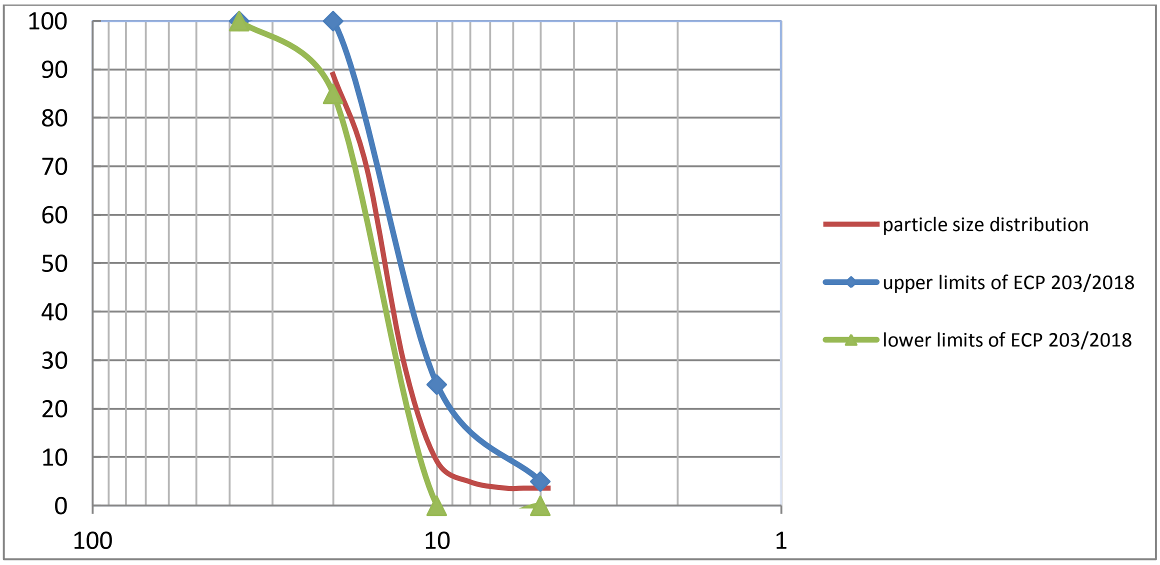

Fig. 3 Grading curve of used coarse aggregate

CERAMIC POLISHING WASTE POWDER

The ceramic polishing waste powder (CPWP) used in this study was from the Ceramica Venezia factory in 6 Octoper, Egypt. The CPWP is difficult to remove from the environment. The CPWP collected was completely dry with average diameter of particles of 1410 nm and with specific surface area 1131 m^2/kg. The chemical composition of CPWP shown in Table 6. Typical Energy Dispersive X-Ray Analysis of CPWP shown in figure 4 and the Figure 5 shows the mass atom density of CPWP.

Table 6 XRF Analysis for the used ceramic waste powder (CPWP)

Compound	Al_2O_3	SiO_2	K_2O	CaO	FeO	Total
Mass %	16.38	70.42	2.64	2.12	8.39	100

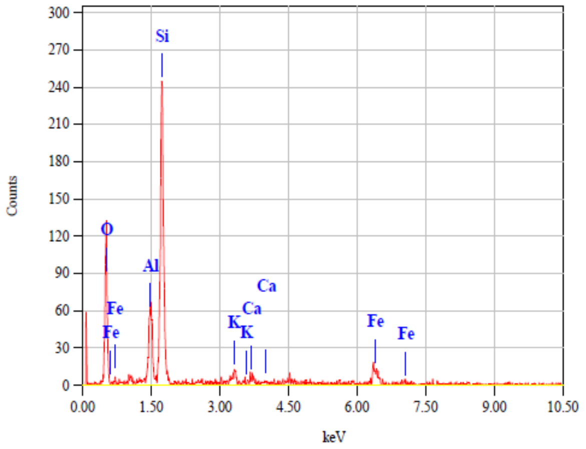

Fig. 4 Typical EDX micrograph of CPWP

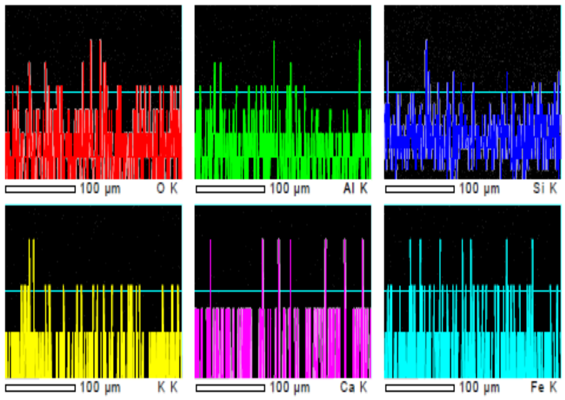

Fig. 5 Mass atom density of CPWP

WATER GLASS

Water glass used in the study was from Egypt Global Silicates Company in the Suez city. It had a modulus of 3.3 (the ratio between SiO_2 and Na_2O = 3.3) in the solution. The sodium silicate solution used was clear and white liquid.

WATER

Portable water was used in mixing and curing of concrete. It is complied with requirements of ECP.

CONCRETE MIX DESIGN

Two groups of concrete mixes with different dosages of CPWP and WG were designed. Group 1 consists of four concrete mixes with 0, 5, 10 and 15% of CPWP, used as a partial replacement of cement. Group 2 consists of four concrete mixes as followed; (5% CPWP+0.5 WG), (5% CPWP+1% WG), (10% CPWP+0.5%WG) and (10% CPWP+1%WG). The WG used as an addition, all percentages by weight of cement. All concrete mixes had water-to-cement ratio of 0.5. Table 7 presents the details of the mix proportions.

Table 7 Concrete mix proportions per cubic meter of concrete

Mixture	Cement (kg/m3)	Natural Sand (kg/m3)	Coarse aggregate (kg/m3)	CPWP (kg/m3)	Water glass (L/ m3)	Water (L/m3)
CM0	400	580	1159	0	0	200
CM1- 5%CPWP	380	580	1159	20	0	200
CM2- 10% CPWP	360	580	1159	40	0	200
CM3-15% CPWP	340	580	1159	60	0	200
CM4- (5% CPWP+0.5 WG)	380	580	1159	20	2	200
CM5- (5% CPWP+1% WG)	380	580	1159	20	4	200
CM6-(10% CPWP+0.5%WG)	360	580	1159	40	2	200
CM7- (10% CPWP+1%WG)	360	580	1159	40	4	200

Methodology of Experiments

Studying the effect of using CPWP and WG begins with concrete mixes testing. The results of all designed mixes are compared with the results of control concrete CM0. All the specimens were casted on molds with water to cement ratio 0.5 and after about 24 hours the specimens were de-molded and cured in water till 28 days.

Fresh state properties

The study contains some fresh state properties tests such as slump, initial and final setting time and air content tests were measured for all mixes of concrete according.

Hardened state tests

Concrete mixtures with CPWP and WG were tested to find their hardened state properties. As individual test findings, an average of three samples of concrete were taken for every test of concrete performed.

1- Compressive strength test at 7 and 28 days was carried out on 100x100x100 mm cubes for all concrete mixes according to Egyptian code for design and construction of building 203/2009 [11].
2- Permeability resistance of water test after 56 days was performed out on (150x150x150) mm cubes according to Egyptian code for design and construction of building 203/2009 [11]
3- Abrasion resistance test at 28 days was carried out on (70 × 70 × 70) mm cubes for concrete according to the Egyptian standard specifications No. 2005 / 1-269 [12].
4- Accelerated corrosion test at 28 days was performed out on 100 × 100 × 500 mm prisms, for best concrete mixes in each group.

III. RESULTS AND DISCUSSION

Fresh properties

Slump

For CPWP mixes, initial slump decreased with increasing CPWP replacement amount. Slump for CM0 was 85 mm and for CM3 was 79 mm. CM1 and CM2 have 84 and 80 mms, respectively. This minor drop may be attributable to CPWP's small mean particle size (1.4 µm) compared to ordinary Portland cement, as well as its high specific surface area (1131 m^2/kg). It may also be related to increased water absorption by fine ceramic particles. However, due to low replacement levels of CPWP, does not show a significant drop. For (CPWP+WG) mixes, initial slump of concrete mixes increased with WG as an addition level. Initial slump for CM0 was 85mm and an optimum value was for CM5 (5% + 1%) was 110 mm. The values for CM4 (5% + 0.5%), CM6 (10% + 0.5%) and CM7 (10% + 1%) were 100, 95 and 105 mm. This minor improvement in workability may be due to liquid state of WG with fixed water to cement ratio in all mixtures. Figure 6 shows slump test results in mm.

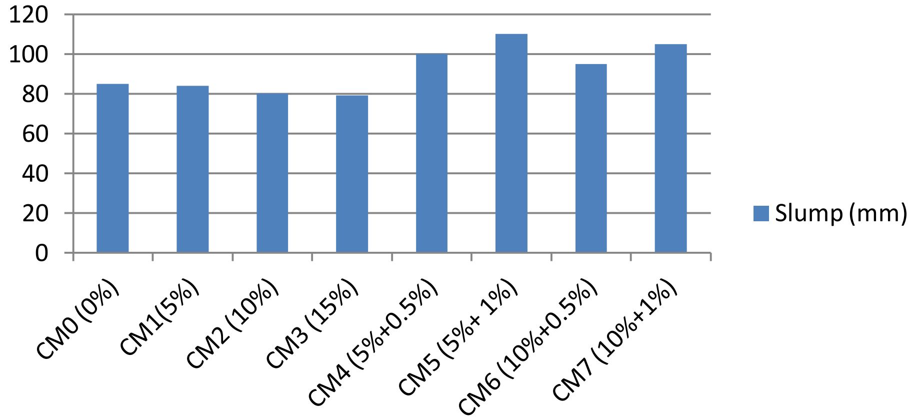

Figure 6 slump test results in mm

Initial and final setting time

For CPWP mixes, Initial and final setting times decreased slightly with increasing CPWP levels compared to CM0. CM3 (15%) required 260 minutes to reach final setting with a 16 minute acceleration compared with CM0 (276 min.). Also, CM1 (5%) and CM2 (10%) took 267 and 262 minutes. It might be due to CPWP's fine particles ability to absorb some of free water, reducing setting time. For (CWP + WG) mixes, using CPWP and WG in concrete mixtures obviously reduced initial setting time and final setting time. Final setting times for CM6 (10% +0.5%) and CM7 (10% + 1%) were 250 and 240 minutes with an acceleration of 26 and 36 minutes compared to CM0 (276 minutes). Also, final setting time for CM4 (5% + 0.5%) was 256 minutes, whereas for CM5 % (5% + 1%) was 255 minutes. Figure 7 shows initial and final setting times for concrete mixes. This acceleration effect obviously seen with WG addition in concrete mixes could be due to the interaction of sodium silicate in water glass with calcium hydroxide from cement hydration process to generate more calcium silicate hydrates (CSH) gel resulting in accelerating effect compared to CM0.

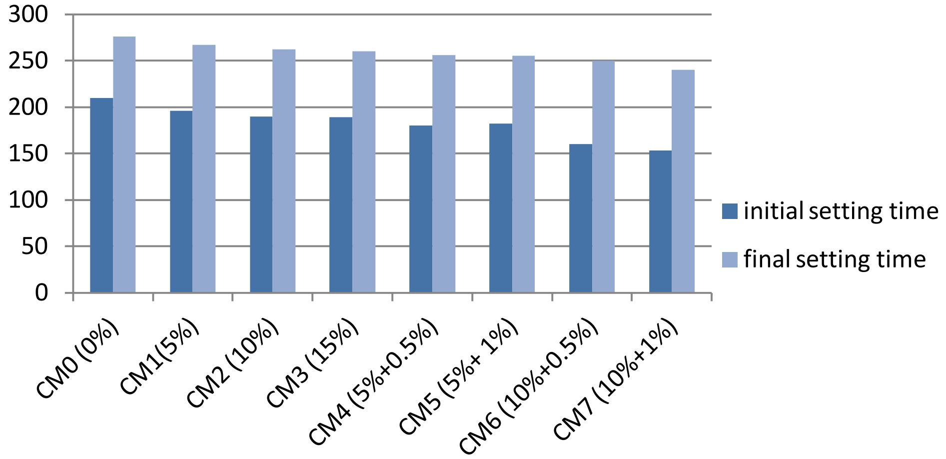

Figure 7 initial and final setting times in minutes

Air content by using pressure method

Three groups exhibited a small rise in air content percentage in fresh mixes. It was more noticeable in group two (CPWP + WG mixtures), maybe due to the water's propensity in WG solution to generate more air bubbles in early fresh mix than control mix. The results of air content ranged between 1.9 % to 2.4 %. Table 8 shows air content percentages in fresh concrete mixes.

Table 8 air content percentages

Mixture	CM0	CM1 (5%)	CM2 (10%)	CM3 (15%)	CM4 (5% + 0.5%)	CM5 (5% + 1%)	CM6 (10%+ 0.5%)	CM7 (10% + 1%)
Air content %	1.9	2.1	2.35	2.4	2.5	2	2.3	2.2

Hardened properties

Compressive strength

For CPWP mixes, results showed that up to 10% replacement of cement by CPWP resulted in an increase in compressive strength relative to CM0 without. After 7 days of curing, the specimens had minimal strength variations compared to 28 days variations and CM2 (10%) having a maximum strength of 21 MPA. After 28, the strength of CM2 (10%) increased to 35.3 MPA compared to 27.3 MPA for CM0. 5, 10 and 15% CWP replacement levels could reach 33, 35.3, 32.5 MPA with sufficient increases of 20.8, 29.3 and 19 % in compressive strength after 28 days. This could be related to pozzolanic reactions in late ages due to high silicon oxide (SiO_2) content in CPWP reacting with calcium hydroxide ($Ca(OH)_2$) from cement hydration products Also, Al_2O_3 in CWP may cause early strength properties. Also, the fine ceramic waste powder particles can fill voids and boost the densification and strength of CPWP mixes. For (CPWP + WG) mixes, the results showed that adding WG to concrete mixes with CPWP did not have a positive effect in compressive strength compared with mixes with CPWP only but the results still higher than CM0 and comparable with CPWP mixes. After 28 days, the best mix was CM4 (5% + 0.5%) reached 33.5 MPA and the results were 27.3, 30.5, 30.7, and 29 for CM0, CM5 (5% + 1%), CM6 (10% + 0.5%), and CM7 (10% + 1%) with 22.7, 11.7, 12.4, 6.2 % strength improvement compared with CM0. This improvement may be due to the capacity of the (C-S-H) gel generated from WG incorporation in concrete mixes to plug micro cracks in the mixture resulted in a denser microstructure and increased strength while strength results showed that hydration process did not affected positively due to combining of CPWP and WG in the same mix. Figure 8 shows compressive strength results after 7 and 28 days of curing for all concrete mixes.

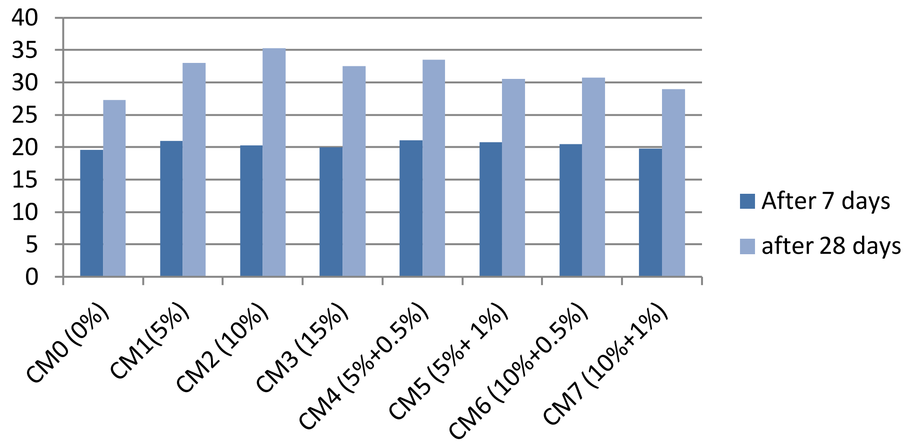

Figure 8 compressive strength in MPA

Permeability test

For CPWP mixes, each specimen was subjected to 5 bar pressure for 72 hours in the test and the water column depth was determined in each one. The results showed that increasing the CPWP dosage in concrete reduced water penetration depth. CM0 has 2.8 cm whereas CM3 (15%) had 1.9 cm. Also, CM1 (5%) and CM2 (10%) were 2.2 and 2 cm. Water resistance is improved by filling pores with CPWP, improving mix consistency and compactness. It also improved the concrete's permeability resistance by increasing the amount of C-S- H (calcium silicate hydrates) and C-A- H (calcium aluminate hydrates) in the secondary hydration process with $Ca(OH)_2$. For (CPWP + WG) mixes, the results of using both CPWP and WG in the same mix showed superior improvement in permeability resistance of mixes. The penetration depth decreased with WG addition and this ensures that WG products from chemical reactions with $Ca(OH)_2$ can infiltrate tiny fractures in concrete mixes, resulting in a denser microstructure and hence higher permeability resistance. CM4 (5% + 0.5%) and CM5 (5% + 1%) had 1.6 and 1.3 cm penetration depths. However, CM6 (10% + 0.5%) was 1.2 cm and the optimum result was for CM7 (10% + 1%) equal to 1 cm deep. Figure 9 shows penetration depth resulted from permeability resistance test in cm.

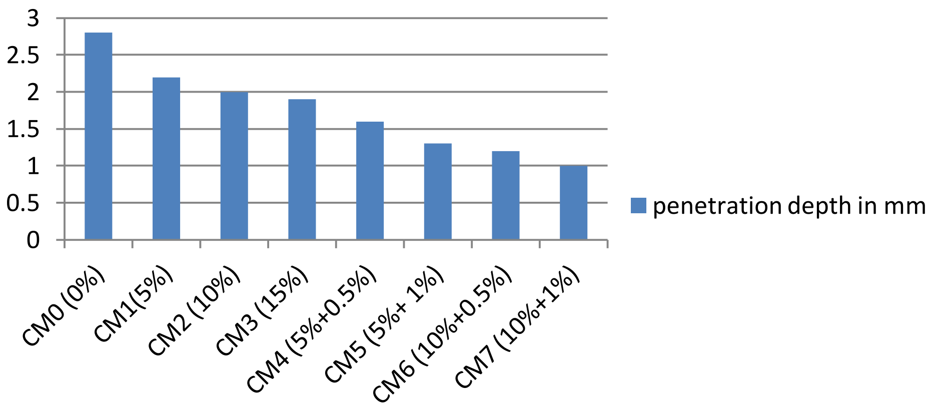

Figure 9 penetration depth in cm.

Abrasion resistance test

Abrasion test was carried out on (70 × 70 × 70) mm standard cubes at the age of 28 days for each mixture and then the actual loss in thickness S in mm was determined for each specimen from equation 1. For CPWP mixes, the results revealed a slight gain in abrasion resistance with increasing CPWP doses. While CM2 (10%) had 1.9 mm loss in thickness with a difference of -2 % compared to CM0 (1.86 MM). But CM1 (5%) and CM3 (15%) lost 1.8 and 1.76 mm in thickness. This minor improvement may be attributable to good ceramic particle-cement paste adhesion. Also, more hydration reaction products could fill voids and improve cohesive forces between mixture components, improving abrasion resistance. For (CWP + WG) mixes, due to usage of both CWP and WG in the mixes, the results had increased abrasion resistance compared to CM0 but without great differences than using CPWP only in mixes. The optimum result was for CM4 (5% + 0.5%) was 1.72 mm with 7.5% improvement over CM0 (1.86 mm). Also it was just 1.8 mm for CM5 (5% + 1%). Also, CM6 (10% +

0.5%) and CM10 (10% + 1%) lost 1.82 and 1.75 mm in thickness. Figure 10 shows loss in thicknesses in mm resulted from abrasion resistance test.

$S = 10\ W / (D \times A)$ Equation 1

Where:
S: the loss in thickness
W: loss on weight
D: Density
A: loading area

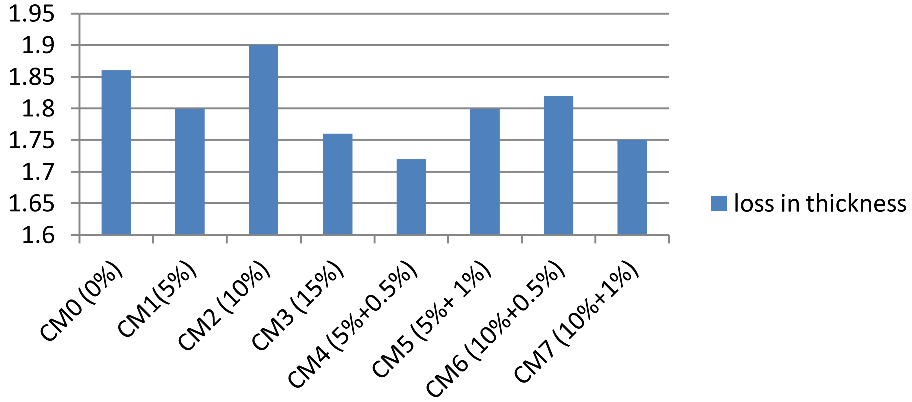

Figure 10 Loss in thicknesses in mm

Accelerated corrosion test

Figure 11 showed concrete accelerated corrosion test procedure which conducted on CM0, CM2 (10%) and CM4 (5% + 0.5%) specimens after 28 days of curing. for creation of an electrical circle, 16 mm diameter with 30 cm length steel rods were utilized as anodes and copper rods with same dimensions as cathodes. All concrete specimens were submerged in a 3.5 percent NaCL solution. The test employed using a 3 volt and 2 amp adaptor for each specimen. Each specimen's time was calculated until the crack thickness reached 0.01 mm at least as shown in figure 12. After the test, the specimens were crushed to extract steel rods from them. Then the weight loss for each steel rod was calculated after cleaning them from corrosion with 12 % HCL solution. Using CPWP and WG in concrete mixtures improved results compared to a control mix. The duration to reach 0.01 mm fracture thickness for CM0 was 918 hours, whereas CM2 (10%) and CM4 (5% + 0.5%) specimens took longer to reach required crack width (946 and 972 hours). Also, weight loss of steel rods due to corrosion followed a similar time of crack trend. CM0 has 4.4 % while CM2 (10%) and CM4 (5% + 0.5%) lost 2.99% and 2.81% of their weight. Chloride ions are aggressive anions in NaCl. Cl^- destroys the hydroxide passive coating produced on steel surface in alkali-environment. As part of the corrosion process, chloride ions must infiltrate the reinforced concrete structure and transfer to steel rod. Porous concrete allows more Cl^- ions to reach the steel rod surface. Using CPWP and WG in concrete mixes improves permeability and compacts microstructure resulted in decreasing corrosion rate due to low Cl^- ions reaching steel rod surfaces. Also, sodium silicate has been observed to work as a corrosion inhibitor [13]. It can produce a thin silicate coating on steel bar surfaces, shielding them from anodic dissolution and thereby decreasing corrosion on steel surface Anodic sites on steel surfaces are protected from cathodic action, resulting in low current density and greater corrosion resistance than the control mix. Table 9 showed time to reach 0.01 crack width, weight losses on tested specimens and differences rates compared with CM0. Figure 12 shows cracks in concrete specimens for (A) CM0, (B) CM2 (10%) and (C) CM4 (5% + 0.5%).

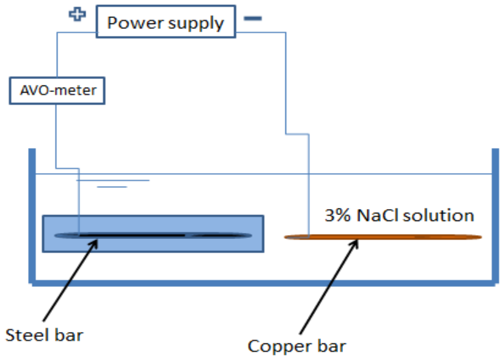

Figure 11 concrete accelerated corrosion test procedure

(A)

(B)

(C)

Figure 12 cracks in concrete specimens

Table 9 Time to reach 0.01 crack width and weight losses in steel rods

Mixture	Weight loss (%)	Variations (%)	Time elapsed to reach 0.1 mm crack thickness (hours)	Variation (%)
CM0	4.4	0	918	0
CM2 (10%)	2.99	32	946	3.05

CM4 (5% + 0.5%)	2.81	36.1	972	5.8

IV. CONCLUSIONS

From the experimental results, the following conclusions can be drawn;

1. Using CPWP as a partial replacement of cement resulted in slight decrease in workability of concrete due to its small particle size and it had a small acceleration effect on setting time compared with control mix
2. An increase in compressive strength of concrete contains CPWPC and it could be due to its double influence of pozzolanic activity and microfilling ability.
3. Optimum compressive strength was from CM2 (10% CWP) by enhancement rate about 33.9% compared with control mix
4. Abrasion resistance improved with 5.3 % and penetration depth decreased with difference of 0.9 cm from CM3 (15%) compared with CM0.
5. Corrosion resistance improved with using CPWP in concrete. Mixture with 10% CPWP had 28 hours late to reach 0.01 crack thickness compared with control mix.
6. Using WG as an addition in CPWP mixes made the mixes more workable and had obvious effect in accelerating setting time compared with mixes with only CPWP and control mix.
7. Adding WG to CPWP mixes did not affect compressive strength improvement compared with mixes of CPWP only but still higher than control mix. CM4 (5% + 0.5%) had maximum compressive strength in group two with 21.5 % increased rate compared with CM0.
8. CM4 (5% + 1%) had maximum abrasion resistance with 7.5 % improved rate compared with CM0.
9. Optimum Penetration depth of water in concrete mixes incorporating CWP and WG was from CM7 (10% + 1%) had minimum penetration depth with 1.8 cm difference compared with CM0.
10. Corrosion resistance improved with using both CPWP and WG in the same mix than using CPWP only. CM4 (5% +0.5%) had 54 hours late to reach 0.01 mm crack thickness compared with control mix.

References

[1] R. Jin, "A statistical modeling approach to studying the effects of alternative and waste materials on green concrete properties," p. 227, 2013.

[2] D. Hardjito, S. E. Wallah, D. M. J. Sumajouw, and B. V Rangan, "Factors influencing the compressive strength of fly ash-based geopolymer concrete," *Civ. Eng. Dimens.*, vol. 6, no. 2, pp. 88–93, 2004.

[3] A. S. El-Dieb and D. M. Kanaan, "Ceramic waste powder an alternative cement replacement – Characterization and evaluation," *Sustain. Mater. Technol.*, vol. 17, pp. 1–11, 2018, doi: 10.1016/j.susmat.2018.e00063.

[4] A. D. Raval, I. N. Patel, and J. Pitroda, "Ceramic Waste : Effective Replacement Of Cement For Establishing Sustainable Concrete," *Int. J. Eng. Trends Technol.*, vol. 4, no. 6, pp. 2324–2329, 2013.

[5] V. K. Atkuri and G. V. Rama Rao, "Strength properties of ceramic waste concrete," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1025, no. 1, pp. 1–10, 2021, doi: 10.1088/1757-899X/1025/1/012017.

[6] L. G. Li, Z. Y. Zhuo, J. Zhu, J. J. Chen, and A. K. H. Kwan, "Reutilizing ceramic polishing waste as powder filler in mortar to reduce cement content by 33% and increase strength by 85%," *Powder Technol.*, vol. 355, pp. 119–126, 2019, doi: 10.1016/j.powtec.2019.07.043.

[7] X. Yang, W. Zhu, and Q. Yang, "The viscosity properties of sodium silicate solutions," *J. Solution Chem.*, vol. 37, no. 1, pp. 73–83, 2008, doi: 10.1007/s10953-007-9214-6.

[8] S. Viktor and K. Galyna, "Effect of Water Glass on Early Hardening of Portland Cement," *Procedia Eng.*, vol. 172, pp. 977–981, 2017, doi: 10.1016/j.proeng.2017.02.119.

[9] P. Giannaros, A. Kanellopoulos, and A. Al-Tabbaa, "Sealing of cracks in cement using microencapsulated sodium silicate," *Smart Mater. Struct.*, vol. 25, no. 8, pp. 1–12, 2016, doi: 10.1088/0964-1726/25/8/084005.

[10] H. Zhang, W. Liu, X. Lin, S. Su, and B. Zhao, "To ameliorate the performance of recycled aggregate concrete (RAC) by pre-treating aggregate in sulfoaluminate cement slurry and water glass solution," *J. Build. Eng.*, vol. 44, no. June, p. 103364, 2021, doi: 10.1016/j.jobe.2021.103364.

[11] "Egyptian code for design and construction of building 203/2009."

[12] "Egyptian standard specifications No. 2005 / 1-269."

[13] F. U. A. Shaikh, "Effects of alkali solutions on corrosion durability of geopolymer concrete," *Adv. Concr. Constr.*, vol. 2, no. 2, pp. 109–123, 2014, doi: 10.12989/acc.2014.2.2.109.

Yasmeen N.Soliman, et. al. "The influence of using ceramic polishing waste powder and water glass on properties of concrete."*American Journal of Engineering Research (AJER)*, vol. 11(04), 2022, pp. 98-107.