https://doi.org/10.36375/prepare_u.iei.a113

Durability properties of Pervious concrete using Nano silica

D.Tarangini*, Dr.P.Sravana and Dr.P.Srinivasa Rao

Department of Civil Engineering
Jawaharlal Nehru Technical University
Kukatpally,Hyderabad,Telangana-500050

Corresponding author's email: dtarangini05@gmail.com

Abstract- The durability qualities of porous concrete created with a cement, nano silica(NS), and a minimum of 5% natural river sand as a partial replacement for coarse aggregate were investigated in this work. This study used two coarse aggregate sizes, 20 mm and 10 mm, in a 50:50 ratio. The pervious mixes for w/b ratios 0.34 and 0.30 were subjected to durability tests such as acid impact, alkali impact, and cantabro abrasion loss. The chemical resistance test revealed that the mass decrease percentage was 20.56 percent at 5% HCl solution, 4.23 percent at 5% H_2So_4 solution, and 0.27 percent for Na_2So_4 solutions after 180 days of immersion. Sulphuric acid was discovered to be the most harmful of the three chemical environments for all concrete mixtures.The abrasion loss found to be in the range of 18 to 28%.The durability of concrete mixes using nano silica was demonstrated.

Keywords – porous, nanosilica, durability, abrasion

INTRODUCTION

With rapid expansion and an ever-increasing population, there is an urgent need to focus on sustainable practises in construction-related development. The most pressing issue resulting from urbanisation is the development in the amount of impervious surfaces such as sidewalks, built-up areas, road networks, and so on, all of which have a direct impact on the environment. These impervious surfaces cause a variety of issues, including storm water runoff, which, if properly managed, can result in an efficient water management technique. Using impervious surfaces diminishes soil-atmosphere interaction, increases heat absorption and radiation, and affects the adjustment of temperature and humidity on the earth's surface. It is also a major cause of ground water depletion.

In recent years, several industrial by-products with high silica and alumina content, including as fly ash (FA), rice husk ash (RHA), ground granulated blast furnace slag (GGBS), silica fume (SF), alccofine (AL), red mud, and others, that are harmful to the environment, have been used as replacement for OPC in concrete [1-6]. Through the use of nanoparticles, extensive research is being conducted to improve the efficiency of building materials and to manufacture durable concrete for the construction sector [7-9]. Nanomaterials with high pozzolanic character, such as nano silica (NS), can greatly improve the qualities of concrete in all aspects. It was discovered that utilising NS in concrete can expedite the pozzolanic process and generate more C-S-H gel in the concrete, and that NS can also improve the density of the concrete's interfacial transition zone (ITZ) by filling the pores [10,11].

LITERATURE REVIEW

Pervious concrete's strength and permeability have been the subject of several research.Some studies were also conducted to evaluate the performance of polymer added pervious concrete, and it was discovered the addition of fibres can increase permeability and compressive strength, as well as the splitting tensile strength [12,13]. According to research on the properties of porous concrete with varying cement paste contents, there are strong relationships between compressive strength, porosity, and critical pore size [14]. Abrasion, durability, and ravelling under continuous traffic loads are all issues with pervious concrete pavement, in addition to strength and permeability. Sulphuric acid (H_2SO_4) and hydrochloric acid (HCL) are the two most potent natural threats to concrete structures [15]. The usage of pozzolanic materials such as rice husk ash, fly ash, and silica fume increases the strength and weight loss against sulphate attack due to a decrease in the porosity of concrete specimens and the development of ettringite[16,17]. The quality of particle dispersion in the transition zone, as well as the features of C-S-H, are critical factors in the permeability of concrete specimens, which impacts the resistance of concrete to sulphate attack[18]. The strength and abrasion resistance of pervious concrete were reduced when palm oil clinker, an industrial by-product, was used as coarse aggregate at varied replacement amounts ranging from 0 to 100% [19]. As the nanoparticle concentration increased, the wear resistance of concrete containing nano-particles such as nano-TiO2 and nano-SiO2 in addition to polypropylene fibre decreased [20].

OBJECTIVE AND SCOPE

The purpose of this research is to see how acids such as HCL and H_2SO_4 affect the characteristics of pervious concrete. The study also looks at Cantabro's abrasion of Pervious Concrete (PC). For the evaluation, four PC mixtures with two distinct aggregate sizes and various w/b were casted and tested.

A. Experimental program

1.Materials Used: Ordinary Portland Cement (OPC) 53 grade, coarse aggregate of sizes 10 mm and 20 mm, river sand at 5% by weight of coarse aggregate,3% nano silica addition by weight of cement and superplasticizer Consplast SP 430, and water were used to make pervious concrete. Granite was employed as the aggregate in this investigation. Four mixes were employed with total aggregate to cement 3.5:1, each with a 50:50 mixtures of

https://doi.org/10.36375/prepare_u.iei.a113

two sizes of coarse aggregate and a 5% replacement of total material. With and without the addition of 3% Nano silica, two w/b ratios of 0.34 and 0.30 are applied (NS).

2)Mix proportions: The following table 1 gives the details of pervious mix.

TABLE 1
(Details of Mix proportions of pervious concrete)

SI No	Mix	Cement Kg/m^3	Sand Kg/m^3	CA Kg/m^3	W/B	Ns Kg/m^3	SP %
1	CPC1	450	79	1568	0.30	-	0.7
2	CPC2	450	79	1568	0.34	-	0.7
3	NPC1	450	79	1568	0.30	13.5	0.7
4	NPC2	450	79	1568	0.34	13.5	0.7

3)Casting of specimens:As per the mix proportions designed using ACI 522 R specimens were casted.The components were first blended dry and then added to the pan mixture with water and SP. After mixing, the concrete is poured into cubes and compacted with a tamping rod. The next day, the cubes are demolded and left to cure normally until the day of testing.

4)Testing procedure: PC cube specimens are cured for 28 days under normal conditions before being immersed in 5 percent HCL solution, 5 percent H_2So_4 solution, and 5 percent sodium sulphate solution (Na_2So_4) for further 28, 90 and 180 days of chemical curing. Figure 1 shows the chemical curing of PC specimens. The cubes are weighed before being immersed in the chemical. For acid curing, the P^H maintained 4.5 to 5, while for alkali curing, it was kept at 8.5 to 9. These are checked every 15 days and PH is thus kept up to date. According to prior literature, the Cantabro test with up to 300 cycles can be used to assess the abrasion resistance of pervious concrete [24]. The Cantabro test is performed without the steel ball charges in the Los Angeles (LA) abrasion machine and the amount of weight lost throughout the test was used to characterise PC's abrasion resistance. Figure 4 shows the PCPC specimens before and after the Cantabro test.

5% H_2So_4 5% HCL 5% Na_2So_4

Fig. 1 showing the variations in PC specimens after immersion in acid and alkali.

B. Results and discussions

1)Weight loss in HCL & H_2So_4:

The mass loss for specimens subjected to 5% hydrochloric acid and 5% sulphuric acid solutions are shown in Figure 2. When comparing CPC and NPC concrete, it was discovered that CPC mixtures without nano silica(NS) packing addition had the maximum mass loss of 20.56 percent for 180 days in hydrochloric acid immersion for w/b ratio of 0.34. In hydrochloric acid immersion, the NPC mixtures with NS addition exhibited the mass loss of 7.98 percent for w/b ratio 0.34. From pozzolanic activity and portlandite, hydrates arising from cement hydration reduce the size of capillary pores when NS is added [25].In sulphuric acid solutions, mass loss is smaller as 1.54 percent for PC combinations using NS as a filler.In sulphuric acid solutions, the concrete mixes lose more mass than in hydrochloric acid solutions. Degradation mechanisms caused by H_2SO_4 and HCl assaults differ for the same type of concrete. Sulphuric acid leaches paste layers from exposed surfaces, whereas hydrochloric acid penetrates the concrete through the exterior porosity interval.

2)Weight loss in Na_2So_4:

For both CPC and NPC, Figure 2 depicts the % weight loss of PC mixes. The mass loss for sodium sulphate curing was found to be in the range of 0.03 percent to 0.32 percent. It is clear from the mechanism of attack of sodium sulphate on concrete structures that the two main reactions that result in expanding ettringite and gypsum are to blame. The first is the reaction of sodium sulphate (Na2SO4) with the calcium hydroxide produced during cement hydration to make gypsum, and the second is the reaction of formed gypsum with calcium aluminate hydrates to produce ettringite [26,27]. The synthesis of gypsum and ettringite causes concrete constructions to expand, crack, deteriorate, and be disrupted.

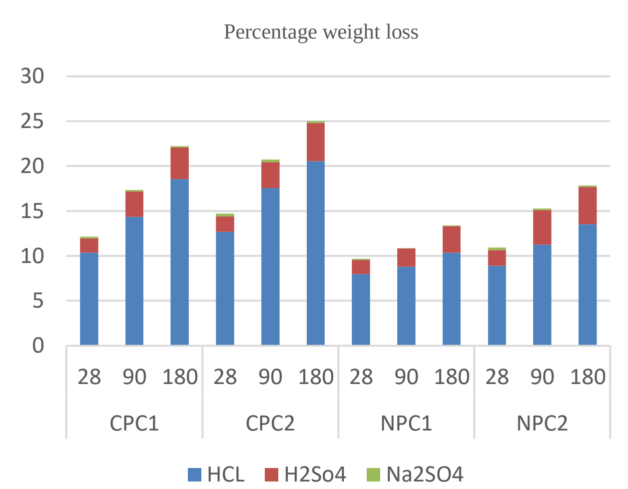

Fig. 2 Graph showing the percentage mass loss of PC mixes after immersion in acid and alkali.

3)Effect on compressive strength:

Figure 3 shows the compressive strength loss of PC mixes exposed to HCl, H_2SO_4, and Na_2so_4. It is clear that sulphuric acid exposure has resulted in the greatest loss of strength. At a 28-day concrete age, the percentage decrease in compressive strength was found to be 6.89 percent for

https://doi.org/10.36375/prepare_u.iei.a113

PC without NS whereas 3.26 percent for PC mix with NS for w/b ratio of 0.34.For later eras of concrete, a similar pattern has been followed. It's worth noting that adding NS to concrete has significantly reduced concrete deterioration by generating a larger C-S-H gel and lowering the open pore structure to some extent.

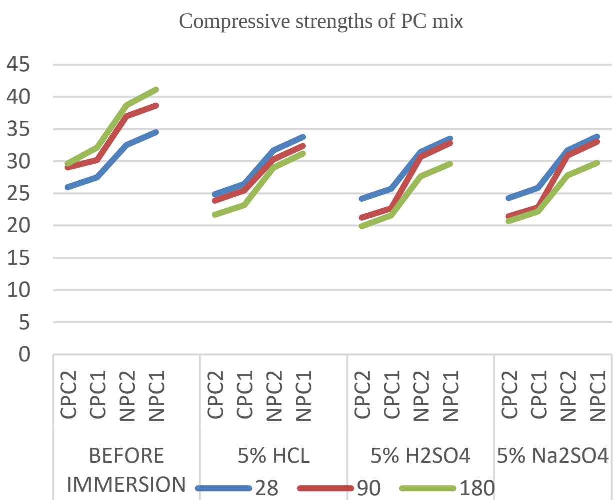

Fig. 3 Graph showing the variations in compressive strengths of PC mixes after immersion in acid and alkali.

4)*Cantabro abrasion loss:*

Figure 4 shows the specimens after Cantabro abrasion testing on the Los angles machine. As shown in Figure 5, the proportion of mass loss for PC mix, there was a maximum weight loss of 28.24 percent for concrete mix without NS at w/b ratio of 0.34. The abrasion mass loss for PC mix on addition of NS for same w/b was 25.66 at concrete age of 28 days.The As a result, adding Nano silica to the cement mix increased its quality by making it denser and less prone to abrasion. The blends that included NS had improved abrasion resistance and minimal weight loss. As a result, the results reveal that the specimen's compressive strength has a significant impact on abrasion resistance. The reason for this is that during Cantabro testing, the specimen is damaged by impact between the specimens collision and the inside side the Los Angeles machine, rather than by surface abrasion. For PC blends, the mass loss due to abrasion was between 20 and 35 percent.This could be because some of the specimens broke due to their poor strength during the first few strikes, rather than aggregate particles being abraded away from the specimen surface. Similarly, the higher specific surface area of nano silica-replaced mixes explains their improved resilience, resulting in a larger region of additive dispersion and a more compact cement matrix.

Fig.4 showing the variation in specimens of PC mix before and after abrasion

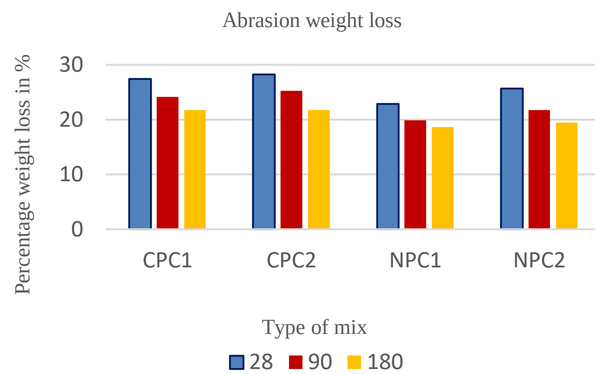

Fig. 5 Graph showing the weight loss of PC mixes after abrasion test at different ages of concrete

CONCLUSIONS

Based on the experimental results presented in this study, the following conclusions have been formed.

1.The pervious mix with w/b ratio 0.30 performs better against chemical and abrasion loss when compared to 0.34.

2.Sulphuric acid and hydrochloric acid medium aggressions are better tolerated by pervious concrete with nano silica added than by standard pervious mix.

3.Chemical resistance has improved in pervious combinations when 3 percent Nano silica was partially added, according to the pozzolanic reaction of NS and its contribution of strength continuing up to 180 days.

4.For all four combinations, the abrasion resistance of Pervious mix with Nano silica increased with increasing curing age.

5. In terms of abrasion resistance values, the Cantabro test has clearly delimited PC mixtures with NS at all ages, and it may be used as one of the ways to determine abrasion resistance of porous concrete pavements.

REFERENCES

[1] Malhotra, V., "Introduction: Sustainable development and concrete technology", Concrete Intelligence, Vol.24, No. 7, pp. 235-242, 2002.

[2] Moncarz. P, "Sustainable concrete: impacts of existing and emerging materials and technologies on the construction industry". Architectural Engineering Conference, June 19-20, 2011.

[3] Suhendro. B, "Toward green concrete for a better sustainable environment," Procedia Engineering, Vol. 95, pp. 305–320, 2014.

[4] P. Kathirvel, V. Saraswathy, S. P. Karthik, and A. S. S. Sekar, "Strength and durability properties of quaternary cement concrete made with fly ash, rice husk ash and limestone powder," Arabian journal of science and technology, Vol. 38, pp. 589–598, 2012.

[5] Temuujin. J, Van Riessen. A, MacKenzie. K, “Preparation and characterization of fly ash-based geopolymer mortars,” Construction and Building Materials, Vol. 24, No. 10, pp. 1906– 1910, 2010.

[6] Worrell. E, Price. L, Martin. N, Hendriks. C, Meida. L.O, “Carbon-dioxide emissions from the global cement industry”, *Annual Review* of *Environment* and Resources, Vol. 26, No.1, pp. 303–329, 2001.

[7] Isfahani, F.T., Redaelli, E., Li, W. and Sun, Y., Effects of Nanosilica on Early Age Stages of Cement Hydration, *Journal of Nanomaterials*, 2017, Vol. 24, pp. 1-9.

[8] Mochamad Solikin, Alfian Nur Zaini, Budi Setiawan, Ali Asroni , "Flexural Strength Analysis of Styrofoam Concrete Hollow Panel Walls Incorporated with High Volume Fly Ash," Civil Engineering and Architecture, Vol. 8, No. 3, pp. 320 - 325, 2020. DOI: 10.13189/cea.2020.080316.

[9] Dalia Elghezanwy, Sara Eltarabily, "A Review of Translucent Concrete as a New Innovative Material in Architecture," Civil Engineering and Architecture, Vol. 8, No. 4, pp. 571 - 579, 2020. DOI: 10.13189/cea.2020.080421.

[10] Hou, P., Kawashima, S., Kong, D., Corr, D.J., Qian, J. and Shah, S.P., “Modification Effects of Colloidal Nanosilica on Cement Hydration and its Gel Properties,” Composites Part B: Engineering, Vol. 45, pp. 440-448, 2013.

[11] Chithra, S., Senthil Kumar, S.R.R. and Chinnaraju, K, “The effect of Colloidal Nano-silica on workability, mechanical and durability properties of High-Performance Concrete with Copper slag as partial fine aggregate,” Construction and Building Materials, Vol. 113, pp. 794-804, 2016.

[12] Kevern, J. T. (2008). “Advancements in pervious concrete.” Ph.D. dissertation, Iowa State Univ., Ames, IA, 85–99.

[13] Huang, B., Wu, H., Shu, X., and Burdette, E. G. (2010). “Laboratory evaluation of permeability and strength of polymer–modified pervious concrete.” Constr. Build. Mater., 24(5), 818–823.

[14] Deo, O., and Neithalath, N. (2011). “Compressive response of pervious concretes proportioned for desired porosities.” Constr. Build. Mater., 25(11), 4181–4189.

[15] Turkel, S., Felekoglu, B., and Dulluc¸, S. 2007. Influence of various acids on the physico–mechanical properties of pozzolanic cement mortars. Sadhana, **32**(6): 683–691. doi:10.1007/s12046-007-0048-0.

[16] Ji, T., Preliminary study on the water permeability and microstructure of concrete incorporating nano-SiO2. Cement and Concrete Research, 2005. 35(10): p. 1943-1947.

[17] Chatveera, B. and P. Lertwattanaruk, Evaluation of sulfate resistance of cement mortars containing black rice husk ash. Journal of Environmental Management, 2009. 90(3): p. 1435-1441

[18] Jo, B.-W., et al., Characteristics of cement mortar with nano-SiO2 particles. Construction and Building Materials, 2007. 21(6): p. 1351-1355.

[19] Ibrahim, H. A., Razak, H. A., & Abutaha, F. (2017). Strength and abrasion resistance of palm oil clinker pervious concrete under different curing method. *Construction and Building Materials*, *147*, 576–587.doi: 10.1016/j.conbuildmat.2017.04.072

[20] Li, H., Zhang, M., & Ou, J. (2006). Abrasion resistance of concrete containing nano-particles for pavement.*Wear*, *260*(*2006*), 1262–1266. doi: 10.1016/j.wear.2005.08.006

[21] Perez-Jimenez, F. E., and Gordillo, J. (1990). “Optimization of porous mixes through the use of special binders.” Transportation Research Record 1265, Transportation Research Board, Washington, DC, 59–68.

[22] Ruiz, A., Alberola, R., Perez, F., and Sanchez, B. (1990). “Porous asphalt mixtures in Spain.” Transportation Research Record 1265, Transportation Research Board, Washington, DC, 87–94.

[23] Sabita. (1995). Porous asphalt, Manual 17, Sabita Ltd., Roggebaai, South Africa

[24] Wu, H., Huang, B., Shu, X., and Dong, Q. (2011). “Laboratory evaluation of abrasion resistance of Portland cement pervious concrete.” J. Mater. Civ. Eng., 23(5), 697–702.

[25] Ghrici, M., Kenai, S., Said-Mansour, M., and Kadri, E. 2006. Some engineering properties of concrete containing natural pozzolana and silica fume. Journal of Asian Architecture and Building Engineering, **5**(2): 349–354. doi:10.3130/jaabe.5.349.

[26] Santhanam M., Cohen M. D., and Olek J. (2003). “Mechanism of sulfate attack: A fresh look part 2: Proposed Mechanisms.” Cement and Concrete Research 33(3), pp. 341-346

[27] Ramezanianpour A.A., Pourbeik P., Moodi F. (2012). “Sulphate Attack of Concretes Containing Rice Husk Ash”. Amirkabir Journal of Science and Research (Civil and Environmental Engineering), Vol. 45, No. 1, pp. 3-5