Review Article **Nano Material and Polymer Science**

International Journal of Pharma and Bio Sciences

ISSN
0975-6299

ROLE OF POLYMERS AND NANO MATERIALS IN ENHANCING ENGINEERING PROPERTIES OF CEMENT CONCRETE

MOHAN KANTHARIA[1*] AND PANKAJ KUMAR MISHRA[2]

*[*1] Dept. of Civil Engineering, Amity School of Engineering and Technology , Amity University Madhya Pradesh, Gwalior, India*
[2.] Dept. of Applied Physics, Amity School of Engineering and Technology, Amity University Madhya Pradesh, Gwalior, India

ABSTRACT

Cement concrete is the only material which has been used maximum for construction of buildings. Now the construction technology is accommodating new materials day by day, Inclusion of polymers and nano materials in cement concrete is getting more attention. Polymers and nano materials are improving the engineering properties of the cement and concrete. Newer kinds of cement concrete composites have more compressive and flexural strength along with improved as chemical resistance, impact resistance and temperature resistance. The polymers which have been commonly used are styrene butadiene rubber, polyvinyl acetate. Acrylic polymers and epoxy polymers have been tested for aggressive exposure such as, for high temperature, chemicals exposures etc. with promising results. Nano materials such as ZnO, nano TiO_2, nano ZrO_2, nano Al_2O_3, nano $CaCO_3$have also shown improved water resistance, flexural strength, compressive strength and in reducing cement cracks.This article presents an analytical review of enhancement of mechanical properties ; such as compressive strength and tensile strength,due to addition of polymers and nano composites with cement mortar and concrete.

KEY WORDS: *Epoxy resin, nano ZnO, nano Al_2O_3, acrylic resin, PMMA*

MOHAN KANTHARIA

Dept. of Civil Engineering, Amity School of Engineering and Technology, Amity University Madhya Pradesh, Gwalior, India

***Corresponding Author**

Received on: 03-08-2016
Revised and Accepted on: 17-06-2017
DOI: http://dx.doi.org/10.22376/ijpbs.2017.8.3.b621-625

INTRODUCTION

Now day's smart materials provided by new technology are getting a lot of attention. Chemistry of Polymers with cement concrete and nano materials are the need of the hour. Green building concept becoming popular day by day. People are trying to find out sustainability in construction materials and technologies. Nano technology is setting new dimensions for construction industry by providing new construction composites with nano and polymeric materials. Different types of polymers have been added into cement concrete to enhance the engineering properties of the cement concrete and mortar. Some of the latest types of cement concrete are developed by using nano materials, polymers are reviewed here.

THERMAL INSULATION WITH NANO MATERIALS IN BUILDINGS

Nano materials were generally used in space research, pharmaceuticals, and electronics products, but nowadays nanotechnology offers many applications in building constructions also. In this paper some of the nano materials which are used as thermal insulator are discussed. These nano materials are (a) Expanded polystyrene Graphite (EPS Graphite) (b) Aerogel (c) nano particle based vacuumed insulator panel (d) Nano ceramic thermal insulating panels. Heat can be transport by three methods from any conventional materials (i) convection (ii) flux (iii) radiation. Heat transfer depends upon surface material's property (heat transfer coefficient), its thickness etc. EPS Graphite, Aerogel, Vacuum insulator panels having lower thermal conductivityEPS Graphite (Expanded polystyrene Graphite) with some additive is used in building construction. It may be used outer facade coating of wall or lower side of slab structure. It has good compressive strength(100-150 kPa).Vacuum Insulator panels are made with compressed fumed silica and silicon carbide, sealed with high barrier laminate of polyethylene-terephthalate and this all is coated with 30 nm Aluminium layers. These can be used for insulating flat and high roof, slab structures, facade walls and floors. Aerogels are primarily derived from silica. In today's time these can be prepared from other materials like Alumina, Carbon, Tin dioxide, chrome etc. It can be applied for thermal insulation of slab column, floors. Aerogel blankets are available 2-10 nm thickness. It may be used on translucent and transparent glasses.[1]

EFFECT OF NANO ZINC OXIDE (ZNO) IN SELF COMPACTING CONCRETE (SSC)

Nano technology showed that by the use of nano particles, the density of cement increases because nano voids are filled by nano materials. The reactivity of materials also increases, because nano particles becomes nuclei for cement particles, which increases the hydration reaction due to their high surface area. Nano zinc oxide exhibits semiconducting and piezoelectric dual properties. Generally, it is added into various composite materials in industries and products. In civil engineering various construction components such as ceramics, glass, cement, paints, sealants this material is used. In cement concrete, the addition of ZnO improves the resistance of cement concrete against water. Nano Zinc Oxide of average size 30 nm was tested in self compacting concrete. Mechanical properties of cement concrete studied with inclusion of nano ZnO. Addition of ZnO at a concentration of 0.1%to 1.0% improved the compressive strength and tensile strength. To understand the synthesis of composite, scanning electron microscope (SEM), and X-ray diffraction images were taken. Split tensile strength increases at 0.5% of ZnO concentration.By increasing concentration up to 1% of nano Zno split tensile strength start decreasing to the control sample. Similarly flexural strength is maximum at 0.5% concentration of nano ZnO, and starts decreasing at 1% concentration. Setting Time reduces considerably with increase of ZnO.[2]

EFFECT OF NANO ZIRCONIUM OXIDE ON STRENGTH OF CEMENT CONCRETE

Nazari et al.in their experiment found the influence of some nano phase oxides of zirconium ZrO_2. They replaced the cement by 0.5%, 1.0%, 1.5%, and 2.0% by nano zirconium oxide . The average size of nano materials was of 15 nm and purity was 99.9%. Water to binder ratio was kept 0.4 in all cases. Other details were, sand locally available size less than 0.5 mm and Fineness modulus of sand was 2.25, specific gravity 2.58gm/cm^3, maximum size of crushed basalt aggregates 15 mm and specific gravity 2.96 gm/cm^3. Curing of concrete is done for 7, 14, 28, days before testing for their mechanical properties like flexural, tensile, compressive strength. The result showed that maximum improvement in strength is found at 1%. After 28 days of curing, The results in their experiments showed that the compressive strength increases up to 18.4% by adding 1 % of nano ZrO_2, adding more zirconium oxide the strength value start decreasing. But slump value (workability) decreases by addition of ZrO_2. It was found that slump value for control mix was 7.8 cm and it reduced to 3,0 cm at 2% addition of nano ZrO_2. So that to maintain normal workability with nano zirconium oxide super plasticizers were necessary to be added.[3]

EFFECT OF NANO TITANIUM OXIDE ON STRENGTH OF CEMENT CONCRETE

Titanium dioxide (TiO_2) possesses very good sterilizing property and antifouling properties. By photo-catalytic process number of air pollutants present in air (organic and inorganic) captures and breaks down because of TiO_2 coating. Glass is now an important surface covering component for any building. In recent times Nano Titanium Dioxide (TiO2) is being used to coat the glasses for making the glass self cleaning.[4] Nazari (2010) in his experiment partially replaced experimented nano phase TiO_2 particles in cement concrete. (Specifications of TiO_2 were; purity 99.9%, size 15$\pm$ 3 nm, surface area 155$\pm$ 12 m^2/g density 0.13 g/cm$^{3)}$. The change in flexural strength, compressive strength, split tensile strength; slump value and setting time have been studied. Split tensile strength and flexural strength increases up to 66% and 25%, and compressive strength increases up to 17.9%, at 1% of nano TiO_2 and

then reduces at more % of nano TiO_2. To conclude, up to 2% TiO_2 can be added in cement. But by adding TiO_2 setting time (initial and final setting time) decreases, and workability (slump value) decreases.[5-6]

EFFECT OF NANO ALUMINA (AL_2O_3) ON STRENGTH OF CEMENT CONCRETE

The addition of nano-Al_2O_3 improves the mechanical properties of cement concretes, in terms of higher split tensile and flexural strength. Nano Alumina Al_2O_3 with higher surface area reacts with Ca $(OH)_2$ produced from the hydration of Calcium Silicates. It is well known that the rate of chemical reaction is directly proportional to the surface area available for chemical reaction. It is observed that cement can be replaced up to 2% with nano Al_2O_3 in the concrete. In this experimental investigation nano Al_2O_3 was taken with cement concrete for test. The specification of nano Al_2O_3 particle size was, size 15$\pm$3 nm, surface area 165$\pm$ 12 m^2/g, density 0.1 g/cm^3, purity 99.9%. Results showed that compressive strength increases up to 16.3%, and split tensile strength increase up to 55.5%, at 1% inclusion of nano alumina and other physical properties setting time decreases .and slump value decreases (Nazari, et al., 2010). Arefi (2011) performed experiment on cement mortar with nano Al_2O_3. Alumina was taken in different proportions (1%, 3%, 5%, of cement). For compressive strength tested on cube of 5x5x5 cm samples, and for flexural strength size of samples were 40x40x160 mm. Fine aggregates were crushed silica sand with fineness modulus 2.4 and apparent density 3.33 gm/cm^3. (Average nano particle was size 20 nm, specific surface area 200 m^2/gm, density 0.9 gm/cm^3,and purity 99.9%). Super plasticizer of relative density 1.15 was used. Experimental results found that 3% results are the best for flexural, compressive, and tensile strength. At this 3% researchers found that the Ca $(OH)_2$ is reduced and micro structure was more dense, the Scanning Electron Microscope (SEM) images also reflected the same. At 5% of nano Al_2O_3. strength results are less than the control mix, due to agglomeration of nano particles voids are created lesson the strength.[7-9]

USE OF NANO CALCIUM CARBONATE ($CACO_3$) PARTICLES IN RETROFITTING OF HISTORICAL MONUMENTS

Experiments show that addition of micro sized $CaCO_3$ cement reduces the strength but by adding nano particles of $CaCO_3$ improves the strength. It has been reported that micro hardness improvement in the strength is found when nano-$CaCO_3$ is added to cement. When about 20% nano-$CaCO_3$ added to the Ordinary Portland Cement (OPC) micro hardness value increased (Hengyang, et al., 2008, Patel, et al., 2013). Nano lime is being used in the consolidation of lime plaster and lime stone for conservation of historical monuments. It is suspended nano particles of calcium hydroxide in alcohol. It penetrates into porous surfaces and alcohol evaporates after some time and calcium hydroxide converts into calcium carbonate. Thus, nano technology aids in the preservation and restoration of aged monuments of cultural heritage. [10-14]

EFFECT OF POLYMERS ON CEMENT CONCRETE (PC)

Polymers can be added to cement concrete to replace cement partially or fully. The air voids present in the concrete reduces the strength of concrete, if the voids can be filled by some suitable materials then the strength of concrete can be increased. In polymer concrete, the slight percentage of low viscosity polyester resin is introduced which fills the micro level voids and concrete is tightly packed and so that the strength of concrete get increased. The percentage of polymers may vary from 5 to 15 %. This polymer concrete is especially suitable for use as repair work, weathering resistant concrete, high ductility performance, chemical resistance is required. Epoxy resin (polymer) concrete is new experimentation in concrete to improve the properties of cement concrete. By using epoxy resin the flexural strength can be increased.(it is also called high performance epoxy resin concrete). The chemical resistance of polymer concrete is also better than Ordinary Portland Cement- concrete. By adding polymers and nano materials electrical and thermal properties also affected. It is best suited in the areas such as bridge decks, sea protection works, aerospace launching platforms, seismic resistant structures, pre-cast concrete structures etc. [15-19, 25-26]

EFFECT OF POLY METHYL METHACRYLATE (PMMA) IMPREGNATION ON PROPERTIES OF CONCRETE

The study (Nair at el. 2010) showed that the strength of Polymer impregnated concrete(PIC) samples and chemical resistance were better than those of traditional cement concrete. impregnation of polymers is done by two method. w/c ratio was taken 0.48. cubes of dimension 50x50x50mm were prepared for compressive strength. For flexural strength moulds of size 40X40X160 mm size were prepared, all specimen were cured for 28 days before polymerization and impregnation. The specimen were dried for 8 hours at 80°C.then samples were immerged in 1% polymer in water bath for 4.5 hour at room temperature. Then samples were polymerized by two methods. (1) keeping the samples in polyethylene terephthalate (PET) bags immerged into 80°C hot water for three hours.(2) keeping these specimen in microwave for two hours, at 80°C.to achieve uniform heating. It is found that compressive and flexural strength increases two folds, water absorption reduces, freezing and thaw resistance increases, chemical resistance increases, microwave impregnation is found better then water bath method.[20]

RESISTANCE OF POLYMERS CEMENT CONCRETE WITH AGGRESSIVE THERMAL AND ACIDIC EXPOSURE

Concrete and cement mortar (repair material) may deteriorate due to many reasons such as excessive loads, temperature variation, moisture, chemical attack etc. Plain cement mortar do not have capacity to bear it

for long-time. Polymer concrete can be the solution of these problems. Polymer concrete has good adhesion and low shrinkage. Polymers can be added in cement concrete mix (polymer modified mortar or concrete) or polymers can be directly mixed with aggregate without cement also (polymer concrete). The choice of polymers depends upon the requirement of the function to be performed. Mortar or repair material not always subjected to room temperature. There may be high rise in temperature or very high temperature continuously, like in chimney, thermal power plants etc. Karde at el.2009 in their experimental research, studied five different samples- control mix of plain cement concrete of cement and sand in ratio 1:3, with w/c ratio 0.4, other specimen prepared with polymer and sand (1:5 ratio), Acrylic, SBR, Epoxy emulsion, Epoxy resin. Investigations were done for aggressive environment; effect of thermal cycles, influence of high temperature, and effect of acidic exposure. In thermal cycles experiment samples were kept at high temperature of 85° for 8 hours a day then cooled at room temperature. Such 30, 60, 90, 120 cycles are applied. Then samples are tested for the strength. And sample are tested for acidic exposure, in which samples are kept in acid solution (5% sulphuric acid) for 180 days, and found that polymer concrete had best resistance to the acidic exposure and thermal cycles, but exhibited poor resistance for high temperate change. In Compressive strength was least in epoxy resin against acidic exposure. Epoxy emulsion showed best results against higher temperature and best resistance against thermal cycles.[21]

COMPARISON OF EFFECTS OF DIFFERENT POLYMERS ON STRENGTH OF CEMENT CONCRETE

Aggarwal LK, et al 2007 presented the comparative study of two types of polymer admixtures of cement concrete, epoxy and acrylic emulsions and found that epoxy emulsion is found better than acrylic emulsions as admixtures. is the authors found that when polymers are added, compressive and flexural strength decreases initially, but at higher level of percentage the flexural strength is better than control mix. But at the same time by adding polymers the other properties like chloride ion, penetration, depth of carbonation, and water absorption decreases. This experiment depicted that the durability of polymer concrete is better than conventional cement concrete

EFFECT OF VERY HIGH TEMPERATURE ON STRENGTH OF POLYMER CONCRETE

Tumadhir MA 2013 studied the effect of high temperature on polymer concrete when Epoxy resin polymer percentage 5%, 7%,10%, 15% of cement is used. Temperature raised 200°C, 400°C, 700°C for half hour, and one hour exposure, after 28 days of curing. After Temperature exposure cement concrete is tested for compressive strength and split tensile strength. The result shows that when the best temperature resistant result are on 7% resin mixed in cement concrete. (Variation in strength is least on 7%).[23]

EFFECT OF REPLACEMENT OF CEMENT BY EPOXY RESIN ON STRENGTH OF POLYMER CONCRETE

Polymer modified Portland polymer concrete posses good ductility, compressive strength over conventional concrete. In the article by Alkhaleefi AM, 2002 epoxy polymer was used. For flexural test mould of 150x150x600 mm was prepared, for compressive test mould of 150x150x150 mm is prepared, and split tensile cylindrical of diameter 150 a height 300 mm is prepared. The strength of cement concrete was examined by replacing the cement 0, 20, 40, 60, 100 percent by epoxy resin. To examine the mix concrete after addition of polymers following test were performed- compressive strength split tensile strength, four point flexural test, and direct shear test. It was found that improvement in the strength were as following: compressive strength increased 75%, split tensile strength increased 98%, the increment in shear strength was 148%, and the increase in flexural strength was 51%. This experiment showed that suitable polymer can successfully replace cement binder. The fact established that polymer concrete is stronger than conventional cement concrete.[24]

Table1

Effect of polymers on strength of cement concrete

Cement replaced by Polymer in concrete ercentage (epoxy resin)	Flexural strength of concrete in Mpa (approx)	Compressive strength of concrete In Mpa (approx)	Tensile Strength of concrete In Mpa (approx)	Shear strength of concrete In Mpa (approx)
20%	4.0	32	3.8	4.1
40%	5.0	35	4.2	4.5
60%	6.0	38	4.4	5.1
100%	20.0	56	7.0	10.0

CONCLUSION

From above results we can conclude that nano particles can we advantageously replaced up to 2% only, Setting time decreases due to fast hydration reaction of nano particles. Different types of polymers can replace cement up to certain amount. With cement the polymers content are useful up to 15-20% for strength enhancement. It is clear from above discussion that we can obtain greater benefits in flexural strength and compressive strength with polymer addition, by adding more polymers mechanical strength starts decreasing. At the same time other properties like chemical resistance, temperature resistance, get increased on the other hand shrinkage, chloride ion penetration, depth of carbonation reduced by use of polymer and nano

materials which is more desirable. Polymer concrete (PC) or Polymer Modified Concrete (PMC) is definitely beneficial for repair work for concrete and for severe chemical exposure. It is clear that the properties of cement concrete is greatly enhanced by polymers and nano materials. However the results of experiments done by different researchers are not consistent leaving much scope for further research work.

CONFLICT OF INTEREST

Conflict of interest declared none.

REFERENCES

1. Bozsaky D, Special thermal insulation methods of building constructions with nanomaterials, Acta Technica Jaurinensis, 2016; 9(1):29-41.
2. (Arefi MR, Zarchi SR, Synthesis of zinc oxide nanoparticles and their effect on the compressive strength and setting time of self-compacted concrete paste as cementitious composites. Int. J. Mol. Sci. 2012; 13:4340-4350.
3. Nazari A, Riahi S, Riahi S, Shamekhi SF, Khademno A, An investigation on the strength and workability of cement based concrete performance by using ZrO_2 nanoparticles. Journal of American Science. 2010;6(4):29-33.
4. Bhuvaneshwari B, Saptarshi, S, Iyer NR, Nanoscience to nanotechnology for civil engineering – poof of concepts, 2011; ISBN: 978-1-61804-022-0: 230-235.
5. Nazari A, Riahi, S, Riahi S, Shamekhi, SF, Khademno A, Assessment of the effects of the cement paste composite in presence TiO_2 nanoparticles. Journal of American Science. 2010;6 (4):43-46.
6. Nazari A, Riahi, S, Riahi S, Shamekhi SF, Khademno A, improvement in the mechanical properties of the cementitious composite by using TiO_2 nanoparticles, Journal of American Science. 2010;6(4): 98-101.
7. Nazari A, Riahi S, Riahi S, Shamekhi, SF, Khademno A, Influence of Al_2O_3 nanoparticles on the compressive strength and workability of blended concrete, Journal of American Science 2010;6(5):6-9.
8. Nazari A, Riahi S, Riahi S, Shamekhi SF, Khademno A, Mechanical properties of cement mortar with Al_2O_3 nanoparticles. Journal of American Science, 2010;6(4):94-97.
9. Arefi MR, Javeri MR, Mollaahmadi E, To study the effect of adding Al_2O_3 nanoparticles on the mechanical properties and microstructure of cement mortar, Life Science Journal. 2011; 8(4):613-617.
10. Casini MS, Materials and nanotechnology for energy retrofit of historic buildings. 2014;ISBN: 978-1-63248-020-0.
11. Duchene S, Detalle V, Nano material for consolidation of marble and wall paintings.12thInternational, Congress on the Deterioration and Conservation of Stone, New York. 2012:1-9
12. Patel AS, Rathod HA, Sharma ND, Overview on Application of Nanotechnology in Construction Industry, IJIRSET. 2013;2(11):6094-6098.
13. Paul DA, Hirst E, Nano-lime for consolidation of plaster and stone, Journal of Architectural Conservation. 2012; ISSN-1355-6205.
14. Hongyun X, Sun S, Van J, Application of modern new materials in product design, IEEE. 2008; 759-764
15. Gunasekaran M, Lightweight Partially nano-particled polymer concrete: a new concept for electrical insulation. IEEE.2007; 172-174.
16. Kerur VS, Patil UP, Effect Of Styrene Butadiene Rubber Latex Polymer on The Compressive And Tensile Strength of Concrete Containing One or Two Admixtures. IRJET, 2015;2,(4): ISSN, 2395-0056.
17. Sivakuma RMVN, Effect of polymer modification on mechanical and structural properties of concrete. International Journal of Civil and Structural Engineering.2010;1: 732-740.
18. Yujie JX, Yin LX, Application and research of high performance polymer concrete in covers. IEEE, 2011; 3366-3369.
19. Tomas U, Ganiron J, Influence of polymer fiber on strength of concrete. IJAST. 2013;55:53-66.
20. Nair P, Ku DH, Lee CW, Park JS, Park HY, Lee WM, Mechanical properties and durability of PMMA impregnated mortar. Korean journal chem.Eng. 2010;27(1): 334-339.
21. Karade SR, Thapliyal PC, Agrawal SP, Influence of aggressive exposure conditions on performance of repair materials. Trends and Challenges in Structural Engineering and Construction Technologies, CBRI Roorkee. 2009:321-327.
22. Aggarwal LK, Thapliyal PC, Karade, SR, Properties of polymer-modified mortars using epoxy acrylic emulsions. Construction and Building Materials. 2007;21:379–383.
23. Tumadhir MA, Resistance of polymer concrete to high temperature. Journal of Babylon University/ Engineering Sciences.2013;2:(21):644-653.
24. Alkhaleefi AM, Hawary MM, Fattah HA, On the behaviour of polymer portland cement concrete, 27th conference on our world in concrete & structures,Singapore. 2002:137-144.
25. Mishra PK, Investigation of polarization and depolarization current measurements in pure and doped pvk nanocomposite ,International Journal of Pharma & Bio Sciences Spl Ed. 2016: 140-152.
26. Srivastava A, Bhat C, Jain SK, Mishra PK, Brajpuriya R. Electronic transport properties of BN sheet on adsorption of ammonia (NH_3) gas. J Mol Model; 2015: 1-8.

Reviewers of this article

P. Ashok Kumar

Associate Professor
Department of Chemical Engineering
Vignan's Foundation for Science, Technology and Research University, Vignan's University,
Vadlamudi, Guntur (Dist), A.P-522 213. India

Dr.U.S. Sharma,

Dr.U.S. Sharma,
Head Physics,RJIT,
Tekanpur ,
Gwalior.

Asst.Prof.Dr. Sujata Bhattachary

Assistant Professor, School of Biological and Environmental Sciences, Shoolini University, Solan (HP)-173212, India

Prof.Dr.K.Suriaprabha

Asst. Editor , International Journal of Pharma and Bio sciences.

Prof.P.Muthuprasanna

Managing Editor , International Journal of Pharma and Bio sciences.

We sincerely thank the above reviewers for peer reviewing the manuscript