ADVANCED TESTS FOR DURABILITY OF CONCRETE WITH NANOSILICA AND PEG400

Chandra Sekhar Malla[1], Mukunda Rao D[2]
[1]Research Scholar, Department of Civil Engineering, Gitam Institute of Technology, Gitam University, Visakhapatnam, India

[2]Associate Professor, Department of Civil Engineering, Gitam Institute of Technology, Gitam University, Visakhapatnam, India

Abstract:
Due to the excellent properties of nanomaterials, it has a wide range of applications in different fields. One among them is their utilization in the manufacturing process of concrete. Even though nanomaterials are of high cost but a small replacement of their substitutes creates a high impact on the durability properties of concrete mixes. Nano silica is considered in the present study with curing compound PEG 400. In this work strength studies are conducted on M35 and M40 Grade concrete with Nano Silica by comparing them with PEG400 and without PEG400. Nano silica is utilized as a fractional substitution to Ordinary Portland binder by 1.5% of the total binder weight. In the present work, the partial replacement of Nano silica to cement showed a good influence in increasing strength properties. An optimal of 1 and 1.5 percent of addition of PEG400 is considered for M35 and m40 mixes. Durability studies such as water absorption test, permeability test on concrete, sorptivity test, acid attack on concrete cubes, bulk density, void ratio, and rapid chloride ions penetration test on concrete samples were also conducted on these mixes. Weight loss of specimens along with compressive strengths are observed when induced in 0.3,1 and 3 percent of sulphuric acid. High density and lower water absorption are observed in M40 concrete with 1.5 percent PEG400. Mixes with the addition of PEG400 have a high void ratio, are highly permeable, less resistant to acid attack.
Keywords: PEG 400, Nano silica, Weight loss, RCPT, Void Ratio, Coefficient of Permeability.

Introduction:
The execution of nanotechnology in concrete has prompted a functioning consolidation of nano-silica in concrete at a worldwide level. Various strategies for nano silica creation are accessible and fluctuate from sweeping to practical courses. The size of the nano-silica particles and their compound and actual nature rely upon the strategy for creation. Many sorts of scattered nano silica are prescribed to be utilized in concrete because of fractional explanation. Nonetheless, the dry powders of nano-silica particles are hard to scatter in concrete and require exceptional kinds of nano super plasticizers. The powerful expansion of NS prompts C-S-H with work on cementitious properties can be seen in figure 1.

Submitted: 24/11/2022 **Accepted**: 13/12/2022

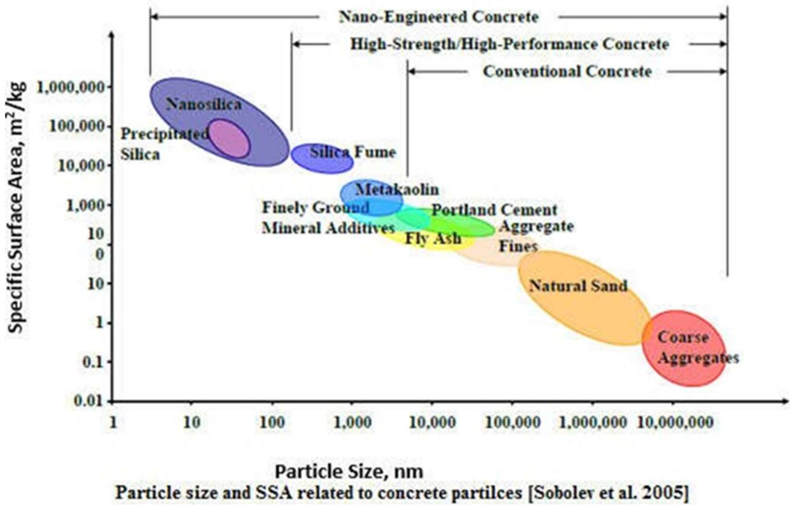
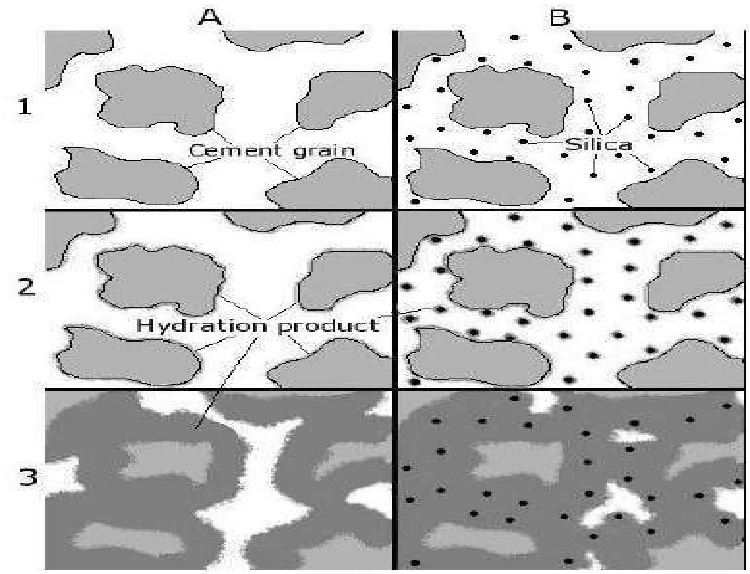


Figure1Relation between surface area and size of concrete particles

As concrete is the most usable material in the development industry it's been expected to work on its quality. Concrete is a profoundly heterogeneous material delivered by a combination of finely powdered concrete, totals of different sizes, and water with innate physical, compound, and mechanical properties. Concrete can be to some extent supplanted by various mineral admixtures, for example, flying debris, silica seethe, metakaolin, and so on, which have specific properties connected with that of concrete. By adding nanomaterials, substantial composites with predominant properties can be created. Nano Innovation implied to concrete incorporates the utilization of nano materials like Nano-silica. On the off chance that nano-particles are coordinated with concrete-based building materials, the new could have a few extraordinary properties. Nano-silica works on the microstructure and diminishes the water porousness of substantial consequently making it denser and more solid. Utilization of Nano-silica in HPC works on the cohesiveness between the particles of cement and decreases isolation and dying. Certain issues like higher setting time and lesser compressive strength at incremented rates can be overwhelmed by attaching Nano-silica. The expansion of valuable cementitious materials in the substantial won't just further develop the mechanical properties of concrete, yet additionally its usefulness, adjustment in setting times, and strength. The pozzolanic movement of Nano-Silica is clearer than that of silica seethe. Nano-Silica can respond with Calcium hydroxide ($Ca(OH_2)$) gems, which are displayed in the Interfacial Progress Zone (ITZ) between solidified concrete glue and totals and produce C-S-H gel. In this manner, the size and how much calcium hydroxide gems are altogether diminished, and the early age strength of the solidified concrete glue is expanded. Nano-Silica can act as a core to firmly security with concrete hydrates. The steady gel designs can be shaped and the mechanical properties of solidified concrete glue can be improved when a more modest measure of Nano-Silica is added. Nano-Silica can further develop the tension delicate properties of concrete mortar. Fly debris concrete with Nano-Silica has a higher thickness and strength likewise demonstrating that high-strength concrete with Nano-silica has higher flexural strength.



hydration of pure cement (A) and with addition of nanosilica (B) after mixing (1-3) [Land et al. 2011]

Figure2Hydrationofpurecementandhydrationofcementwith Nanosilicacement

The job of Nanoparticles of silica goes about as fillers in the voids or void spaces, observed from figure 2. The very much scattered Nano-Silica goes about as a nucleation or crystallization focus of the hydrated items, in this way expanding the hydration rate, or at least, Nano-Silica helps towards the development of more modest size CH gems and homogeneous groups of C-S-H piece. In addition, it was found that Nano-Silica worked on the strength of the design.

Expected Materials for Self-Restoring:

The accompanying materials can give inner water supplies

- Lightweight Total (regular and engineered, extended shale's)
- Super-retentive polymers - SAP
- SRA (Shrinkage Lessening Admixture) (for example polyethylene-glycol)
- Wood powder

Necessity of Present Study:

Customarily concrete is a combination of concrete, sand, and totals. Properties of total impact the toughness and execution of cement, so coarse total is a fundamental part of cement. Restoring cement is keeping up with palatable dampness content in concrete during its beginning phases to foster the ideal properties. Anyway, great restoring isn't generally down to earth by and large. The point of this examination is to assess the usage of water-dissolved monomeric glycol as self-relieving specialist. The adoption of self-restoring admixture is vital according to the perspective that the water assets became significantly consistent. The advantage of self-relieving admixtures is more critical in desert regions where water isn't ample attainable. In this study, the mechanical properties of self-restoring at various rates of polyethylene glycol will be assessed and contrasted and regular substantial examples. The extent of the review is to distinguish the impact of polyethylene glycol (Stake) on the strength qualities of self-relieving concrete and furthermore to assess the impact of polyethylene glycol on mechanical properties which are tentatively explored. This section designed by multiple creators on the employment of nanomaterials in substantial self-restoring of cement by PEG400 has been assessed in a nutshell.

Targets:

- To assess the solidness of cement with corrosive assault by various rate 0.3%, 1.0% and 3.0% of sulphuric corrosive (H2SO4).
- To assess water retention of M35 with 1% PEG400 and M40 with 1.5% PEG400 grades of cement with 1.5% of Nano silica.
- To assess water porousness of M35 with 1% PEG400 and M40 with 1.5% PEG400 grades of cement with 1.5% of Nano silica.
- To assess sorptivity of M35 with 1% PEG400 and M40 with 1.5% PEG400 grades of cement with 1.5% of Nano silica.
- To assess Fast Chloride Penetrability Test (RCPT) of M35 with 1% PEG400 and M40 with 1.5% PEG400 grades of cement with 1.5% of Nano silica.

- **Literature Review:**
-
- Stutzman (2000) concentrated on the substantial microstructure and the translation of reasons for disintegration. SEM imaging offices for ID of solidified concrete glue constituents with more noteworthy differentiation and more prominent spatial goal. He additionally concentrated on how quantitative stage data can be separated from this information, for example, arrangement stage overflow and conveyance.
- AlirzaNajiGivi et al. (2010) concentrated on the size impact of Nano silica particles. They supplanted concrete with Nano silica of size 15nm and 80nm with 0-5, 1, 1.5 and 2% by weight of concrete. An expansion in the compressive strength was seen with 1.5% by weight of concrete appearance greatest compressive strength.
- Mukharjee et al. (2012)introduced the exploratory investigation of the impact of nano estimated molecule of colloidal nano silica on the mechanical properties of cement. The substantial blends are delivered by supplanting a small part of Portland concrete with 1.5% and 3.0% of colloidal nano silica separately. Also, because of expansion of nano silica in concrete, the improvement in elasticity has been accomplished and quantitative improvement of cement affirmed by leading non-disastrous tests.
- Raghavendra and Aswath (2012) Utilizing Film restoring and Self-Relieving strategies one can accomplish 90% of effectiveness when contrasted with Customary Restoring technique. Film relieving compounds are most down to earth and generally utilized technique it is most appropriate in water scant region.
- Mateusz Wyrzykowskiet et al. (2012) investigated how superabsorbent polymers displayed water migration during inward relieving (SAP). The SAP should be evenly distributed throughout the structure and serve as internal water reservoirs, first holding onto

water during mixing and delivering it to the surrounding concrete glue. It is possible to provide water relief in combinations with low water-to-solids proportions (w/c) by adding SAP.

- A study on "self-relieving concrete cemented with polyethylene glycol" was conducted in 2014 by Mohanraj and Rajendran. Self-relieved concrete has a greater compressive strength of block and chamber measured by NDT than ordinary cement restored by complete relieving and sprinkler restoration. Concrete that has been self-replaced has been shown to have lower water retention and water sorptivity values than concrete that has been alleviated using other methods.Self-replaced substantial in this manner have a lower units of permeability.
- **Experimental Investigation:**
-
- The exploratory examination was wanted to give adequate data about the strength and sturdiness qualities of cement with the expansion of Nanosilica and Restoring compound. Tests were led on materials to know their actual properties. Results were investigated to determine valuable ends in regard to the strongest attributes of cement with the expansion of PEG400. M35 and M40 grades of cement have been utilized as reference blends. A sum of 6 blends was considered for testing the examples are as per the following:
- MIX 1 = G+1.5%NanoSilica+0.3% H_2SO_4
- MIX 2 = G+1.5%NanoSilica+1% H_2SO_4
- MIX 3 = G+1.5%NanoSilica+3% H_2SO_4
- MIX 4 = G+1.5%NanoSilica+X%PEG400+0.3% H_2SO_4
- MIX 5 = G+1.5%NanoSilica+X%PEG400+1% H_2SO_4
- MIX 6 = G+1.5%NanoSilica+X%PEG400+3% H_2SO_4
-
- Where G = Grade of concrete M35/M40, X=1 for M35 and 1.5 for M40 grade concretes considered based on requirement.
-
- **Cement:**
- The cement utilized in the preparation of concrete is OPC 53 Graded of the JAYPEE brand.
-
- **FineAggregate:**
- The aggregate utilized in the preparation of concrete is zone 2 sand obtained from the river.
- **CoarseAggregate:**
- The metal used is under acceptable grading limits and of the total weight 60 percent of 20 mm and remaining of 10 mm aggregates were considered in the mix design.
- **Water:**
- Portable water which is clean to visible with no traces of dust and impurities is utilized.

- **Admixture:**
- CEMSYNXLP Nano silicais the type taken into consideration.

Polyethylene Glycol:

PEG400 has wide range of utilities in different industries as emulsifier and flocculent and also as cement suspension agent. It has a relative density of 1.124, PH of 6.5, atomic weight of 400 and dampness of 0.2 percentages. It appears to be opaque in nature.

Methodology:

Foracidattackcubesofsize100mmx100mmx100mm(lengthxbreadthxdepth), sorptivity and RCPT test for concrete cylinder 100mm x50mm (diameterxdepth) are considered for testing.The following specimens were casted for durability concrete tests:

Numbersofcubesforpermeabilityofconcrete	=12samples
NumberofcylindercastforsorptivityandRCPT	=24samples
Numberofcubescastforacidattack	=156samples
Totalnumberofspecimenscast	=192 samples

After proper water curing the specimens (cubes) were exposed to dilute Sulphuricacid of 0.3%, 1% and 3% concentrations. The strength of acid was measured at regularintervalsandthedepletedacidwasreplenished.

Results and Discussions:

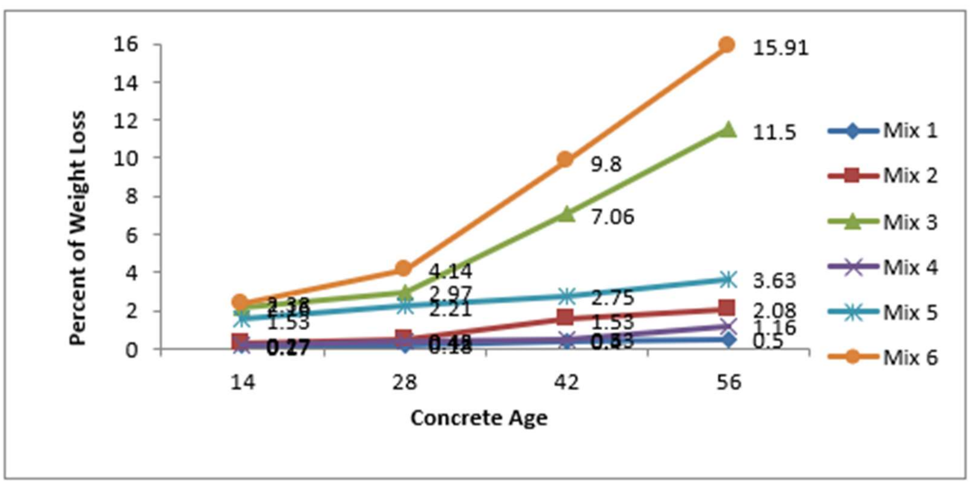


Figure 1.1PercentageWeightreductionofM35 Gradeconcretewith1.5%Nanosilicawith and without 1%PEG400 for 0.3%, 1%, 3% H_2SO_4 solution at different curingperiods

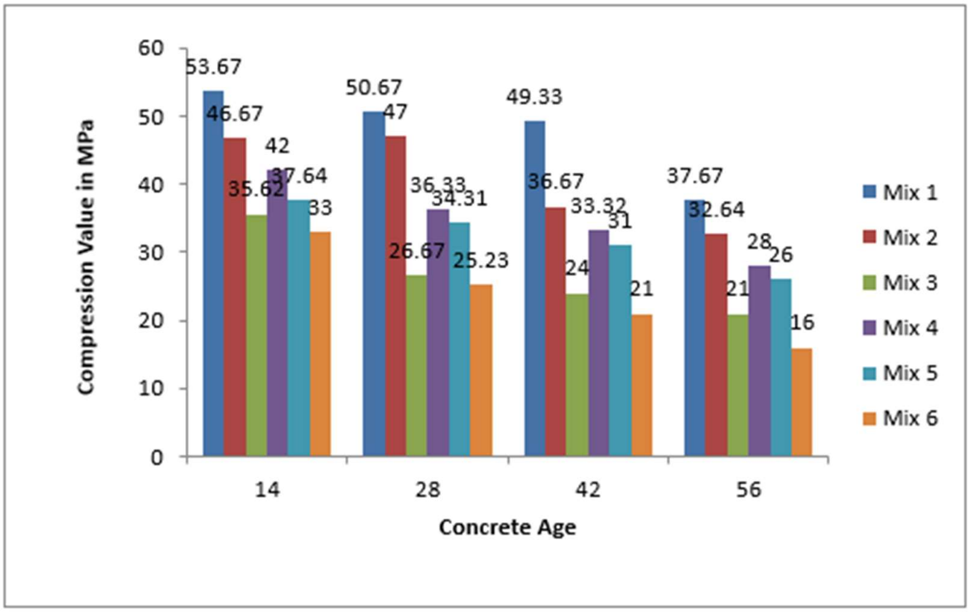


Figure 1.2 CompressiveStrengthsof M35 Grade concrete with 1.5%Nano silicawithandwithout1%PEG400for0.3%,1%,3%H_2SO_4 solutionatdifferentcuringperiods

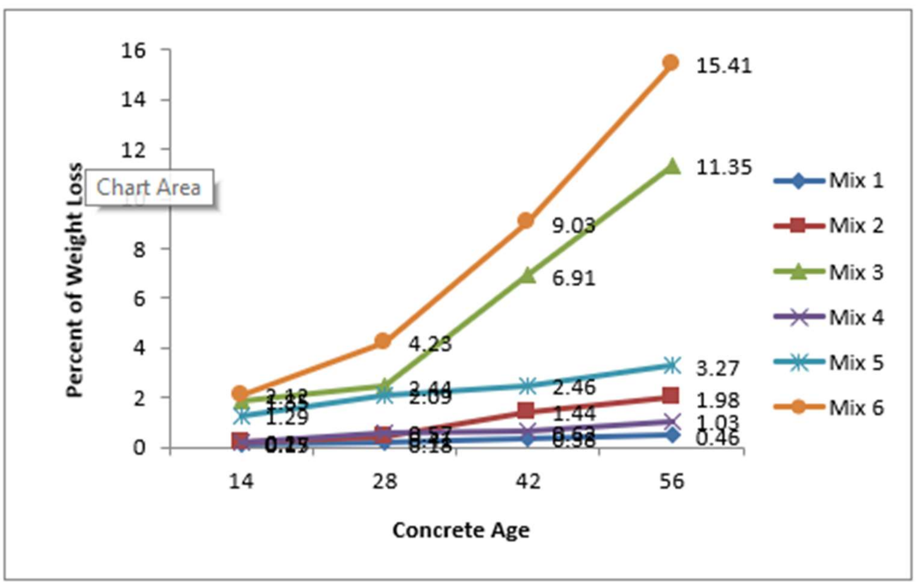


Figure 1.3PercentageWeightreductionofM40 Gradeconcretewith1.5%Nanosilicawith and without 1.5%PEG400 for 0.3%, 1%, 3% H_2SO_4 solution at different curingperiods

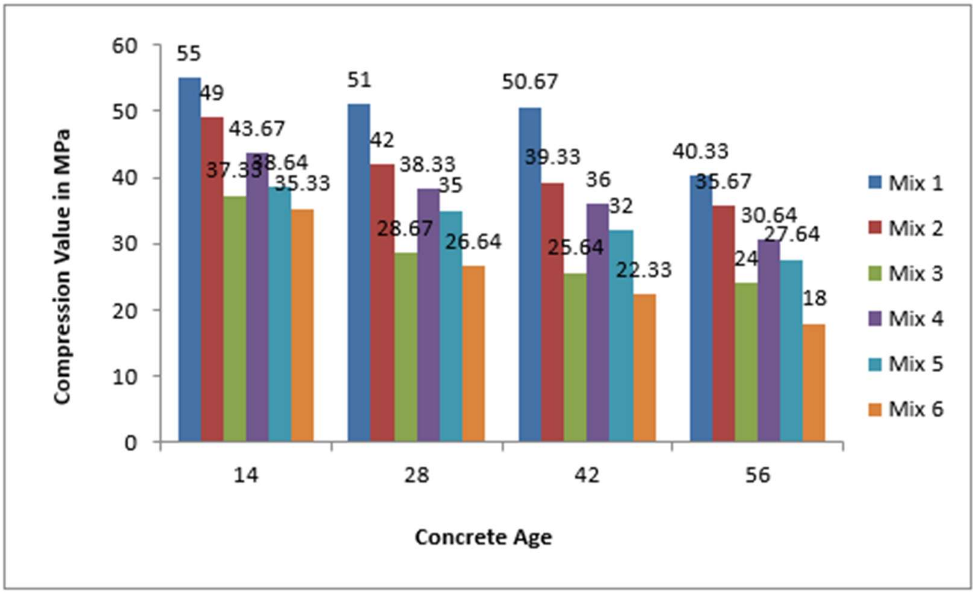


Figure 1.4 CompressiveStrengthsof M40 Grade concrete with 1.5%Nano silicawithandwithout1.5%PEG400for0.3%,1%,3%H_2SO_4 solutionatdifferentcuringperiods

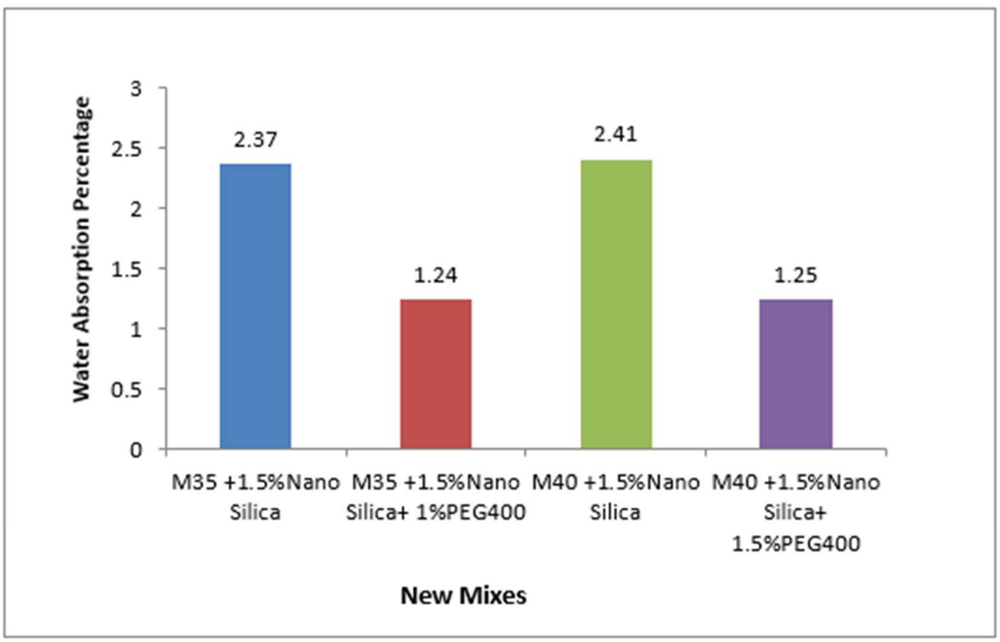


Figure 1.5 AbsorptionofwaterafterimmersionofM35andM40Gradesconcretewith1.5%Nanosilicawithandwithout1%PEG400&1.5%PEG400

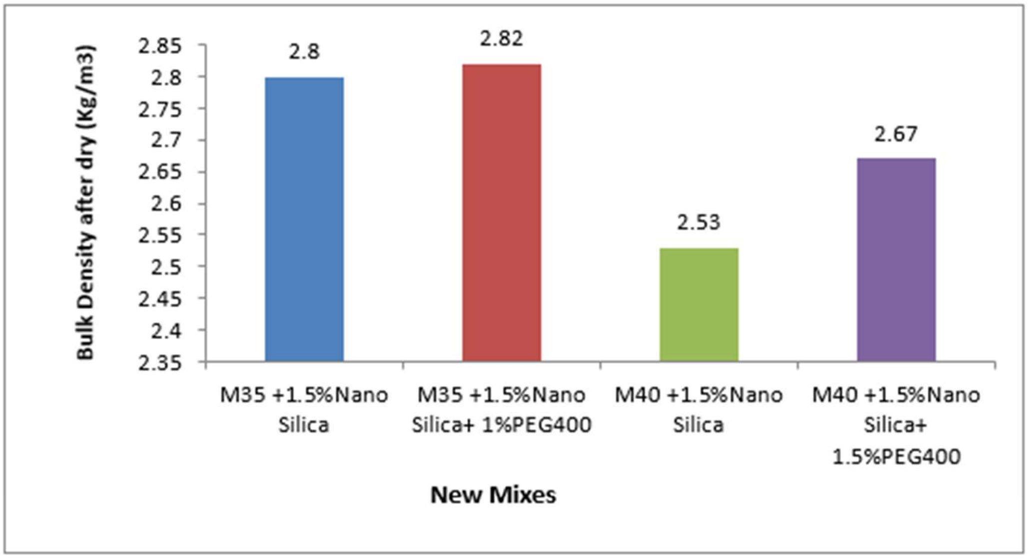


Figure 1.6Bulk densitiesofM35andM40Gradesconcretewith1.5%Nanosilicawithandwithout1%PEG400& 1.5%PEG400

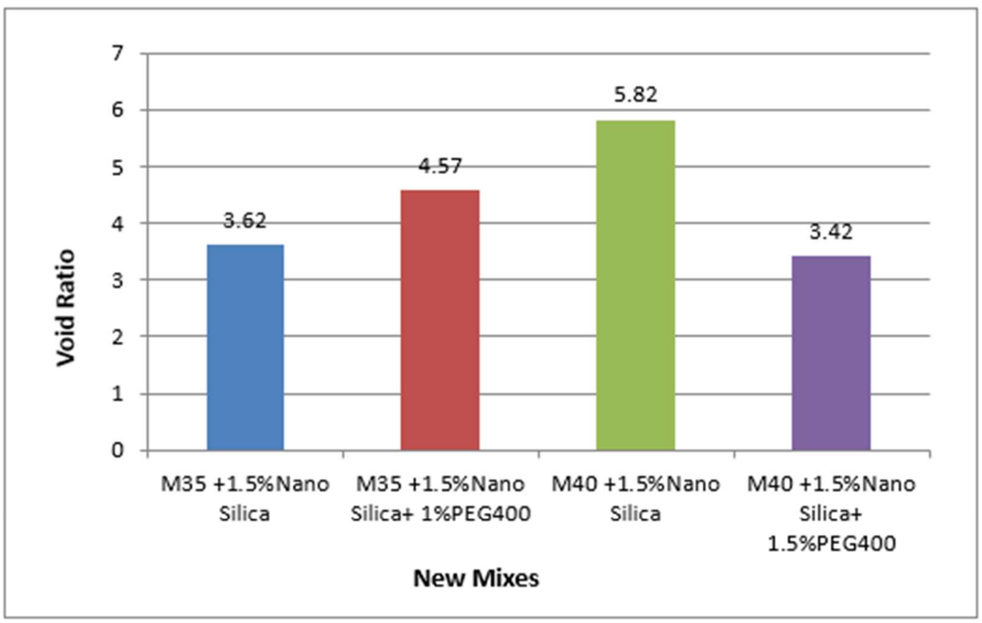


Figure1.7VoidratioofM35andM40Gradesconcretewith1.5%Nanosilicawithandwithout1%PEG400&1.5%PEG400

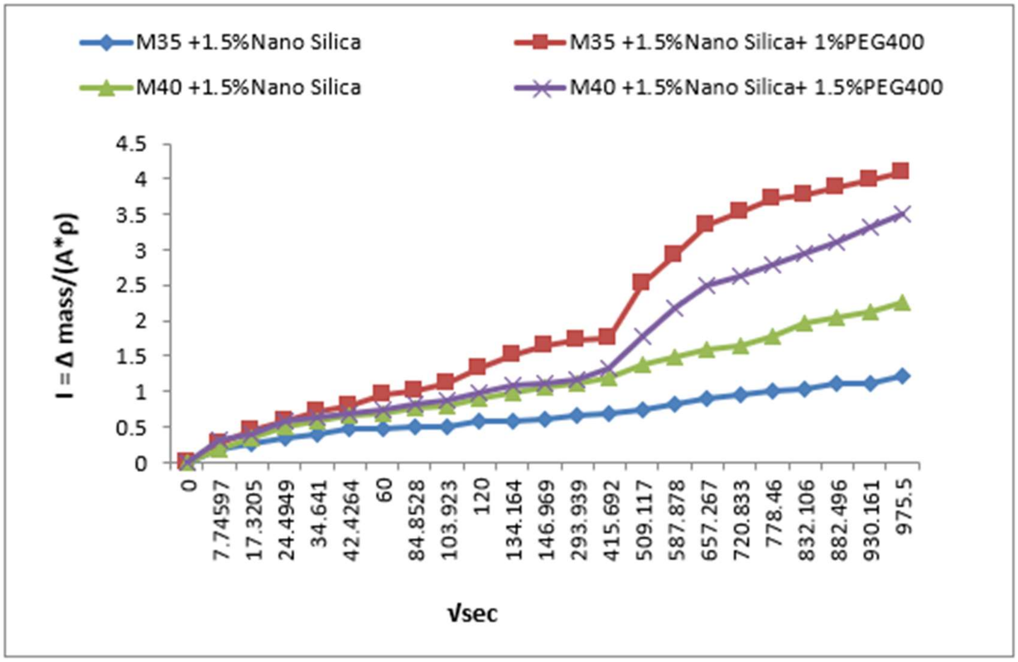


Figure 1.8Sorptivityof Different Types of Concrete Mixes

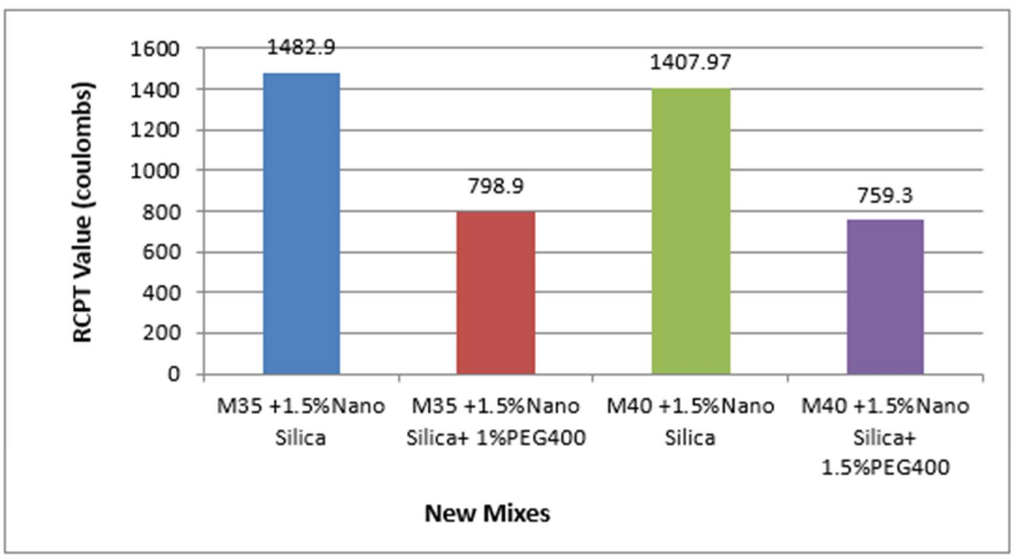


Figure1.9ComparisonofRCPTvaluebetween ConcreteGradesM35+1.5%NanoSilica andM40+1.5%NanoSilicawithandwithout1%and1.5%PEG400

RCPT = Rapid chloride penetration test

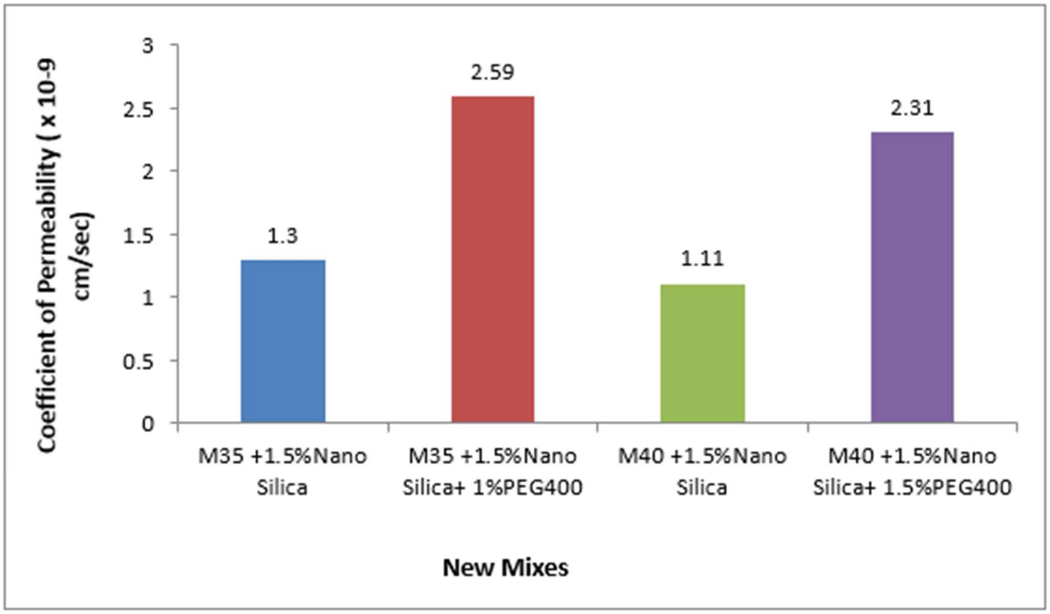


Figure1.10CoefficientofpermeabilityofConcreteGradesM35+1.5%NanoSilicaandM40+1.5%Nano Silicawithandwithout1%and1.5%PEG400

All substantial blends show strength loss with age after submersion in sulphuric corrosive arrangement. The Mix 1 blends are having higher obstruction compared with remaining blends for both grades of concrete. From Fig 1-4, it is seen that the weight reduction of the multitude of blends expands with expansion in age of specimens. Higher level of weight reduction is noticed for Mix 6 in both concrete grades. Highest coefficient of permeability of 2.59 is observed in M35 +1.5%Nanosilica+ 1%PEG400 mix, which means it is having higher porosity. Based on Fig 5-10,the voids ratio, water absorption, density, sorptivity, and RCPT values it is observed that the M40 grade concrete is not suggest able when adopted with 1.5% Nano silica.

Conclusions:

Four different concrete mixes of M35 and M40 grades were prepared with limited substitution ofcement by weight with 1.5 % of Nano silica. In addition to Nano silica curing compound PEG400was also added at different percentages. The concrete mixes are tested for durability propertiesintermsofSorptivity, effect of acid on concrete, Water Absorption, Rapid ChloridePenetrationtest (RCPT)and Permeability.

From thetestdata,below conclusions are drawn:
The effect of acid attack on concrete is more on concrete with 1% PEG400 when compared to concrete without PEG400. The compressive strength of all concrete reduces with an increase in acid percentage as well as duration in an acid attack. Higher weight loss is observed in all concretes with the rise in acid content and duration. The void ratio of concrete increases with the addition of PEG400 for M35 concrete and decreases for M40 grade concrete. The chloride

ion passage through concrete reduces with the addition of PEG400 for both grades of concrete. The concrete mixes with PEG400 are more permeable than the concrete mixes without PEG400. Lower density and higher water absorption capacity of M40 grade with 1.5% nano-silica is not recommended compared to the same mix along with 1.5%PEG400. It is concluded that the addition of Nano silica improves strength parameters and the addition of PEG400 helps in internal curing.

References:

1. Abdulkadircuneytaydin (2018),"The synergic influence of nano silica and carbon nano tube on self compacting concrete", Journal of building engineering.

2. A. Karthik (2017), "Investigation on mechanical properties of fly ash ground granulated blast furnace slag based self curing bio geopolymer concrete", Construction and building materials 149.

3. AlirezaNajiGivi, Surya Abdul Rashid, Farah Nora A. Aziz and MohamadAmraMohdSalleh (2010), "Experimental investigation of the size effects of SiO2 Nanoparticlesonthemechanicalpropertiesofbinaryblendedconcrete",Composites:PartB41, 673-677.

4. Byung-WanJo,Chang-HyunKim,Ghi-hoTaeandJang-BinPark.(2007),"CharacteristicsofcementmortarwithNano-SiO2particles",ConstructionandBuildingMaterials,Vol.21,pp.1351-1355(2007).

5. Doha M. Al Saffer (2018),"Effect of internal curing on behaviour of high performance concrete: An Overview", Case study in construction materials.

6. HuiLi,Hui-gangXiao,JieYuanandJinpingOu (2004), "MicrostructureofcementmortarwithNanoparticles",Composites:PartB35,185-189.

7. OveysAfzaliNaniz (2018), "Effect of colloidal nano silica on fresh and hardened properties of self compacting lightweight concrete", Journal of building engineering.

8. Magda I.Mousa (2015), "Self curing concrete types water retention and durability", Alexandra engineering journal.

9. MagdaI.Mousa,MohamedG.Mahdy,AhmedH.Abdel-Reheem,AkramZ.Yehia(2014), " Mechanicalpropertiesofself-curingconcrete(scuc)",HousingandBuildingNationalResearchCentreHBRCJournal.

10. MateuszWyrzykowski,PietroLura,FrancescoPesavento,andDariuszGawin(2012),"ModellingofWaterMigrationduringInternalCuringwithSuperabsorbentPolymers",journalofmaterialsincivilengineering©ASCE/AUGUST2012.

11. MohanRajA,RajendranM,RameshAS,MahalakshmiM,ManojPrabhakarS.(2014), " An Experimental Investigation of Eco-Friendly Self –Curing ConcreteIncorporated with Polyethylene Glycol", International Advanced Research Journal inScience,EngineeringandTechnology,2(1),2393-8021

12. Mukharjee,BibhutiBhusan,BaraiandSudhirkumarV.(2014),"Influenceofincorporation of Nano-silica and recycled aggregates on compressive strength andmicrostructureofconcrete", ConstructionandBuildingMaterials71,570-578.