“EFFECT OF NANO SILICA AND COIR FIBER ON COMPRESSIVE STRENGTH AND ABRASION RESISTANCE OF CONCRETE”

A thesis report submitted

In the partial fulfillment of the requirement for the award of the degree of

MASTERS OF ENGINEERING

IN

STRUCTURAL ENGINEERING

Submitted by

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DECLARATION

I, hereby declare that the thesis report entitled **"EFFECT OF NANO SILICA AND COIR FIBER ON COMPRESSIVE STRENGTH AND ABRASION RESISTANCE OF CONCRETE",** submitted as per partial fulfillment of the requirements for degree of Masters of Engineering in Structural Engineering under the Department of Civil Engineering, Thapar University, Patiala is my own work under the guidance of Dr. Maneek Kumar, (Professor and DOSA, Civil Engineering Department) during the academic year 2016-17. I confirm that the library may lend of copy of this upon request for academic purposes.

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CERTIFICATE

This is to certify that the work presented in thesis entitled **"EFFECT OF NANO SILICA AND COIR FIBER ON COMPRESSIVE STRENGTH AND ABRASION RESISTANCE OF CONCRETE",** submitted by Mayank Gupta, Roll No. 801524018 is an authentic record of work carried out by the student under my guidance.

Dated: 14 / 07 / 2017

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ABSTRACT

Natural aggregate and cement are the basic elements of concrete. Due to exploding world population, construction activities are growing by leaps and bounds, leading to a whole new jungle of concrete, thus enhancing the requirement of the natural aggregate and cement. The production of the aggregates and cement is one of the major causes for environmental pollution. To set a balance between the environmental pollution and the cost of construction, search for other substitute material is the need of the hour, which can enhance the properties of concrete.

This research is the investigation for examining the effect of nano silica and coir fiber on compressive strength and abrasion resistance of concrete. For completing the objective of the study, Coir fiber has been added in the concrete with the variation of 0.25 %, 0.5 %, and 0.75 % by the weight of the fine aggregates and 2 % and 3 % nano silica and 15 % fly ash have partially replaced cement in the mix . Different samples with varying percentages of nano silica and coir fiber have been prepared keeping water to binder ratios as 0.47, 0.45 and 0.42 for calculating the compressive strength and abrasion resistance and results have been compared with the controlled specimens.

After studying of the results, it is concluded that as the percentage of the Nano silica and Coir fiber is increasing, the compressive strength of the concrete increases up to the use of 0.5 % coir fiber and after that it drastically reduced. The improvement in the 7 days strength is more than the 28 days strength, thereby concluded that nano silica addition in concrete improves the early age strength. But as the percentage of the coir fiber is increased, the abrasion resistance of the concrete decreased thereby concluding that coir fiber may be not completely fill the present voids of the mix.

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CHAPTER 1

INTRODUCTION

The demand for constructing buildings has been on the rise, particularly in the last 2 decades due to enhanced world population and increase standard of living. It has been forecast that the population of the world will become 6–9 billion by the year 2050 and to 11 billion by the end of the century from the present day and for that population, the demand for school, houses, hospitals, shopping malls, etc. will also increase. As we know that concrete is the primary important building construction material, in the year 2050, the concrete demand will become approximately 18 billion tons a year (Shafigh, P. et al. (2014).

Concrete is a widely used man made material for civil engineering construction all across the globe. The production of concrete is less expensive as compared to some other building materials like steel. Concrete is the mixture of ingredients like cement, coarse and fine aggregates, and water, with or without admixture(s). When we mix these ingredients in a fixed proportion it makes concrete. This is in semi-solid state and has high workability, durability and strength. After some time it transform into a solid state. Up to some period the strength of concrete increase then the strength may decrease due to development of cracks and decrement of bond strength.

The aggregates generally fill 70% to 80% volume of the concrete and therefore, highly influence the fresh and hardened properties of concrete. It is, therefore, important to select good quality of the aggregate, because the main matrix of the concrete is formed by aggregates. Generally, we get fine aggregates from the river bed and coarse aggregates after crushing of stone. After completing some action like cleaning, washing, etc., aggregates are used in the concrete.

Due to the high usage of natural aggregate, leads to a question about the saving of natural aggregate sources. Other than that, extraction and processing of the aggregate are the principal causes of environmental concerns. To save the environment and natural aggregates an alternative solution or an alternative to natural aggregates is required. New materials that would be less in cost and at the same time provide equal or better properties when used in concrete is the need of hour . We have enough natural resources and an effort must be made to look for an alternative to replace the frequently used natural aggregates.

Plain concrete is strong in compression and weak in tension. Sometimes cracks forms into the concrete because of plastic and drying shrinkage and modification in the volume of concrete. For improving the tensile strength of the concrete, fibers are frequently used as reinforcement in the matrix. As the fibers used in the concrete act as a reinforcement material so this type of concrete is called as fiber reinforced concrete. Fiber reduces the rate of crack propagation and work as a crack holder. Now a day's synthetic and natural fiber are also available in the market for improving the properties of the concrete.

Coconut, jute, sisal, hemp, flax, cotton and pineapple are the natural fiber those are obtained from the vegetables. These fibers are cheap, renewable, biodegradable, environmental friendly and abundantly available. When these fibers are used in the concrete composite, then it will reduce the cost and weight of composites as compared to the synthetic fibers like steel, glass etc. The handling or use of natural fiber is very easy as compare to the synthetic fiber because of the flexibility of the fiber. Use of the natural fiber is on the increase in developing countries, like India, Sri lanka, New Zealand etc.

Ali et al. (2012) and Yan et al. (2016) reported that, among all the natural fibers, coconut fibers (Coir Fiber) are used to a great extent because it has less cost, high toughness and good durability. A large amount of lignin coating on the coir fiber provides the higher strength to the fiber as compared to the other fiber as reported by Lertwattanaruk et al. (2015). Coir is highly available in the coastal area of the India, Bangladesh, Sri lanka, Thailand, Malaysia etc.

Coconut fiber is found from the coconut shell husk. For getting the coir, firstly the husk with a spike is removed and after retting, the fibers are extracted by beating and washing of the husk. The fibers have enough strength, are less in weight, have lowest thermal conductivity, less bulk density and possess high resistivity for the heat and salty water.

A global coir trade report of Coir Board of India reported that the total production of the coir fiber (Globally) is about 350,000 metric tons (MT). India and Sri Lanka are the two highest productive countries of the coir in the world, which produce more than 90 % of the total coir. The executive report of Coir Board India also says that more than 28 % of total coconut husks are not use in the coir industries and remaining 72% are used for developing fuel or as a waste material in rural areas.

By using the coir fiber in the concrete we can reduce the cost of construction and environmental pollution (which is developed due to extraction of the natural aggregates), and also improve the properties of concrete. It was reported by many researchers that by providing coir fiber in the concrete the compressive strength, flexural strength, spilt tensile strength, durability, post cracking strength etc do improve. The investigation on the coir fiber indicate that coir containing concrete or mortar may be used for developing light weight cement board (Asasutjarit et al. 2007), cement composites roofing tiles (Abraham et al. 2016), cement mortar for surface plastering purposes (Sathiparan et al. 2017) and also used for construction in the aggressive environment (Ramli et al. 2013). At this moment many researches are going on the concrete incorporated with coir fiber for studying the behavior of concrete under dynamic conditions.

Other than natural aggregate, cement is also an important ingredient of the concrete. Cement works as a binder material in the concrete. It binds the other ingredients of the concrete and provides strength to the concrete matrix. The other work of the cement is to fill the existing voids between the fine aggregates and coarse aggregates. Said et al. (2012) reported that cement industry consume maximum energy as compared to the other industries and also emits high quantity of carbon dioxide gas (CO_2). This is another major cause of environmental pollution.

As the world population increases, the requirements of the cement (for construction) are also on the rise. Thus the pollution also increases due to emission of CO_2 in the environment. In the present time many research is ongoing for searching a substitute material for the cement. New materials should be such that those are less in cost and improve properties of the concrete. Many substitute cementitious material are available like Ash of waste materials, slag of the materials, micro and nano size material like nano silica etc, which can partially replace cement in concrete.

For the last many decades, fly ash is used in concrete as the replacement of the cement up to some limits for improving the properties of the concrete, so formed. Fly ash is a fine powder which is produced from combustion of coal at temperature of 1500 – 1600 ºC in electric generation power plants. Fly ash is the material that moves with the flue gases and it can be collected and stored in silos. Electrostatic precipitators are used for capturing the fly ash before the flue gases reach to the chimneys.

The use of fly ash as a replacement material or a binding material can reduce the cost of the cement. Other than that, Fly ash is an environmental friendly material because it is a byproduct of coal and has low embodied energy. Fly ash requires less water as compare to the cement and thus it can be easily used in cold weather condition as well. Other benefits of fly ash include improving the initial and final setting times, increase later age strengths, improve workability, permeability and reduced bleeding, decrement in heat of hydration, decrease water/cement ratio for equal slumps value as compare to without fly ash mixes and Reduces CO_2 emissions by reducing the quantity of cement etc.

Now days, use of nano silica in the concrete is also on rise due to its suitable physical and chemical properties. Due to the presence of high silica content in the nano silica, it easily reacts with calcium hydroxide and develops high quantities of the C – S – H gel, which improve the property of the concrete. The particle size of the nano silica being reduces the fluidity and increases the water demand when used as the replacement of cement but it improves the early age strength of mortar or concrete. In order overcome the disadvantage posed due to use of the nano silica, fly ash is also being mixed with nano silica in the concrete. Hou et al. (2013) reports that Fly ash improves the flow-ability property of the concrete and nano silica improve the early age strength of the concrete. nano silica with the fly ash is used for developing the high performance and ultra-high performance concrete.

In the present study, the effect of nano silica and coir fiber on the compressive strength and abrasion resistance of the concrete has been presented. Coir fiber improves the physical and mechanical properties of the concrete. Due to the use of coir fibers flow ability decreases, whereas on the other hand use of nano silica and fly ash in the coir contained concrete, flow ability and early age strength of the concrete improves. There by using the nano silica and fly ash with coir fibers containing concrete, the strength and durability of the concrete will more improve as compared to only coir containing concrete.

1.1 OBJECTIVE OF THE STUDY

The principal aim of this research study is:

- To study the effect of coconut fiber when added by the weight of fine aggregates and nano silica with fly ash when replaced with cement in concrete.
- To study the compressive strength and abrasion resistance of concrete containing coir fibre and nano silica.
- To determine optimum replacement percentages of fine aggregate and cement for replacement with the coir and nano silica in the concrete mixtures respectively.

The main benefit of the research is to find an alternative solution of natural fiber in the concrete.

1.2 ORGANIZATION OF WORK

Chapter 1 – This chapter presents a general introduction of coir fiber and nano silica. **Chapter 2 –** Here in literature review of the nano silica and coir containing concrete or mortar is presented.

Chapter 3 – This chapter highlight the experimental program, wherein the test procedures and measures to be followed during experiments are explained in detail.

Chapter 4 – This chapter deals with results and discussions where findings of the experimental program are explained in detail.

Chapter 5 – This chapter present the conclusion and future scope of the study. This chapter is followed by the list of references used in the present study.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

This chapter contains, in depth study of the previous research work done in the area of finding the effect of nano silica and coir fibre on the properties of resulting concrete. The literature review would provide some insight into how the properties of concrete can change due to the addition of coir fibers and with partially replacement of cement with nano silica and Fly ash.

2.2 EFFECT OF NANO SILICA

Said et al. (2012) studies the effect of colloidal nano silica (with or without Fly ash) on properties concrete. The researchers conducted the test on strength and rapid chloride ion permeability (RCPT) test.

For the experiment 6 mixtures were prepared, 3 mixtures contains 0 %, 3 % and 6 % nano silica without the fly ash and 3 mixtures with 30 % fly ash with 0 %, 3% and 6 % nano silica. An aqueous solution of colloidal nano silica with 50 % SiO_2 was used. The average particle size, specific gravity and pH of the nano silica were 35nm, 1.36 and 9.5, respectively. All 6 mixtures were designed for a constant water to cement ratio of 0.40.

It was concluded that, there was a significant improvement in reactivity and strength. As nano silica has higher surface area and smaller particle size, so it provides an improvement in the pore structure, better compaction of the interfacial transition zone, providing the filler effect on the cemenetitious matrix and reducing the conductivity. About the mechanical properties, it was found that, the compressive strength and tensile strength of the nano silica containing concrete (with and without fly ash) increased up to 6 % for the all curing ages. It was also concluded that the rate of increment in the compressive strength of concrete incorporated with fly ash can be increased by addition of a small amount of nano silica. The results obtained from the RCPT exhibit that there was a significant loss in the passing charges and physical penetration depth with the incorporation of the nano silica in the concrete. Fig 2.1 and 2.2 shows the results obtained in this research.

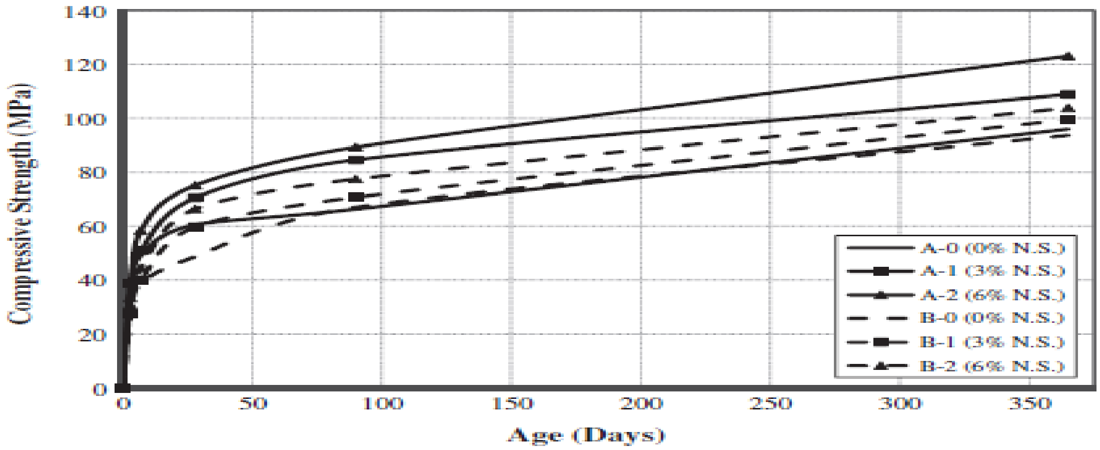


Fig. 2. 1 Compressive strength versus curing time [Said et al. (2012)]

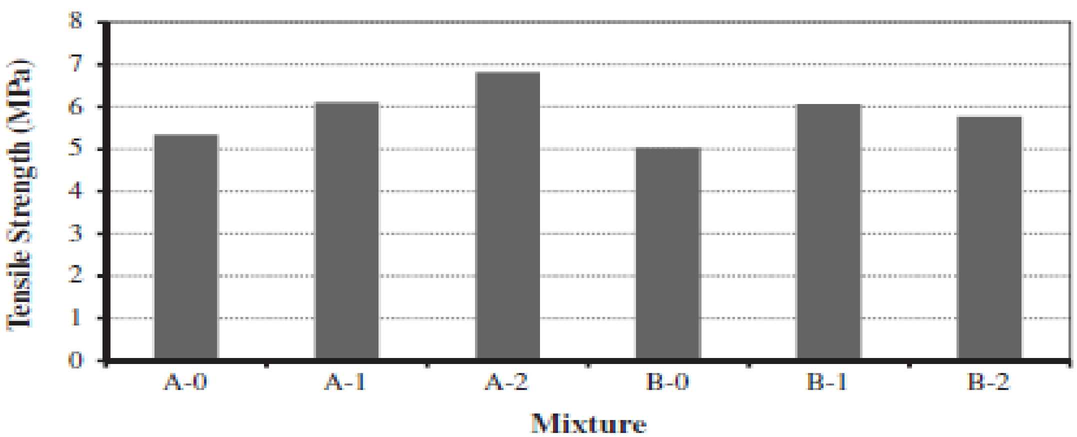


Fig. 2. 2 Split tensile strength of all the mixtures at 28days [Said et al. (2012)]

Zhang et al. (2012) studies the effect on the early age strength and setting time of concretes when nano silica and slag were used as ingredients of concrete as a partial replacement of cement. In this research, the effect of the dosage and size of the nano silica on the strength of the mortar containing slag was also investigated.

In all the mixtures, a fixed water to cement ratio 0.45 was used. In the designed concrete, cement is replaced with slag in proportion of 50 % and nano silica with the variation of 0

%, 0.5 %, 1 % and 2%. Two different particle size (12 nm and 7 nm) and different specific surface area (200.1 and 321.6 m^2/g) of the nano silica were used in comparison to the silica fume of 21.3 m^2/g specific surface area.

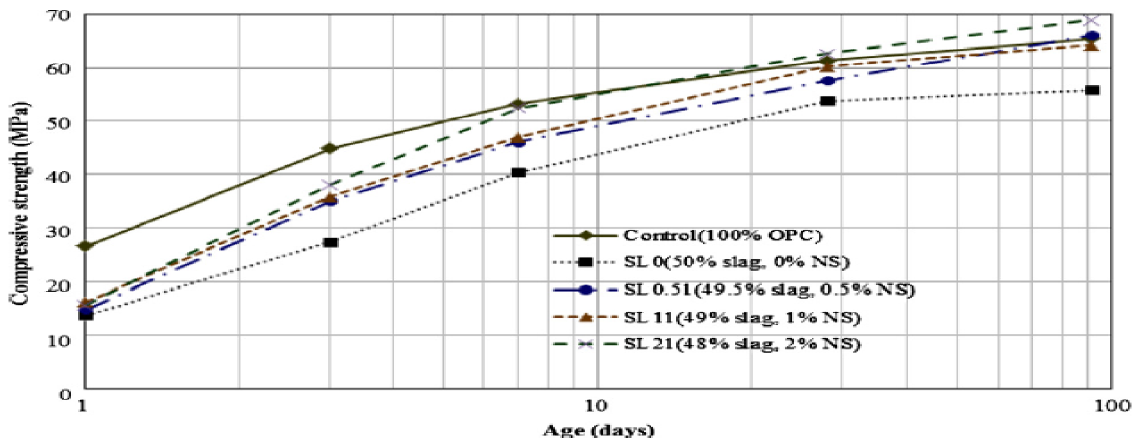


Fig. 2.3 Effect of nano silica dosage on the compressive strength of mortar [Zhang et al. (2012)]

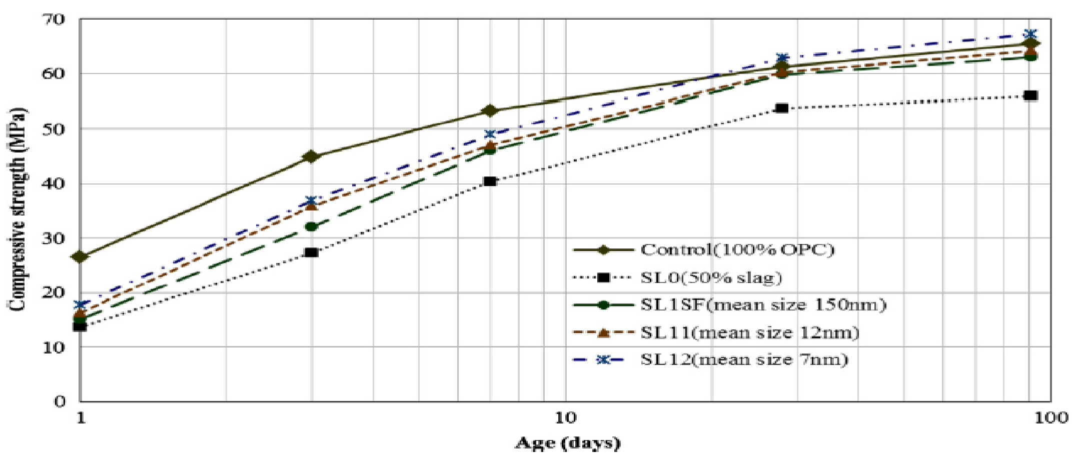


Fig. 2.4 Effect of nano silica size on the compressive strength of mortar [Zhang et al. (2012)]

The results showed that, even a small dose of nano silica decreases the setting time of cement and increases the compressive strength of the resulting concrete after 3 and 7 days of curing but after 1 day of curing, the increase is not very significant. It was also concluded that, as the percentage of nano silica dosage increases the compressive strength of slag concrete will also increase even after the 91 days of the curing. It was reported that, at the early ages, as the particle size of the nano silica is decreased, the compressive strength of the slag containing mortar is increases. Fig 2.3 and 2.4 shows the effect of the different dosage and different particle size on the compressive strength of slag mortar.

Zhang et al. (2012) performed an experimental analysis for determining the effect of nano silica on the setting time and strength of the concrete containing 50 % fly ash or slag. In this research, effect on the resistance to the chloride – ion penetration due the nano silica or silica fume on the fly ash and slag containing concrete was also evaluated.

In all mortars mixes, water – cement ratio of 0.45 and sand – cementitious material ratio of 2.75 were used. In the experiment, 50 % of cement is replaced with fly ash or slag in addition 1 % and 2 % nano silica or silica fume were used for the calculating the compressive strength and setting time of the resulting mortar and concrete, respectively. Calculated compressive strength and setting time of the mortar and concrete were compared with that of concrete containing only fly ash or slag.

After the analysis, they concluded that replacement of cement with 1 % nano silica or silica fume (with 50 % Fly ash or slag in the mortar), increased the strength of the mortar up to the 91 days as compare to the fly ash or slag containing mortar and when 2 % nano silica or silica fume (with 50 % Fly ash or slag) was used in the concrete as the replacement of cement, it reduced the setting time and improved the strength of the concrete. They also observed that, after 1 day of curing the strength of mortar as well as concrete does not improve much as compare to that at 3 and 7 days of curing. On the basis of chloride – ion penetration test, they conclude that the effect of nano silica or silica fume and fly ash or slag on concrete was not much significant.

Hou et al. (2013) inquired the effect on the fresh and hardened properties of mortar when cement is replaced with colloidal nano silica and fly ash.

In this research, Nano silica developed by the Sol – Gel technique (having average particle size of Nano silica, pH and solid density 10 nm, 10.5 and 2.39 g/cm^3) was used with two different types of fly ash. For the experiments, variation of the fly ash replacement of 20 %, 40 % and 60 % by the mass of the cement and variation of the nano silica (as replacement material) by 0 %, 2.25 % and 5 % by the weight of the binder were used. All mortar mixtures had constant water – binder ratio of 0.5. The effect on nano silica on the compressive strength ratio of the fly ash and cement mixture, were calculated by the following equation:

$$R\ (\%) = \frac{100\ \times f_i}{f_c}$$

Where, R = Compressive strength ratio (%),

f_i = Compressive strength of the mortar with fly silica and nano silica

f_c = Compressive strength of the normal mortar

After the experiments, they concluded that, due to speeding up of the hydration process, nano silica increases the setting time of cement with fly ash but decrease the fluidity. It was also observed that, nano silica ameliorates the strength before the 7 days and after that (28 Days) decreased the strength gain for the cement- fly ash mixtures as compare to the without nano silica contained mixtures. Fig 2.5 exhibited that, as the dosage of nano silica increased in the mixture of (20 % fly ash and cement), the compressive strength is increased during the early ages but not in the later ages.

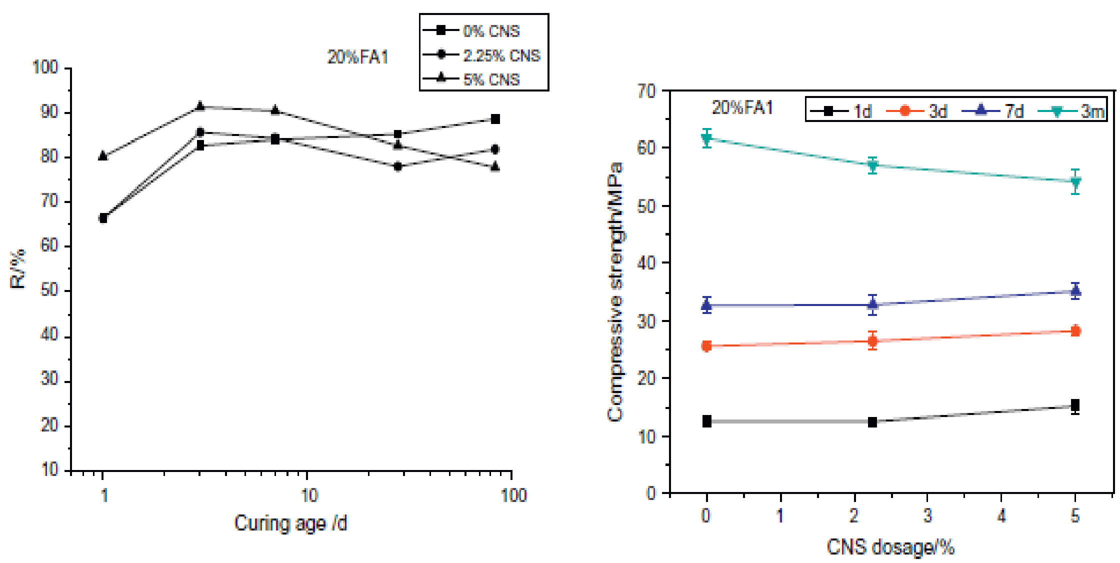


Fig. 2. 5 Effect of nano silica on the compressive strength ratio of fly ash and cement mortar [Hou et al. (2013)]

Du et al. (2014) studied the effect of the nano silica on the strength durability properties like water penetration depth, water sorptivity of the concrete.

For the completing the objective of this study, nano silica (Powder form) of the 13 nm particle size and 200 m^2/kg surface area was used in the concrete. The percentage variation of the nano silica in the concrete was 0.3 % and 0.9 % and results were compared with the normal concrete. For getting a constant slump, the dosage of the super plasticizer was changes. In all mixes, constant water to cement ratio of 0.5 were used.

It was concluded that, as the nano silica percentage increased, the super plasticizer dosage in the concrete increased for keeping a constant water to cement ratio. Due to the filler property and pozzolonic behaviors of the Nano silica, Microstructure becomes denser, and permeability decreases. Compressive strength test results showed that, Strength of concrete after 28 days were increased by 9 % and 12 %, when cement partially replaced with nano silica by 0.3 % and 0.9 %, respectively. The effect of nano silica was present on the compressive strength even after 91 days. Due to the usage of nano silica, a beneficial effect on the durability properties but reduced the water penetration depth. They also observed that, nano silica continuously alter the microstructure of concrete, thus meliorate the durability properties. Initial and secondary sorptivity continuously diminish even after 91 days.

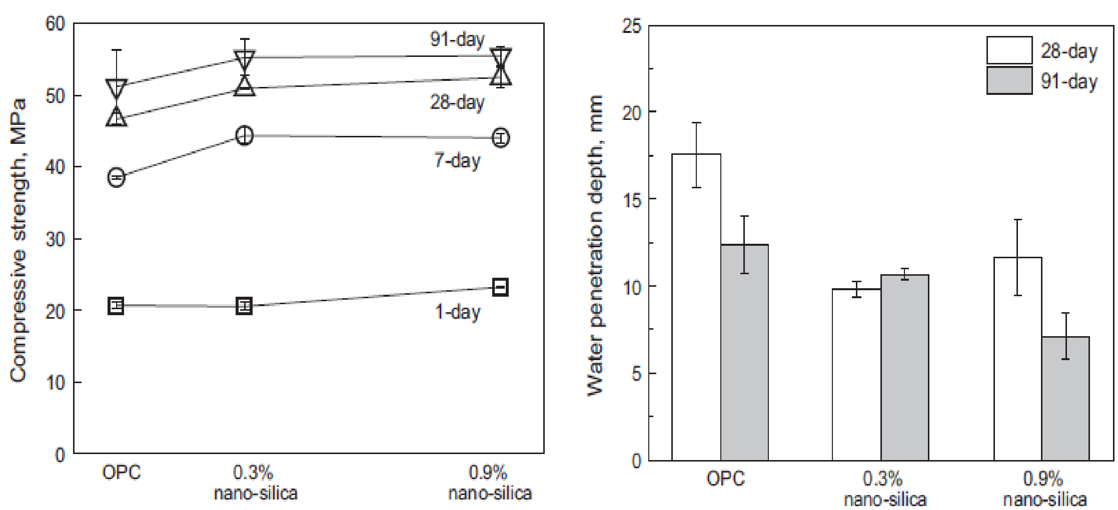


Fig. 2. 6 Effect of nano silica on the compressive strength and water penetration depth [Du et al. (2014)]

Haruehansapong et al. (2014) studied the effect of particle size and variation of the nano silica on the compressive strength of the cement mortar. In this research optimum dosage of nano silica was also determine and results compared with or without silica fume mortar.

For the experiment, nano silica with particle size 12 nm, 20 nm and 40 nm with the variation of 3 %, 6 %, 9 % and 12 % and silica fume of particle size 100 nm with the same variation of nano silica were used in the cement mortar. For all the mixes constant water to binder ratio of 0.65 were used. Super plasticizer dosages were selected on the basis of segregation, bleeding and flowability properties of the cement paste and results were compared with conventional mortar.

It was concluded, the improvement in the compressive strength of mortar contained silica fume is lesser than the mortar contained nano silica. The possible reason for that, the quantity of SiO_2 is less in the silica fume so it decreases the pozzolanic reaction. The other fact that, nano silica particle size is lesser than the silica fume so it easily fill the voids and provides good packing ability to the cement paste. From fig 2.7, nano silica with 40 nm particle size and 9 % variation provides highest strength as compare to the other particle size and variation of the nano silica in the cement mortar. It was also observed that less particle size (12 nm and 20 nm) cover the particle and stop pozzolanic reaction.

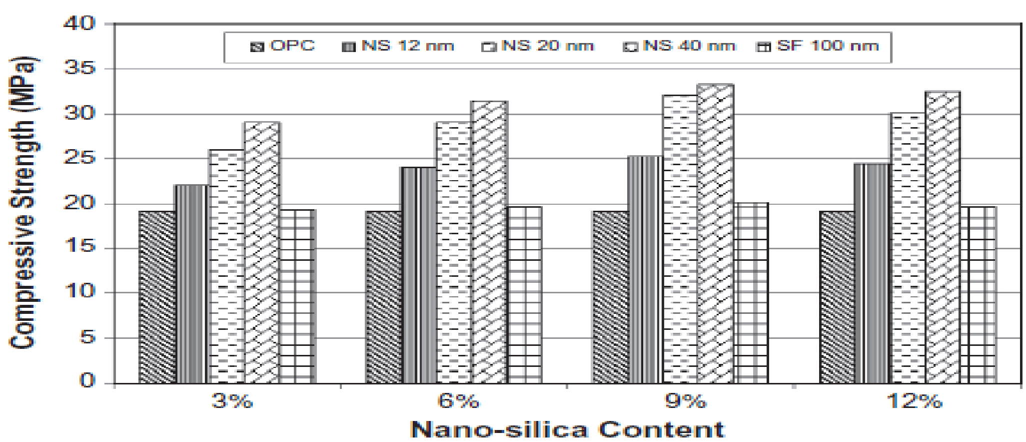


Fig. 2. 7 Effect of particle size and variation of nano silica and silica fume on the compressive strength [Haruehansapong et al (2014)]

Shaikh et al. (2014) studies on the development of compresive strength when nano silica mixed with high volume fly ash in the mortar and concrete. When the replacement of cement with fly ash is more than or equal to the 50 % , than fly ash known as the high volume fly ash.

For determining the effect of nano silica on the mortar and concrete, they used nano silica in the amorphous form with 25 nm average particle size, 2.2 to 2.6 specific gravity and 160 m^2/kg. For the experient, they devided whole work in the three parts, firstly they replaced cement with nano silica with the variation of 1 %, 2 %, 4 %, and 6 % by the weight after the test which variation provide the maximum compressive strength consider for second observation. In second observation they replaced cement with fly ash with variation of 40 %, 50 %, 60 % and 70 % and max variation of nano silica. From the second part observation, the variation which improve the strength, consider for third part observation.

After observation (Fig 2.8) it was conclude that, amoung the all variation of nano silica 2 % and amoung all the variation of fly ash 40 % and 50 % are exhibited the highest compressive strength of mortar. Results showed, when 2 % nano silica mingled with 40 % and 50 % fly ash in the mortar, then the strength increases by 5 % and 7 %, respectively after the 7 days. While the increment in the compressive strength of mortar, beyond the 50 % Fly ash is not much signifcant. The improvement in the mortar with 2 % nano silica and 50 % fly ash is significant after the 28 days. In the concrete due to the presence of 2 % nano silica, the strength improvement is detected after the 3 days.

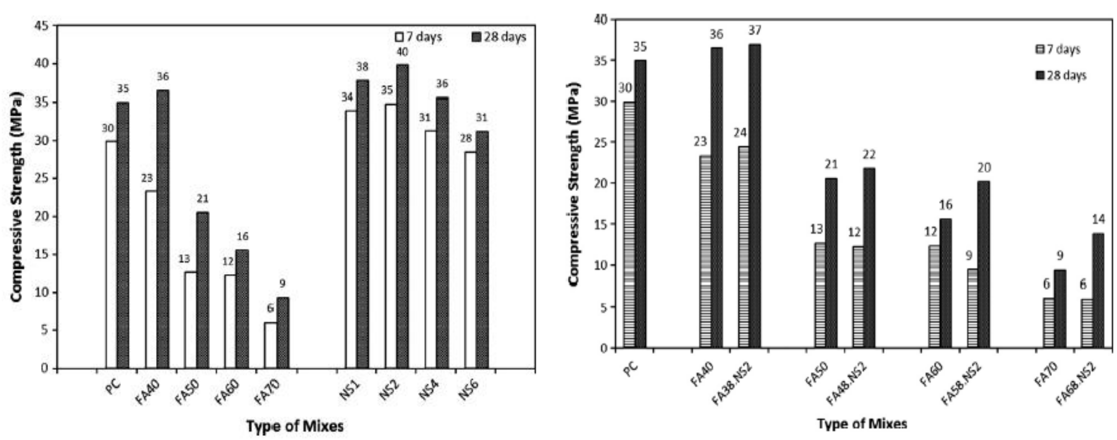


Fig. 2. 8 Compressive strength test results from part 1 and 2 [Shaikh et al. (2014)]

Eskandari et al. (2015) studied effect of nano silica and micro zeolite on the strength and durability of the concrete were observed. For determining the effect on the strength, compressive strength test and tensile strength test had been performed on the concrete sample and for determining the effect on the durability, electrical resistivity and Rapid Chloride Penetration Test (RCPT) had been performed.

For determining the effect, cement was partially replaced with 2 % nano silica (Powder form) and 5, 8, and 10 % of micro zeolite with Water – Cementitious material ratio of 0.45 and 0.4. Due to the presence of nano silica and micro zeolite, the workability was decreases thus for maintaining the slump between 80 – 100mm, the dosage of super plasticizer were varying in the range of 5 % to 10 %.

Results indicate that, there was decrement in the compressive strength of the concrete due to incorporation of nano silica and micro zeolite as compare to the normal concrete. The rate of increment in the tensile strength is not much. Due to these mineral admixture chloride ion penetration depth decreases and electrical resistivity increases. From the Fig 2.9, it was observed that, cement replacement with Hybrid nano silica with micro zeolite was not improve the mechanical property but improve the durability of the concrete.

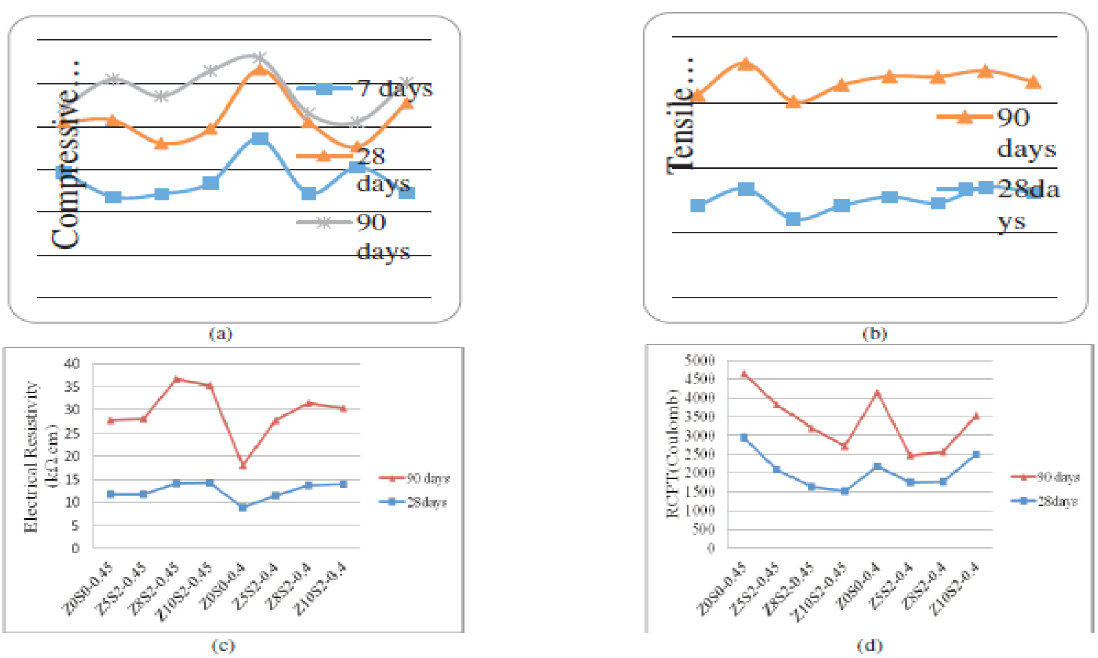


Fig. 2. 9 The effect of the mineral admixture (a) Compressive strength (b) Tensile strength (c) Electrical resistivity (d) Rapid Chloride Penetration [Eskandari et al.(2015)]

Saloma et al. (2015) provide the process by which concrete can be prevented by sulfate attack when nano silica comprises in the concrete thus durability improve. The compressive strength of the mixtures was also calculated.

For the experiment, nano silica 10 – 150 nm particle size, and quartz powder 0.3 – 25 µm particle sizes were used with other constituents of the concrete. Cement was replaced with 10 % nano silica and uniform water to cement ratio of 0.20 were used. All results were compare with without Nano silica containing concrete.

From the results, it was concluded that, the concrete incorporated with nano silica has higher compressive strength as compared to without nano silica concrete. The increment in the compressive strength of concrete is not only due to filling property but nano silica also accelerate the hydration process. Due to the sulfate attacks, loss in the strength reached 6.21 % in mortar and 9.90 % in the concrete after 180 days. Nano silica improves the impermeability and corrosion resistance of the concrete and reduce the quantity of calcium aluminate in the cement thus prevent from the sulphate attacks.

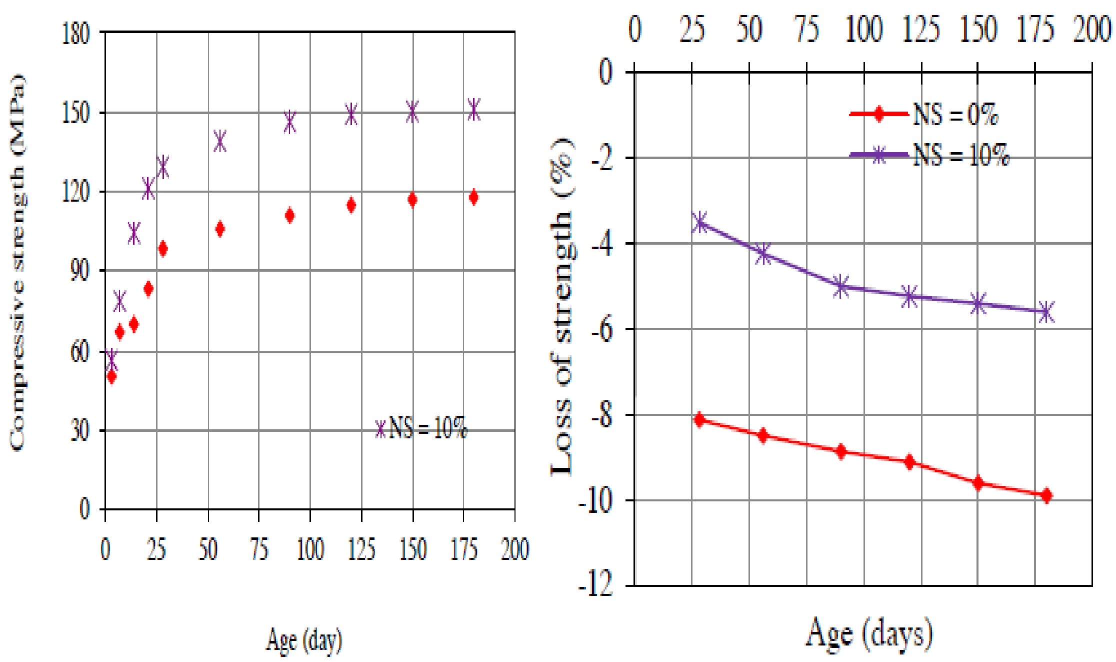


Fig. 2. 10 Effect of nano silica on the compressive strength and loss of strength (%) due to the sulfate attacks [Saloma et al. (2015)]

Sikora et al. (2015) studied the effect of nano silica variation on the mechanical properties of polymer cement composites (PCC).

For this research, 100 and 250 nm particle size and 1 %, 3 % and 5 % variation of nano silica were used for determining the effect on the mechanical property and consistency of the PCC. Six specimens with variation of nano silica and particle size by considering fixed water to cement ratio of 0.5 were prepared for getting constant workability.

They concluded that, nano silica increase the formation of C – S – H gel by accelerating the pozzolanic reaction. Due the high formation of C – S – H gel, it increased the mechanical property, reduced the consistency and liquidity of the PCC. Due to the addition of 1 % nano silica in mortar showed not much effect on the consistency as compare to the other variation. From the flexural test (Fig 2.11), it was observed that nano silica (100 nm particle size) did not shows significant improvement but strength were improved for 3 % and 5 % variation nano silica with 250 nm particle size,. The compressive strength test results (Fig 2.11) shows that the optimum dosage of nano silica was 3 %.

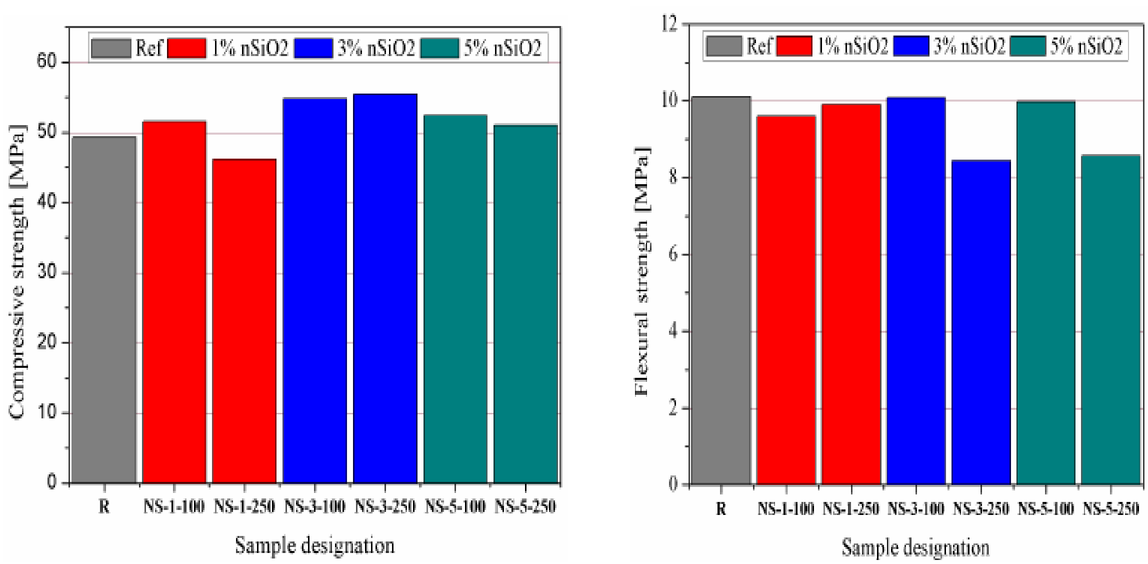


Fig. 2. 11 Compressive strength and flexural strength due to variation of nano silica and particle size [Sikora et al. (2015)]

2.3 EFFECT OF COIR FIBER

Asasutjarit et al. (2007) studied the use of the coir fiber for developing the light weight cement board. Coir fiber based board is used for the preservation of energy in the building. The prime objective of this study is determined the length, pretreatment and mixture proportion of the coir fiber which improve the physical, mechanical and thermal property of the cement board.

For completing the objective of the study, whole process is divided into 2 parts. In the first part, determine the optimal pretreatment process and in the second part, optimal mixture proportion were determine on the basis of optimum fiber length and optimum pretreatment process founded in the first part. For the first part, mixture proportion were fixed at 1:2:1 (cement: coir fiber: water by weight) and different lengths of the fiber was 1 – 13 cm, 1 – 6 and 1 – 4 mm.

Three pretreatment processes are as follows:

1. Raw coir fibers: The coir was used without any pretreatment.

2. Washed coir fibers: The fibers obtained from factory, were washed with tap water until the pH of water become 7.

3. Boiled and Washed coir fiber: For reducing chemical presents in the coir, firstly boil for 2 hours and the washed with tap water until the water become clear.

After the research, it was concluded that, coir fiber makes bond with cement by the various physical and chemical process, thus improve the density. Moment of resistance and internal bond improve as the density of the coir fiber based cement board were increased. From the first part of the study, it was observed that Boiled and Washed pretreatment process improved the properties of the cement board. Second part of the study shows that length of fiber is 1 – 6 cm and mixture proportion 2:1:2 (Cement: Fiber: Water by weight) is optimal. Thermal property investigation shows that the thermal conductivity of the coir fiber based cement board is more than the normal cement board.

Gu (2009) studied effect on the tensile strength of the coir fiber treated with NaOH solution.

For the study, coir fiber usage as the reinforcement material and for the construction of the composites, polypropylene was used as a matrix. Brown coir fiber treated with 2 %, 4 %, 6 %, 8 % and 10 % concentration of NaOH solution. In the composite, coir variations were 30 %, 40%, 50 %, 60 %, 70 % and 80 %.

It was concluded that, due to the use of NaOH treatment, many impurities like pectin, lignin etc. were removed from the fiber. From the Fig 2.12, it was note that, due to the treatment lots of pits were developed on the surface of coir fiber. These pits may be improved the bonding between coir fiber and composites. Tensile strength of coir fibers were decreased as the percentage of NaOH increases. Due the treatment of the fiber, the ductility improved and flexibility occurred in the fiber. There was not much difference in the strength when fibers were treated with less than8 % NaOH solution. The optimum dose of NaOH is 2 % for improving the bonding property and strength of composite.

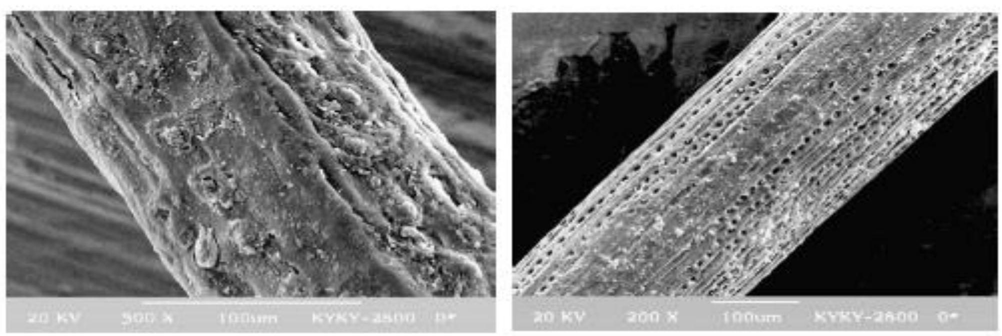


Fig. 2. 12 Coir fiber before and after treatment with NaOH [Gu (2009)]

Ali et al. (2012) studied the effect of variation in the quantity and size of the coir fiber on the properties of the concrete. For determining the effect, compressive strength test, split tensile strength test and density were performed. The maximum stress of the stress – strain curve is considered as the compressive strength of the concrete.

For completing the object of the study, 2.5, 5 and 7.5 cm length of coir fiber (0.25 mm average diameter) and 1 %, 2 %, 3 % and 5 % variation in the fiber quantity (By the weight of the cement) with water to cement ratio of 0.48 were used.

It was concluded that, the density of fiber containing concrete is increases with high fiber quantity and decreasing with small size of the fiber. Less density of the concrete reduces the inertia force thus for reducing the earthquake impact, a small section required. It was also observed that as the percentage and length of the fiber increases, the water to cement ratio and slump were increases. For economical purposes, 7.5 cm fiber length and 2 % or 3 % variation of the concrete were used. Load versus time results shows that, normal concrete fail after 200 sec and concrete reinforced with coir fiber failed at the after 800 sec. There was seen increment in the compressive strength, toughness and moment of resistance up to the coir length 5 cm and variation 5 %. But the split tensile strength and density of concrete decrease with increment of the coir fiber in the concrete.

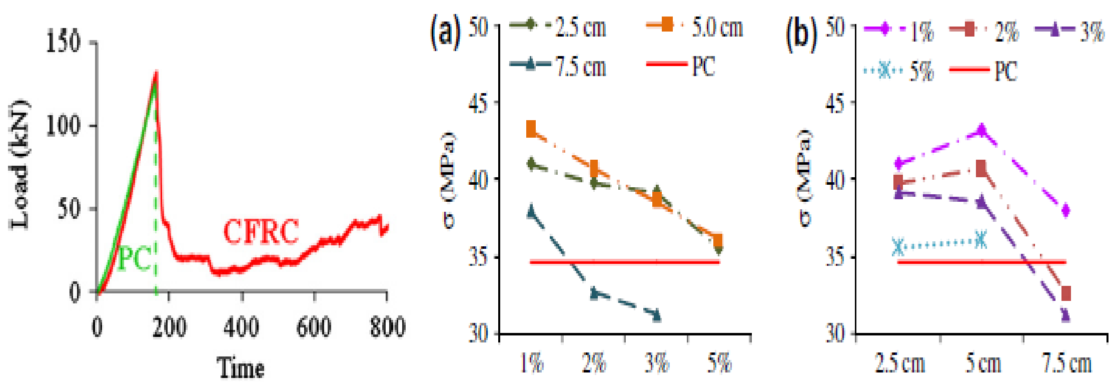


Fig. 2. 13 Load v/s time graph and effect of coir on the compressive strength [Ali et al. (2012)]

Ali et al. (2013) investigate the effect on the bond strength between concrete and coir fiber because of the variation of length and diameter of coir fiber, pretreatment process and different mix design ratio. From the experimental analysis, bond strength and energy required for extracting the coir were determined.

Table 2.1 shows the all experimental program used for the study, in which different mix design proportion, different embedment length, variation in the fiber diameter and pretreatment process used in fiber were discussed. For manufacturing the concrete with fiber, water/cement ratio 0.48 were taken.

Results indicate that, as the embedment length of the fiber increases, the bond strength and energy required to pull out is also increases. Fiber treated with chemical show the decrement in the tensile strength and bond strength. The maximum strength is for boiled fiber, thick diameter with 30 mm length and mix design ratio was 1:3:3.

Table 2. 1 Experimental program [Ali et al. (2013)]

Considered Factors	**Cases**
Mix design (M)	i. 1:2:2 ii. 1:3:3 iii. 1:4:4
Embedment length (L)	i. 10 mm ii. 20 mm iii. 30 mm iv. 40 mm
Fiber Diameter (D)	i. Thin, ϕ 0.15 – 0.20 mm ii. Medium, ϕ 0.20 – 0.30 mm iii. Thick, ϕ 0.30 – 0.35 mm
Fiber pretreatment process (P)	i. Soaked Fiber ii. Chemical treated Fiber iii. Boiled Fiber

Ramli et al. (2013) studied the effect of coir fiber for improving the strength and durability properties of the concrete during the seawater environment.

For completing the aim of the study they use small and distinct coir fiber with 0.32 mm diameter, 20 to 30 mm length and specific gravity 1.13, into the high strength concrete with variation of the 0.6 %, 1.2 %, 1.8 %, 2.4 %. Concrete were exposed in three different exposure conditions like air environment of the tropical environment, alternative air and seawater environment and completely immersion in seawater. All results were compared with the normal concrete.

From the compressive strength test, it was conclude that as the coir percentage increases the compressive strength of concrete increase even after 546 days except for percentage 2.4 %. Strength of the coir containing concrete was increases even after the exposure for variation less than 2.4 %. High quantities of coir fiber increase the water absorption by the concrete so the strength was decrease. Continue supply of water may be increases the strength, but when strength start decreases it shows that seawater affects predominant to hydration process. Chloride penetration, carbonation depth and permeability of the concrete increases with increase the percentage of coir fiber. It was also observed, due the seawater exposure of the concrete specimen, a gap formed between concrete and coir fiber and salt crystal available in that gaps. After considering all parameter, the optimum dose of coir fiber is 1.2 % for improving the strength and durability of concrete in the exposure conditions.

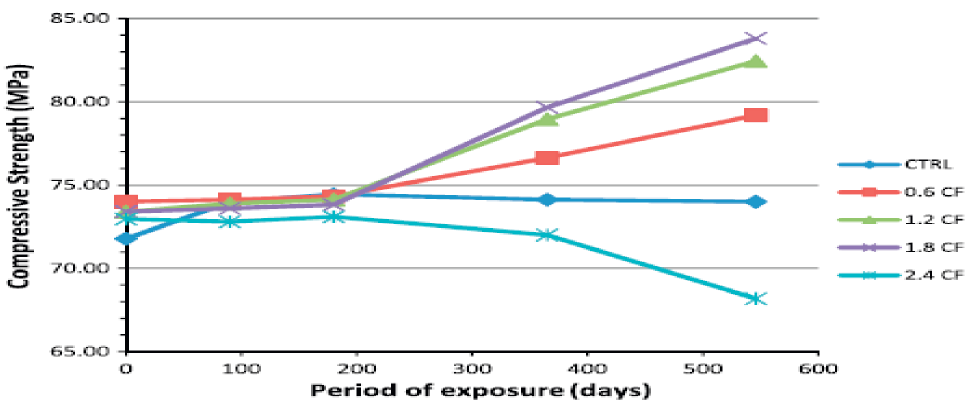


Fig. 2. 14 Effect of exposure on the coir fiber reinforced concrete [Ramli et al. (2013)]

Andic-Cakir et al. (2014) investigated the effect of coir fiber on the mechanical and physical properties of the cement mortar. Mechanical properties like compressive and flexural strength of concrete, physical properties like workability, water absorption and thermal conductivity of mortar were determined.

For the experiment, 2 cm long coir fiber of 1.37 g/cm^3 specific gravity and treated with 5 % NaOH solution were used. The doses of the super plasticizer were decided on the basis of workability property. Coir fibers were added in the mixture in ratio of 0.4 %, 0.6 % and 0.75 % by the weight of the total mixture. All results were compared with the conventional mortar.

Results showed that, as the percentage of the coir fiber increase in the mortar, workability, unit weight and water absorption decreased. The mechanical properties and thermal conductivity were improved as the percentage of the fiber increases in the mortal.

The rate of improvement in the mechanical properties was increases, if the fiber were treated with NaOH solution. After the alkali treatment of the fiber, hemicelluloses, waxes and impurities were remove from the coir fiber thus surface become rough and fiber bonding increases Due to improvement in the adhesive and bonding property in the concrete thus improve the strength of the concrete. Fig 2.15 described the effect on the flexural and compressive strength of the concrete due to incorporation of the coir fiber in the mortar mixture.

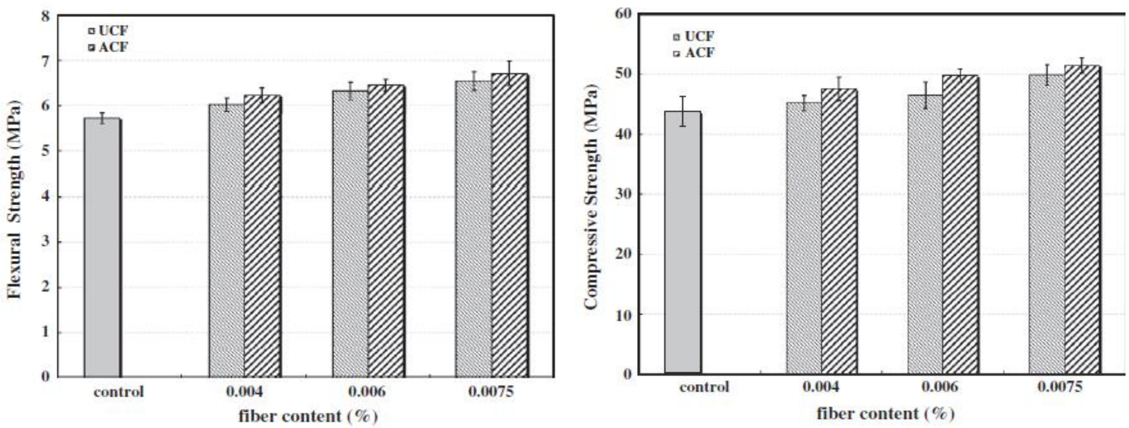


Fig. 2. 15 Effect of coir fiber on the mechanical properties [Andic-Cakir et al. (2014)]

Lertwattanaruk et al. (2015) performed an experiment for the determining the properties of composite building material those were made up with the natural fiber and useful for the hot and humid climate area. The main objective of this study was determining physical, mechanical and thermal properties of composite building material due to the use of coconut fiber and oil palm fiber.

For the experiment, the fibers (coconut fiber and oil palm fiber) of length 5 – 10 mm were use with the variation of 5 %, 10 % and 15 % by the weight of cement and Water to binder ratio was 0.25 which is use for manufacturing the roof sheets. The fiber pretreatment processes were shown in Fig 2.16.

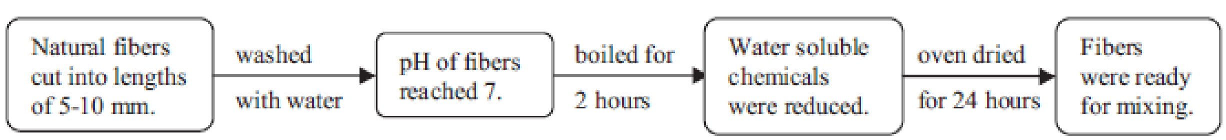


Fig. 2. 16 Pretreatment process of fiber [Lertwattanaruk et al. (2015)]

It was concluded that the porosity and water – absorption were less in the oil palm shell containing composite as compare to the coconut shell containing composite mortar. As the percentage of fiber increased in the mortar, porosity and water – absorption increased and bulk density decreased. The compressive strength and flexural strength of fibers containing concrete were decreased as the percentage of the fiber increased. Composite mortar incorporated with fiber, improves in the thermal conductivity.

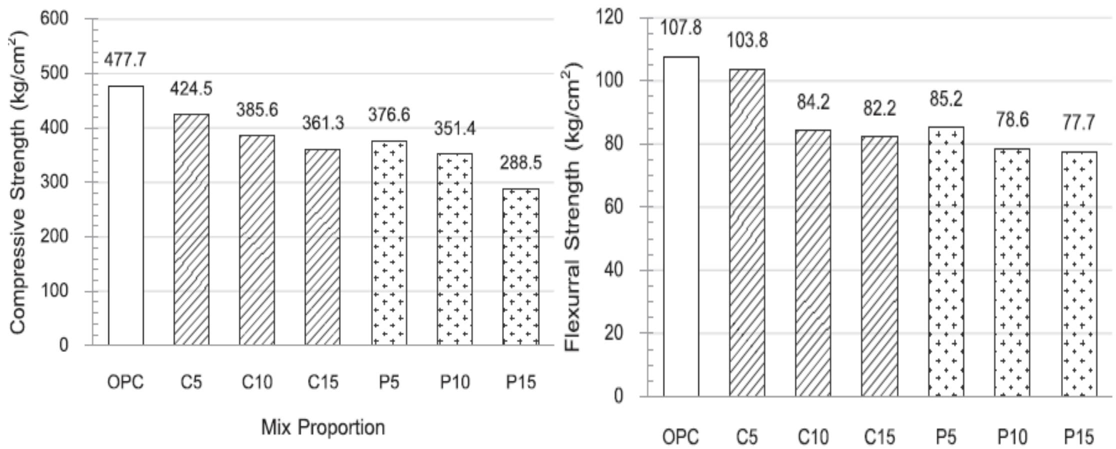


Fig. 2. 17 Effect of the Natural fibers on the strength of the composite

Darsana et al. (2016) done the investigation on the development of the composite roofing tiles incorporated with coir fiber. The prime target of the research is development of the cost efficient roofing tiles but the quality of the tiles will not be compromise.

For completing the object, cement replaced with coir of length 25 mm in the variation of 10 % and 15 %. Mix proportion 1:4 and water to cement ratio of 0.6 was selected for manufacturing for roofing tiles. Curing was done by accelerated curing method.

It was concluded that, compressive strength of 10 % replacement concrete cube was approximate same as compare to the control mix but it drastically decrease for the 15 % replacement concrete cube. As the percentage of fiber increases, self- weight and cost of the product reduces. With the addition of fiber in the concrete roofing tile, the breaking load, water absorptivity and ductility were improved and less sharpness in the crack pattern were occurred.

Yan et al. (2016) investigated the effect of treated and untreated coir fiber use in the cement composites as the reinforcement material. The effect on the microstructure by

SEM (Scanning Electronic Microscope) analysis and mechanical property due to the use of coir fibers was determined.

Length of the fiber 50 mm and variation in the matrix 1 % by the weight of the cement were used in the analysis. Fibers were treated with 5 % NaOH solution and results were compared with the Normal cement and untreated fiber. For the determining the compressive strength "Avery Danison machines" were used by controlling the stress at 0.20 MPa/sec.

It was concluded that slump, density and modulus of elasticity were decreased for the treated and untreated fiber as compare to the normal concrete and porosity, axial stain, compressive strength and flexural toughness increased due to the addition of the coir fiber in the concrete. These values more increases for the alkali treated fibers. Fig 2.18 shows the effect of the coir fiber on the compressive strength of the concrete.

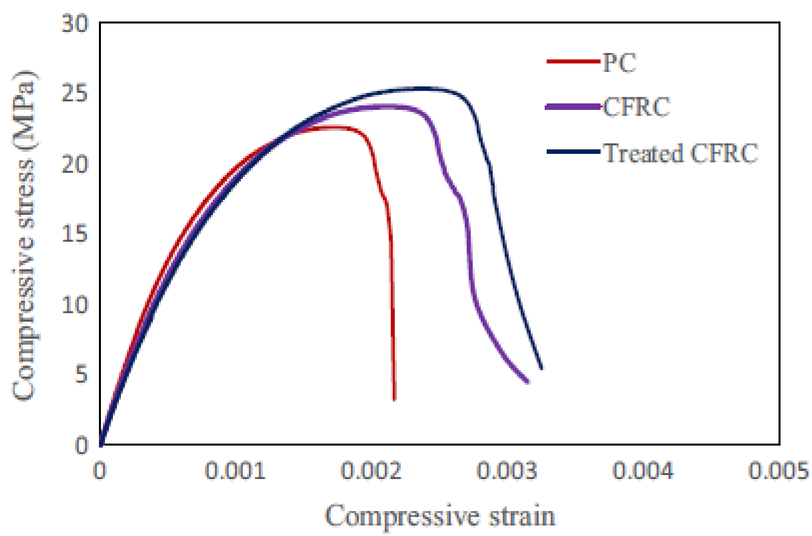


Fig. 2. 18 Effect of the fiber on the compressive strength [Yan et al (2016)]

Fig 2.19, shows the load – deflection curve for the treated and untreated fiber and compare with the normal concrete. From the results it was concluded that, the normal concrete fail at a small deflection but if coir was incorporated in the concrete the deflection were increases. it means that coir fiber reinforced composite prove the more time for the repair after the failure as compare to the normal concrete.

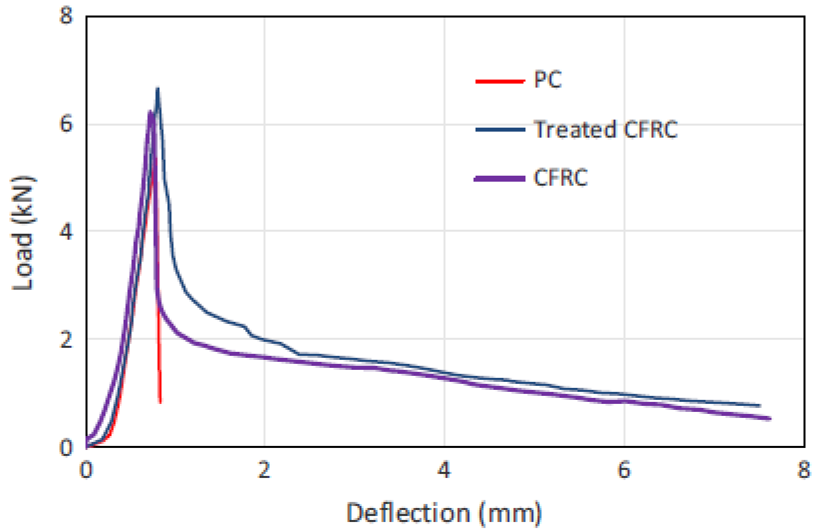


Fig. 2. 19 Load - Deflection curve [Yan et al (2016)]

Sathiparan et al. (2017) studied the effect on the strength and durability property of the coconut fiber containing cement – lime mortar. For determining the effect on the physical property - water absorption, porosity, sorpotivity tests, for determining the effect on the strength - compression and flexural bending and for durability - acid attack resistance, alkaline attack resistance tests were performed.

For determining the effect, untreated coir fiber of 24 mm average length and 20 µm approximate diameter were used in the variation of 0.125 %, 0.25 %, 0.5 % and 0.75 % by the weight of cement, lime and sand. For the control mixture water to binder ratio was 0.62 and it will increase as the percentage of coir fiber increases in the mortar mix.

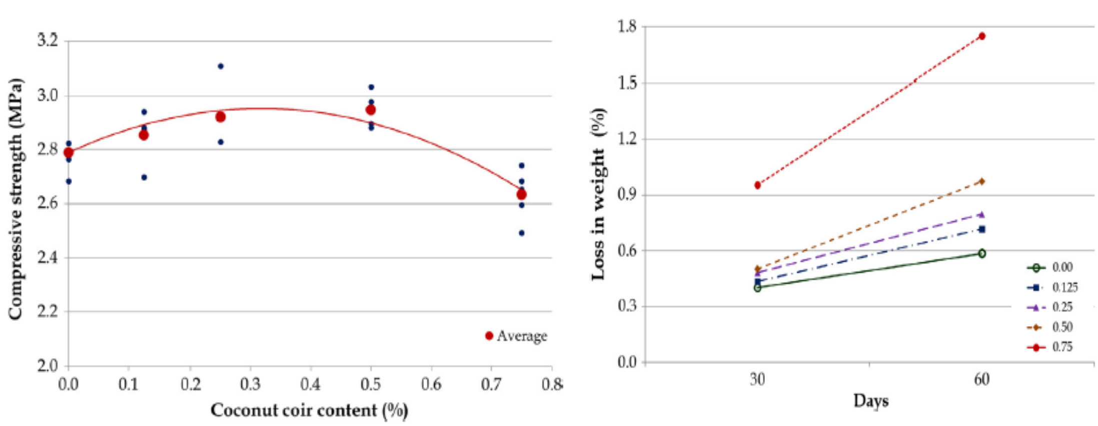


Fig. 2. 20 Effect of coir fiber on the compressive strength and weight loss due to acid and alkaline attacks [Sathiparan et al. (2017)]

It was concluded that workability, setting time, density and durability properties like resistance against acid and alkaline attack were reduced and water absorption, porosity, sorpotivity, residual strength, toughness, ductility and compression strength of the resulted concrete improved (Up to the 0.5 % replacement) as the percentage of the coir fiber increases in the mortar. The optimum replacement percentage of the coir fiber was 0.5 % for improving the strength and durability properties of the mortar use for surface plastering.

CHAPTER 3

EXPERIMENTAL PROGRAM

3.1 GENERAL

The selection of various materials required for developing a concrete is very important for achieving the desired strength of concrete. This chapter contains discussion about the physical and chemical properties of the material, mix design calculations and sample preparation. For fulfilling the objective of the present study, an experiment was performed for finding the compressive strength and abrasion resistance of concrete specimens, when coir is used as fiber, and nano silica and fly ash are used as partial replacement materials along with the OPC 43 grade cement and aggregates.

3.2 PROPERTIES OF MATERIALS USED

The physical and chemical properties of materials used in concrete were evaluated in laboratory as per the Indian standard and compared with limits prescribed by the specific Indian standard. The materials used in the present study are cement, coarse and fine aggregates, and water along with super plasticizer, in addition to fly ash, nano silica, and coir fibers at various percentages. The properties of the material are described in the specific subsection.

3.2.1 Ordinary Portland Cement

Cement is a highly active material in concrete and has the highest cost. The important property of cement is to fill the voids present between the fine aggregates and make the concrete dense. When water is mixed to cement, it gives strength to the concrete by developing a bond between the aggregates after setting and harden.

OPC is divided into 3 grades namely 33 Grade, 43 Grade, and 53 Grade depending upon the strength achieved in 28 days. IS 8112: 1989, provides the specification of OPC 43 Grade cement. The cement is obtained, after the burning of a mixture of calcareous and argillaceous materials at a very high temperature. The ingredients should be intimate in a correct proportion. Gypsum is added to the (calcined product) clinker in a small quantity and it is then demolished into very fine powder which is known as the cement. It is grey in colour.

Ordinary Portland Cement (OPC) of 43 Grade (Ultratech Cement) is used throughout the present study. It was noted that the cement was fresh and free from any lumps.

Table 3. 1 Physical properties of cement

S. No.	Characteristics	Obtained value	Specified value (as per the IS code 269:2015)	IS codes referred for Test
1	Specific gravity	3.14	-	IS 4031 Part 11
2	Standard consistency (in %)	28	-	IS 4031 Part 4
3	Setting time (Minutes)			IS 4031 Part 5
	Initial Final	110 240	30 (Minimum) 600 (Maximum)	
4	Compressive strength (MPa)			IS 4031 Part 6
	3 Days 7 Days 28 Days	27.91 35.64 47.34	23 33 43 (Min) – 58 (Max)	

The physical properties of the cement were determined as per IS 4031 and Chemical Properties of cement were given by cement manufacture and these were compare with the limits prescribed in IS 8112:1989 and IS 269:2015. The test results are listed in the Table 3.1 and 3.2, respectively.

Table 3. 2 Chemical properties of cement (as receives from Manufacturer)

S. No.	Particular	Test Result	IS 269: 2015 Specified Value
1	$\frac{CaO - 0.7\,SO_3}{2.8\,SiO_2 + 1.2\,Al_2O_3 + 0.65\,Fe_2O_3}$	0.86	0.66 (Min) 1.02 (Max)
2	$\frac{Al_2O_3}{Fe_2O_3}$	1.27	0.66 (Min)
3	Insoluble Residue (% by Mass)	2.48	5.00 (Max)
4	Magnesia (% by mass)	0.96	6.00 (Max)
5	Sulphuric Anhydride (% by mass)	2.29	3.50 (Max)
6	Total Loss on Ignition (% by mass)	2.24	5.00 (Max)
7	Total Chlorides (% by mass)	0.031	0.10 (Max)

3.2.2 Aggregates

Aggregates are made up by igneous, sedimentary and metamorphic rocks or are produced from clays, slag etc. It is expected that they should be hard, strong**,** durable, and free from clay, loam, vegetables and other such foreign matters. If clay is present in aggregate, it prevents the bond between cement and aggregates, and thereby reduces the setting time of cement and decreases the strength, durability and soundness of concrete.

Aggregates generally fill and provide maximum volume of the concrete and can therefore be assume to have a high impact on the properties of concrete. The aggregates should be of proper shape and size, clean, hard and well graded. Based on the size of the particle, the aggregates are divided into two groups

- **Fine Aggregate –** The particle size is less than 4.75 mm and,
- **Coarse Aggregate –** The size of the particle is more than 4.75 mm.

A solid hard mass is formed, when coarse aggregate mixed with cement and fine aggregates and this majorly contributes to the compressive strength of concrete. Sand is formed of small angular or rounded shape particles of silica and is generally known as a fine aggregate in concrete. It fills the voids present between the coarse aggregate and retards the shrinkage and cracking properties of the concrete. The fine aggregate helps the cement paste to bind the coarse aggregates, this action boost the plasticity of the mixture and prevent segregation and bleeding in the concrete.

a) **Fine Aggregates:** The aggregates which are passed through BIS test sieve no. 480 (4.75 mm sieve) are considered as fine aggregates. Aggregates obtained from sea, river, lake or pit may be used as fine aggregate, but they should be free from any impurities. Angular shape particles of sand should be used, it makes the concrete good and strong by providing proper interlocking property, while the round shape particle of sand do not provide such interlocking.

Depending on the size of the particle, IS 383 has divided the fine aggregate into four grading zones (Grade I to IV). The size of the particle gradually decreases from grading zone I to grading zone IV.

Table 3. 3 Sieve analysis of fine aggregate

I. S. Sieve	Weight retained (gm)	Cumulative weight retained (gm)	Cumulative % retained	Weight % Passing	Limit by IS code (for Zone II)
4.75 mm	13	13	1.3	98.7	90 - 100
2.36 mm	10	23	2.3	97.7	75 – 100
1.18 mm	385	408	40.8	59.2	55 – 90
600 micron	169	577	57.7	42.3	35 – 59
300 micron	267	844	84.4	15.6	8 – 30
150 micron	120	964	96.4	3.6	0 – 10
pan	36	1000	-	-	
Total	**1000**		**282.9**		
Fineness Modulus			**2.83**	**Zone II**	

Table 3. 4 Specific gravity and water absorption of fine aggregate

Weight of saturated sand A (gm)	500
Weight of pycnometer with sand B (gm)	1833
Weight of pycnometer with Water C (gm)	1522
Weight of Oven dry aggregate D (gm)	560
Specific Gravity = 2.65	**(A / [A - (B – C)]**
Weight of Saturated sand (gm)	1000
Weight of Oven Dry Sample (gm)	984
Water Absorption = 1.6%	

For the study, fine aggregates of zone II grade were purchased from the local supplier and confirmed from the sieve analysis, given in IS 383: 1970 and the results are shown in Table 3.3. Specific gravity and water absorption of fine aggregates was experimentally determined as 2.65 and 1.6%, respectively as shown in Table 3.4.

b) **Coarse Aggregate:** The material which is retained on BIS test sieve no. 480(4.75 mm sieve) is considered as the coarse aggregate. The size of the coarse aggregates used depends upon the nature of work. Normally Crushed hard stone and gravel is used as coarse aggregates for structural concretes.

The various types of coarse aggregates are as follows: - Crushed gravels or stone, found by crushing gravel or hard stone or uncrushed gravel resulting from natural disintegration of rocks. The nominal sizes of gravel or stone are 10mm to 20mm. The properties of different type of aggregates affect the property of concrete, like angular shape particle provide better interlocking, due to this strength improves, while the rounded shape particle provide better workability because of less internal friction between particles. The coarse aggregates of 20 mm and 10 mm size are used for this study, purchased from local market. The specific gravity and water absorption of 20 mm size aggregate are 2.77 and 0.17% and for 10 mm size aggregates are 2.68 and 0.37%, respectively. The sieve analysis of 20 mm and 10 mm size aggregate is performed in laboratory as per IS 383: 1970 and results are shown in Table 3.5 and Table 3.6.

Table 3. 5 Sieve analysis of 20 mm size aggregates

I. S. Sieve	Weight retained (gm)	Cumulative weight retained (gm)	Cumulative % retained
40 mm	00	00	00
20 mm	114	114	2.28
10 mm	4655	4769	95.38
4.75 mm	187	4956	99.12
2.36 mm	12	4968	99.36
1.18 mm	09	4977	99.54
600 micron	06	4983	99.66
300 micron	08	4991	99.82
150 micron	06	4997	99.94
pan	03	5000	-
Total	**5000**	**-**	**695.1**
Fineness Modulus 6.95			

Table 3. 6 Sieve analysis of 10 mm size aggregates

I. S. Sieve	Weight retained (gm)	Cumulative weight retained (gm)	Cumulative % retained
20 mm	00	00	00
10 mm	1130	1130	22.6
4.75 mm	3301	4431	88.62
2.36 mm	238	4669	93.38
1.18 mm	95	4764	95.28
600 micron	105	4869	97.38
300 micron	87	4956	99.12
150 micron	38	4994	99.88
pan	06	5000	-
Total	**5000**	**-**	**596.16**
Fineness Modulus 5.97			

3.2.3 Fly ash

Fly ash is a fine powder which is produced from combustion of coal at a high temperature of 1500 – 1600 ºC in electric generation power plants. Fly ash is the material that moves with the flue gases, it can be collected and stored in silos and electrostatic precipitators are generally used for capturing the fly ash before the flue gases reach to the chimneys.

Fly ash is a pozzolanic material which is allowed as ingredients in manufacturing blended cement and other ash based products. The properties of fly ash allow it to be used in construction of embankments, structural and reinforced fills, low lying area development etc. The shape of the fly ash particle is spherical and size varies from 0.5 micron to 300 micron. The size of fly ash is finer than cement so it fill the existing voids in cement and makes the concrete denser.

Fly ash usage in concrete production can significantly reduce the concrete cost due to reduced use of cement. Other than that, fly ash being a byproduct of coal has low embodied energy. Fly ash requires less water as compared to cement and it can be easily use in cold weather. Other benefits of fly ash include increased later age strength, improved workability permeability and reduced bleeding, decreased heat of hydration, decrease water/cement ratio for equal slumps value as compared to mixes without fly ash and reducesd CO_2 emissions by reducing the quantity of cement etc.

Silica (SiO_2), alumina (Al_2O_3), ferric oxide (Fe_2O_3) and calcium oxide (CaO) are the prime and MgO, Na_2O, K_2O, SO_2, MnO, TiO and unburnt carbon are the minor constituents of fly ash. The variation in the quantity of the prime constituents of the fly ash are, Silica (25- 60%), Alumina (10-30%) and ferric oxide (5-25%). When the total quantity of the principal elements in fly ash are 70% or more and calcium oxide quantity is less than 10%, the fly ash is known as class fly ash.

Fig. 3. 1 Fly ash used for this study

Table 3. 7 Physical properties of fly ash

Color	Grey
Specific Gravity	2.2
Bulk Density (Kg/m^3)	1.034
Moisture (%)	3.12

Table 3. 8 Chemical properties of fly ash

Compounds	**Content (%)**
SiO_2	54.2
Al_2O_3	21.4
Fe_2O_3	7.5
CaO	6.25
SO_3	0.46
MgO	0.86
K_2O	1.04
LOI	4.78

If the total quantity of the principal elements in fly ash are equal or more than 50% and calcium oxide quantity is not less than 10%, fly ash is known as class C fly ash.

The fly ash used in the study is procured from BalaJi Agro Industry, Patiala (Fig 3.1). The physical and chemical properties of Fly ash (Given by manufacturer) are shown in Table 3.7 and Table 3.8. Table 3.8 shows that, Fly ash which is used in the experiment is Class F Fly ash.

3.2.4 Nano silica

Nano silica is a nano size particle solution of silicon dioxide. Nano silica is available in colloidal (liquid) as well as in amorphous (Powder) forms.

Nano-silica affects the concrete chemically as well as physically. The pozzolonic reaction of nano silica with $Ca(OH)_2$ results in formation C-S-H gel in the last stage due to the chemical reaction of nano silica with the available calcium in the mix. Nano-silica is 1000 times finer than the cement because of that it can fill the existing voids in the cement paste even after a part has been filled by Fly ash, and increases the density of concrete. Nano silica improves workability, provides excellent binding property, improved water resistance, and eliminates water seepage, reduces the segregation and erosion in constructions like Dams, Tunnels, and Bridges etc.

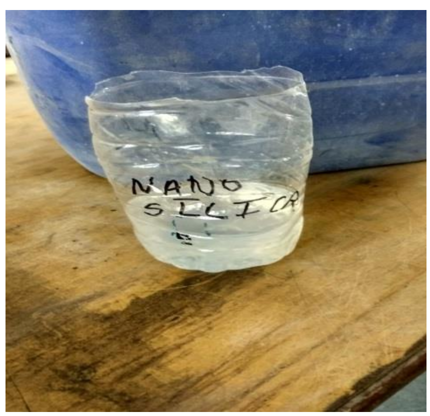


Fig. 3. 2 Nano silica use for the study

CemSyn XTX type of nano silica was used in that study, which is colloidal in form, odour less and is completely soluble (Fig 3.2). The nano silica is purchased from Bee Chems, Kanpur. The properties of the nano silica as provided by the manufacturer, is shown in Table 3.9.

Table 3. 9 Properties of nano silica

Colour	Whitish
Active Nano Content (%)	30.0 – 32.0
pH (20ºC)	9.0 – 10.0
Specific Gravity	1.20 – 1.22
Particle Size	8.0 – 20 nm

3.2.5 Coir

Coconut fiber is found from the coconut shell husk. For getting the coir, the husk is first removed with a spike and after retting, the fibers are extracted by beating and washing of the husk. The fibers have enough strength, are less in weight, have low thermal conductivity, less bulk density and high resistivity to heat and salty water. Coir is inexhaustible, cheap, and a biodegradable fiber available in high quantity. Due the use of coir in concrete, the thermal conductivity of concrete can be reduced and the weight of the concrete specimen is also decreases. The coir containing concrete is known as light weight composite specimen. As the use of natural fiber like coir in the concrete is increasing, it definitely contributes in its own way resolving the environmental issues.

Fig. 3. 3 Coir Fiber use for the study

Coir has the maximum strength when compared to the other natural fibers. It can be used in earthquake prone area and less priced reinforced concrete structures. Coir becomes brown in colour after the twelve month growth. The use of coir in concrete delays the plastic shrinkage, and controls crack development at early ages.

Table 3. 10 Properties of coir fiber

Colour	Light Brown
Length	20 – 40 mm
Diameter	0.1 – 0.23 mm (Average)
Aspect Ratio	170 – 200
Bulk Density	1538 Kg/m^3
Water Absorption	57 %

For the study, Coir fibers are purchased from the local market and are freed from any dust before use in concrete. It is available in length 15 – 20 cm in market, but for the study purpose it was cut up to 2 – 5 cm manually (Fig 3.3). The physical properties of coir fiber are shown in Table 3.10.

3.2.6 Super Plasticizer

Due the presence of coir, the workability of concrete is expected to reduce. For improving the workability of the concrete, super plasticizer is used. FOSROC Auromix 200 super plasticizer in varying proportions (as per requirements of slumps) is used throughout the study (Fig 3.4).

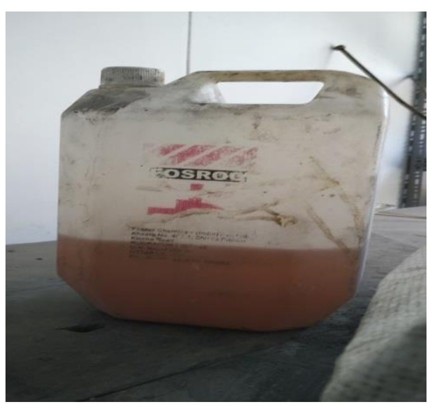


Fig. 3. 4 Super Plasticizer use for the study

FOSROC Auromix 200 is Naphthalene based super plasticizer and is available in light Brown colour liquid and easily mixed with water. Super plasticizer properties are provided by manufacturer and those are represented in Table 3.11. The dosage of super plasticizer is decided by slump test.

Table 3. 11 Properties of super plasticizer

Specific Gravity	1.145
pH	6.55
Dry Material content	21.72 % by mass
Chloride content	0.02 g

3.2.7 Water

Water is an important element of the concrete. The quality of water is important, when it used in concrete. The thumb rule for the selection of water is "If you can drink it, you can use it in concrete." As per the Indian Standard, the usable water is free from organic matter, silt, oil, sugar, chloride and acidic material. In the present study clear and fresh tap water is used in the concrete.

3.3 MIX DESIGN CALCULATIONS

3.3.1 Test Data for Materials

1. Type of Cement Used — OPC grade 43
2. Specific Gravity of Cement — 3.14
3. Specific Gravity of Coarse Aggregate (20 mm) — 2.77
4. Specific Gravity of Coarse Aggregate (10 mm) — 2.68
5. Specific gravity of Fine Aggregate — 2.65
6. Free Surface Moisture of Coarse Aggregate (20mm &10mm) — Nil
7. Sieve Analysis of Coarse Aggregate — Conforming to Table 4 (IS: 383-1970)
8. Sieve Analysis of Fine Aggregate — Conforming to Zone II (IS: 383-1970)
9. Specific Gravity of Fly ash — 2.20
10. Specific Gravity of Nano silica — 1.20

11. Specific Gravity of Super Plasticizer 1.145

3.3.2 Mix proportions used in that study

In the present study, the effect of coir fiber and nano silica has been examined, when cement is replaced with 2% and 3 % of nano silica and 15% fly ash (by the weight) along with coir fibers added in concrete with 0.25%, 0.5% and 0.75% by the weight of the fine aggregate. 6 cubes (150 × 150 × 150 mm) were cast for determination of the compressive strength of concrete after 7 and 28 days curing and 3 cubes (70 × 70 × 2.5 mm) for the finding the abrasion resistance of the concrete. A constant workability of 50 to 75 mm slump was maintained for all the mixes by varying the super plasticizer dosage. Water to Binder ratios 0.47, 0.45 and 0.42 are used for designing concrete mixes.

The mix design calculation had been done according to IS 10262:2009 by considering the test material data (section 3.3.1) as the basic requirement. On the basis of mix design the concrete were casting for completing the objective of the study. The mix proportion for concrete prepared with water/cement ratio 0.47, 0.45 and 0.42 is shown in Table 3.13, 3.14, and 3.15.

Table 3. 12 Percentage variations of ingredients in the concrete

Specimen	Nano silica (NS)	Coir fiber (CF)	Fly ash
A1, B1, C1	0 %	0 %	0 %
A2, B2, C2	2 %	0.25 %	15 %
A3, B3, C3	2 %	0.5 %	15 %
A4, B4, C4	2 %	0.75 %	15 %
A5, B5, C5	3 %	0.25 %	15 %
A6, B6, C6	3 %	0.5 %	15 %
A7, B7, C7	3 %	0.75 %	15 %

A, B and C in Table 3.12, denotes three different concretes prepared for water/binder ratios 0.47, 0.45 and 0.42, respectively.

Table 3. 13 Mix proportions for water to binder ratio of 0.47 concrete

Material	A1	A2	A3	A4	A5	A6	A7
Cement (kg/m^3)	407.62	316.33	316.33	316.33	312.52	312.52	312.52
Water (kg/m^3)	191.58	162.84	162.84	162.84	162.84	162.84	162.84
20 mm Aggregate (kg/m^3)	630	609.5	609.5	609.5	607	607	607
10 mm Aggregate (kg/m^3)	630	609.5	609.5	609.5	607	607	607
Sand (kg/m^3)	720	694.12	694.12	694.12	693.77	693.77	693.77
Nano silica (kg/m^3)	0	7.62	7.62	7.62	11.434	11.434	11.434
Coir (kg/m^3)	0	1.74	3.47	5.34	1.734	3.468	5.2
Fly ash (kg/m^3)	0	57.168	57.168	57.168	57.168	57.168	57.168
Super Plasticizer (kg/m^3)	0	1.73	2.08	2.43	1.8	2.17	2.52

Table 3. 14 Mix proportions for water to binder ratio of 0.45 concrete

Material	B1	B2	B3	B4	B5	B6	B7
Cement (kg/m^3)	425.73	330.4	330.4	330.4	326.41	326.41	326.41
Water (kg/m^3)	191.58	162.84	162.84	162.84	162.84	162.84	162.84
20 mm Aggregate (kg/m^3)	691.9	669.35	669.35	669.35	666.11	666.11	666.11
10 mm Aggregate (kg/m^3)	566.32	547.65	547.65	547.65	545	545	545
Sand (kg/m^3)	706.94	683.4	683.4	683.4	680.47	680.47	680.47
Nano silica (kg/m^3)	0	7.96	7.96	7.96	11.94	11.94	11.94
Coir (kg/m^3))	0	1.71	3.41	5.12	1.7	3.4	5.1
Fly ash (kg/m^3)	0	59.71	59.71	59.71	59.71	59.71	59.71
Super Plasticizer (kg/m^3)	0	2.17	2.53	2.89	2.27	2.62	3.0

Table 3.15: **Mix proportions for water to binder ratio of 0.42 concrete**

Material	C1	C2	C3	C4	C5	C6	C7
Cement (kg/m^3)	456.14	354	354	354	349.28	349.28	349.28
Water (kg/m^3)	191.58	162.84	162.84	162.84	162.84	162.84	162.84
20 mm Aggregate (kg/m^3)	752.61	726	726	726	721.2	721.2	721.2
10 mm Aggregate (kg/m^3)	501.74	484	484	484	481	481	481
Sand (kg/m^3)	686.8	662.68	662.68	662.68	658.24	658.24	658.24
Nano silica (kg/m^3)	0	8.53	8.53	8.53	12.79	12.79	12.79
Coir (kg/m^3)	0	1.66	3.31	5.1	1.646	3.3	4.9
Fly ash (kg/m^3)	0	63.97	63.97	63.97	63.97	63.97	63.97
Super Plasticizer (kg/m^3)	0	2.71	3.1	3.5	2.8	3.24	3.62

3.4 PREPARATION OF SAMPLE

For achieving the objectives of the study, 6 cubes of size 150 mm× 150 m × 150 mm were cast for the determination of the compressive strength of concrete after the 7 and 28 days curing and 3 cubes of size 70 mm × 70 mm × 2.5 mm for the finding the abrasion resistance of concrete after the 28 days curing. Thus, for the determination of compressive strength 126 cubes (42 cubes for each water to binder ratio) and for abrasion test 63 cubes (21 cubes for each water to binder ratio) were casted. Hand Mixing has been used for mixing all the ingredients.

3.4.1 Mixing of concrete without coir fiber and nano silica

For mixing of conventional concrete, initially all dry material like coarse and fine aggregate has been mixed. The mixing of dry material will continue until cement and sand is not properly mixed with coarse aggregate. After the mixing of dry materials, half water of the total required quantity is added to dry mix to start mixing of the material.

Adequate precautions were taken during the mixing that there is no lump formed in the concrete. After some time, remaining water is added in concrete and whole material is mixed properly. After few minutes of hand mixing, mixing is stopped to check for any lump formation.

3.4.2 Mixing of concrete with coir fiber and nano silica

If coir fiber is added in the concrete, the workability of concrete bound to is decrease. For maintaining the slump of the concrete super plasticizer is used in the concrete. For proper distribution of coir fiber in concrete, coir layer is placed after each material layer like one third quantity is placed after 20mm aggregate, half of the remaining quantity is placed after 10mm aggregate and remaining quantity placed after sand placement. All materials (coarse and fine aggregate and coir) are mixed properly and checked that coir is not concentrated at one place, if it so happened then proper distribution is done. After that cement and fly ash has been completely mixed with mixture of aggregate and coir fiber. Colloidal nano silica and super plasticizer are mixed with water to make a perfect solution. Half solution of nano silica, super plasticizer and water is added in dry material and all materials are mixed. Care was taken so that no formation of lump appeared in the mix. Subsequently, remaining solution was mixed in concrete. Due the use of super plasticizer, all the materials were mixed for some more time to initiate the chemical reaction of super plasticizer in concrete. After few minute of hand mixing, mixing was stop and check that, lumped is not formed in concrete. During the whole study, a constant workability, of 50 to 75 mm slump, has been maintained, by varying the super plasticizer dosage. Before the casting of sample slump test has been performed according to IS 7320:1974.

3.4.3 Casting

After the mixing of the all material, it is placed in pre prepared mould in the three layers. The moulds were placed on a vibrator for compaction of concrete and for removing the available voids and air from the concrete. The casted moulds were then placed on a flat surface for 24 hours to allow for final setting of concrete.

3.4.4 Curing

After 24 hours of the casting, moulds have been demoulded and the concrete specimen were placed it in the curing tank for 7 and 28 days. Curing is compulsory for reducing the heat of hydration and crack formation in concrete. The temperature of the curing tank was maintained at 27± 2 ºC throughout the designated period of curing.

3.5 TESTING OF SAMPLE

3.5.1 Compressive Strength

Concrete is casted, primarily to resist the compressive forces. This test is important for getting the idea about the quality and characteristics of concrete. The compressive strength is the resistance to failure of any material under the application of compressive forces. Compressive strength is dependent upon many components like water to cement ratio, quality of material, quality control during the casting.

For the determination of compressive strength of concrete cubes of size 150mm x 150mm x 150mm have been casted under controlled conditions and were tested after 7 and 28 days of curing period. The specimens were taken out from the curing tank, and kept for half to an hour at the room temperature for removing the moisture present on the surface. The prepared specimens were then tested in the Automatic Compression Testing Machine (ACTM) of 500 tons capacity. The procedure for finding the compressive strength of concrete in explained in IS: 516-1959. Load was continuously applied on the cube at the rate of 5.1 KN per second (140 kg/cm^2 per minute) until the specimen fails. Fig 3.5 shows testing of cube specimen under automatic compression testing machine.

3.5.2 Abrasion Resistance

Durability is the capability to keep a material for a long time without much deterioration. Durability of the concrete is defined as the capability to resist the attack from atmosphere and chemical, abrasion and other degradation process. In the study, for durability analysis, abrasion resistance test has been performed. Abrasion resistance of concrete is the process of rubbing the concrete by an abrasive material in the controlled environment.

Fig. 3. 5 Cube Specimen under compression in ACTM

Fig. 3. 6 Abrasion resistance testing machine

Durability of concrete is mainly dependent upon the cement content, compaction, grade of concrete, aggregate properties, surface finishing, curing, and permeability.

For finding the abrasion resistance of concrete, cubes of size 70mm x 70mm x 2.5mm were cast under controlled laboratory conditions and were tested after 28 days of curing period. The specimens were taken out from the curing tank, and kept for half to an hour at the room temperature for removing the moisture present on the surface.

After that sample were placed in oven at temperature 100 ±5 ºC for 24 hours for removing the complete moisture present in the sample. After 24 hours, samples were taken out from the oven and cooling of the samples was done at the room temperature and weighed to the nearest 0.1g. Abrasion Resistance test has been performed according to the IS 1237: 2012. Aluminum oxide is used as the abrasive material. After completing the test, the samples were reweighed. With the help of both weights the loss was be determined. Fig 3.6 shows the machines used for the abrasion resistance test.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 GENERAL

In this chapter, discussion on the results obtained from the compressive strength and abrasion resistance tests on concrete specimens, when cement is replaced with nano silica and fly ash and coir fibers are added to concrete. By comparing the results, optimum percentage of coir fiber and nano silica in concrete is determined, which improve the properties of concrete.

4.2 EFFECT ON THE WORKABILITY OF CONCRETE

In this research, coir fibers have been additionally added to the concrete. Primarily due to this reason, the workability of concrete is decreasing as the percentage of coir fiber in concrete increases. For maintaining a constant slump between 50 to 75 mm, super plasticizer was added in concrete. Table 4.1 shows the results of the super plasticizer dosage required at three considered water to binder ratios to maintain the desired slump value. Fig. 4.1 shows the photographs of the slump test being performed in the laboratory. It is observed during the mixing and from the slump values, that as the percentage of nano silica in the mix increases, the requirement of super plasticizer also increases. The particle size of the nano silica and fly ash are smaller than the cement, making the concrete denser, thus for proper mixing and maintaining the slump the dosage of super plasticizer is found to increase. Also it is seen that addition of coir fiber to decrease the workability leading to requirement of higher dosage of super plasticizer.

Fig. 4. 1 Slump Test

Table 4. 1 Slump and super plasticizer dosages for different samples

w/b = 0.47			w/b = 0.45			w/b = 0.42		
Sample	**Slump (mm)**	**Super Plasticizer dosage (%)**	**Sample**	**Slump (mm)**	**Super Plasticizer dosage (%)**	**Sample**	**Slump (mm)**	**Super Plasticizer dosage (%)**
A1	70	0	B1	65	0	C1	63	0
A2	62	1.73	B2	68	2.17	C2	67	2.71
A3	68	2.08	B3	61	2.53	C3	63	3.1
A4	58	2.43	B4	63	2.89	C4	56	3.5
A5	65	1.8	B5	70	2.27	C5	61	2.8
A6	61	2.17	B6	64	2.62	C6	67	3.24
A7	60	2.52	B7	67	3.0	C7	64	3.62

4.3 COMPRESSIVE STRENGTH TEST RESULTS

The average compressive strength of the three specimens, after the 7 and 28 days of curing period were considered as compressive strength of concrete, which is shown in Tables 4.2, 4.3 and 4.4 for water to binder ratio 0.47, 0.45 and 0.42, respectively.

Table 4. 2 Compressive strength of concrete for water to binder of 0.47

Sample No.	After 7 days (MPa)	After 28 days (MPa)
A1 (Control)	24.8	30.9
A2 (2 % NS, 0.25 % CF)	26.7	32.9
A3 (2 % NS, 0.50 % CF)	28.2	34.6
A4 (2 % NS, 0.75 % CF)	21.8	26.6
A5 (3 % NS, 0.25 % CF)	27.4	33.8
A6 (3 % NS, 0.50 % CF)	29.5	35.8
A7 (3 % NS, 0.75 % CF)	23.3	28.1

Table 4. 3 Compressive strength of concrete for water to binder of 0.45

Sample No.	After 7 days (MPa)	After 28 days (MPa)
B1 (Control)	29.9	37.9
B2 (2 % NS, 0.25 % CF)	31.9	39.8
B3 (2 % NS, 0.50 % CF)	33.8	40.9
B4 (2 % NS, 0.75 % CF)	26.6	34.7
B5 (3 % NS, 0.25 % CF)	32.7	40.5
B6 (3 % NS, 0.50 % CF)	34.8	41.7
B7 (3 % NS, 0.75 % CF)	27.8	36.3

Table 4. 4 Compressive strength of concrete for water to binder of 0.42

Sample No.	After 7 days (MPa)	After 28 days (MPa)
C1 (Control)	34.3	42.8
C2 (2 % NS, 0.25 % CF)	35.6	44.0
C3 (2 % NS, 0.50 % CF)	37.2	45.7
C4 (2 % NS, 0.75 % CF)	31.4	39.4
C5 (3 % NS, 0.25 % CF)	36.7	45.8
C6 (3 % NS, 0.50 % CF)	38.5	47.6
C7 (3 % NS, 0.75 % CF)	33.5	41.7

4.4 DISCUSSION ON THE COMPRESSIVE STRENGTH TEST RESULT

Figures 4.2, 4.3, 4.4 show the 7 days compressive strength of concrete for the w/b ratios of 0.47, 0.45 and 0.42, respectively whereas figures 4.5, 4.6 and 4.7 shows the 28 days compressive strength of concrete for w/b ratios of, 0.47, 0.45 and 0.42, respectively. The compressive strength test results are categorized to discuss the variation of one parameter by keeping the other two parameters constants.

4.4.1 Effect of variation of coir fiber

In this subsection the graphs have been drawn for a fixed nano silica contents and the effect of variation in percentage of coir fiber in the mix is studied.

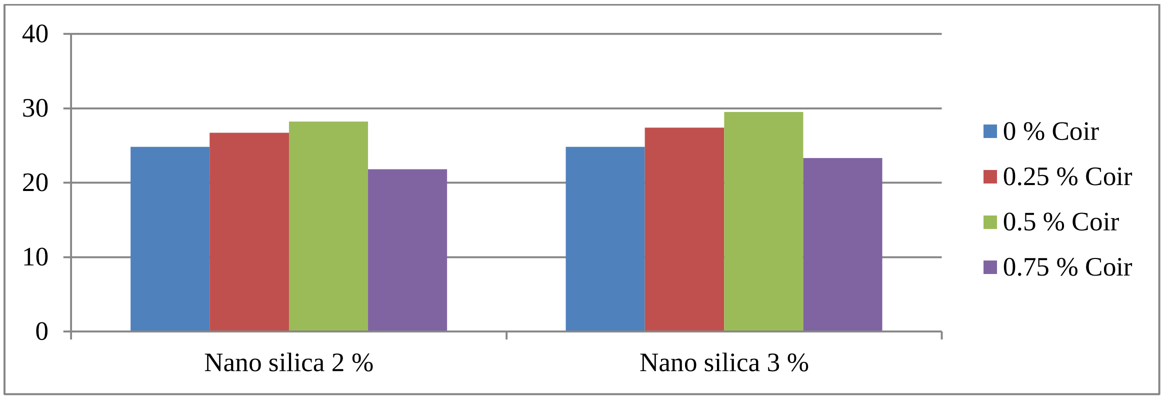


Fig. 4. 2 7 d**ays compressive strength for the w/b ratio of 0.47**

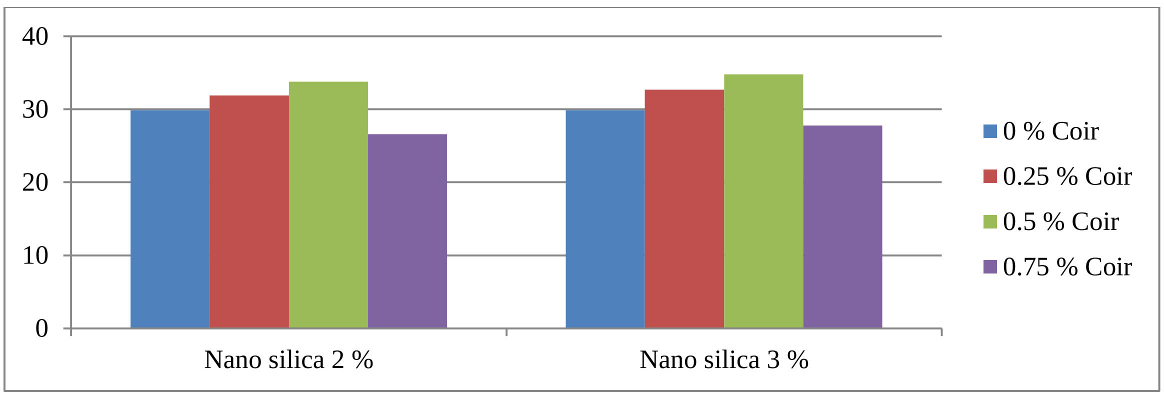


Fig. 4. 3 7 **days compressive strength for the w/b ratio of 0.45**

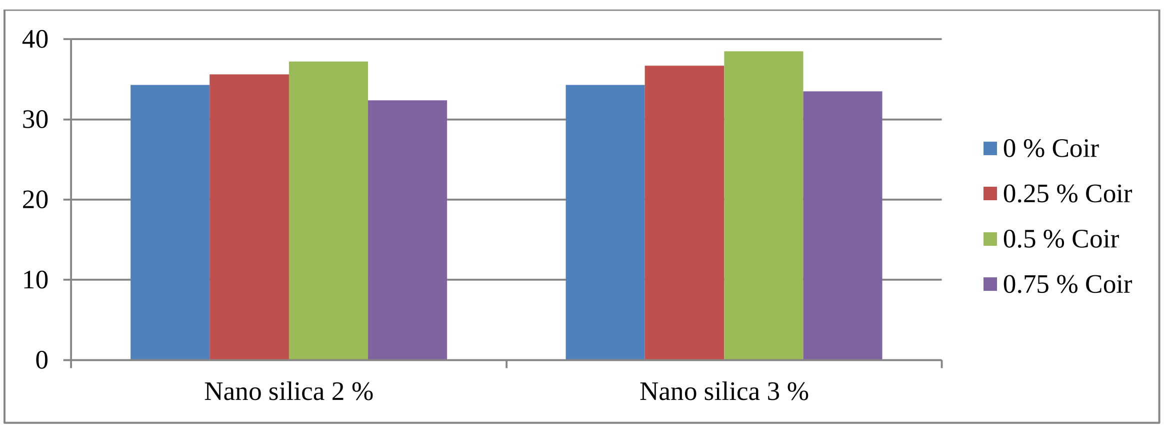


Fig. 4. 4 7 **days compressive strength for the w/b ratio of 0.42**

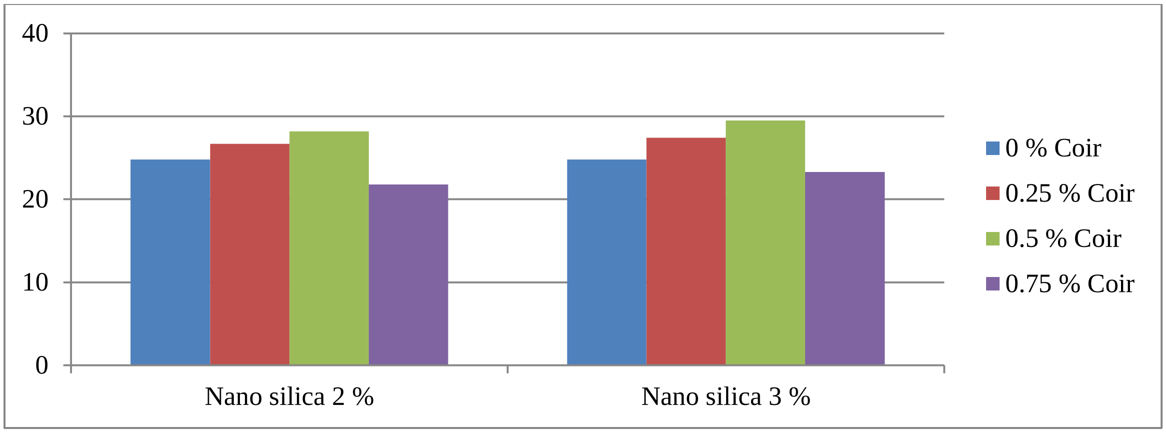


Fig. 4. 5 28 **day compressive strength for the w/b ratio of 0.47**

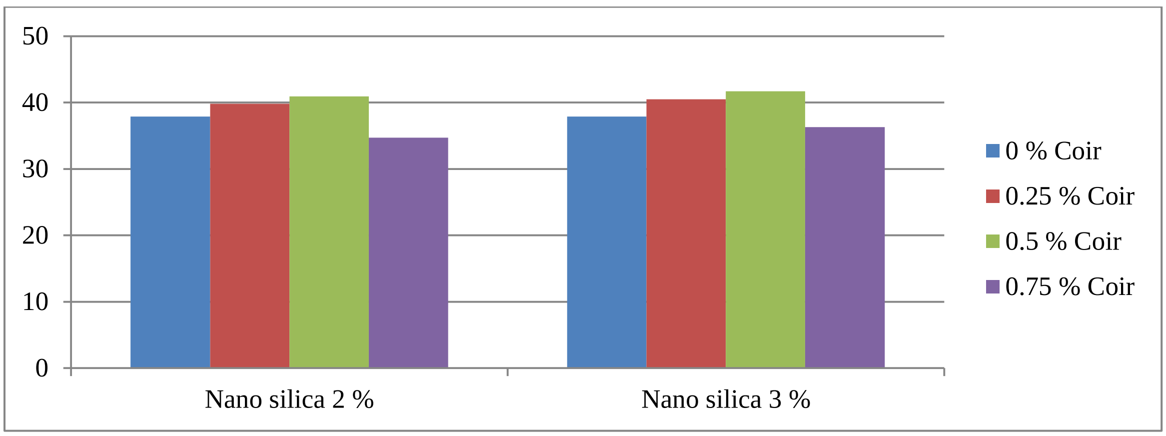


Fig. 4. 6 28 **day compressive strength for the w/b ratio of 0.45**

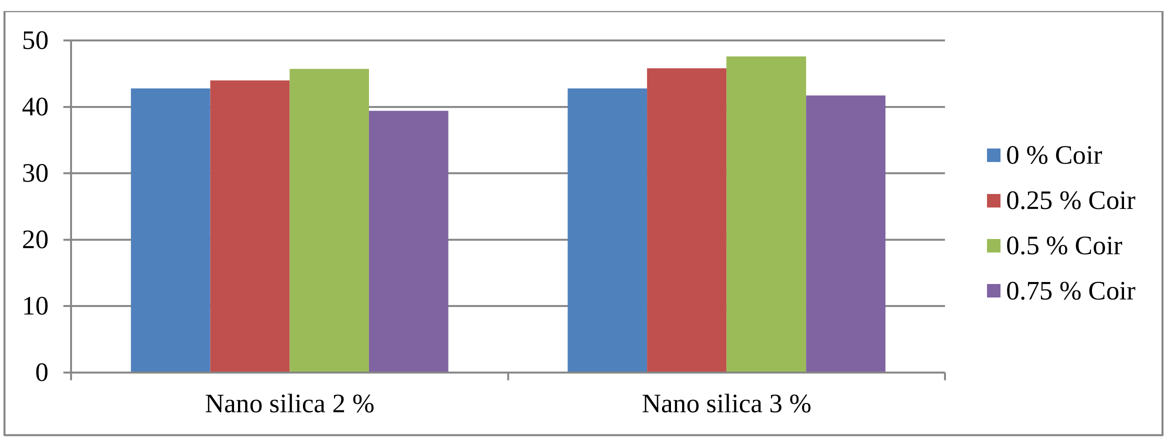


Fig. 4. 7 28 day compressive strength for the w/b ratio of 0.42

Fig 4.2 shows the 7 days compressive strength of concrete for w/b ratio of 0.47. The compressive strength of the conventional concrete (without any replacement) is observed be 24.8 MPa whereas for 2 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 7 % and 13 %, respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 12 % below the control sample. For 3 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 10 % and 18 %, respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 7 % below the control sample.

Fig 4.3 shows the 7 days compressive strength of concrete for w/b ratio of 0.45. The compressive strength of the conventional concrete (without any replacement) is observed to be 29.9 MPa whereas 2 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 6 % and 12 %, respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 11 % below the control sample. For 3 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 9% and 16 % respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 6 % below the control sample.

Fig 4.4 shows the 7 days compressive strength of concrete for w/b ratio of 0.42. The compressive strength of the conventional concrete (without any replacement) is observed to be 34.3 MPa whereas 2 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 4 % and 8 % respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 5 % below the control sample. For 3 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 7% and 12 % respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 3 % below the control sample.

Fig 4.5 shows the 28 days compressive strength of concrete for w/b ratio of 0.47. The compressive strength of the conventional concrete (without any replacement) is observed to be 30.9 MPa whereas 2 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 7 % and 11 % respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 13 % below the control sample. For 3 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 9 % and 15 % respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 9 % below the control sample.

Fig 4.6 shows the 28 days compressive strength of concrete for w/b ratio of 0.45. The compressive strength of the conventional concrete (without any replacement) is observed to be 37.9 MPa. For 2 % Nano silica and 15 % Fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 5 % and 8 % respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 8 % below the control sample. For 3 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 7% and 12 % respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 4 % below the control sample.

Fig 4.7 shows the 28 days compressive strength of concrete for w/b ratio of 0.42. The compressive strength of the conventional concrete (without any replacement) is observed to be 42.8 MPa. For 2 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 3 % and 7 % respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 7 % below the control sample. For 3 % nano silica and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 0.25 % and 0.5 % coir fiber is 7 % and 11 % respectively but as the percentage of coir fiber is increased to 0.75 % there is a sharp decline in the compressive strength and it reduced to 3 % below the control sample.

From the discussion of results for 7 and 28 days compressive strength it is seen that the value of compressive strength is higher for 3 % nano silica in the mix. Hence it can be said that 0.5 % of coir fiber in the mix is the optimum percentage as it helps to bind the mix together. A further increase in coir fiber percentage leads to coarser mix making it harder to place and proper bonding is not achieved. It can also be concluded that for higher water to binder ratio the strength increases will increase in coir fiber up to 0.5 %, is higher. This could be attributed to the fact that the higher water – binder ratios have higher water content which makes it easy to mix the ingredients resulting in formation of more homogeneous mix. The strength decrement due to higher coir fiber contents also be attributed to the fact that coir fiber unites at a place in the concrete leading to lump formation. Thus when the crack is formed due to application of the compressive force, it will easily propagate to the other face of the cube there by reducing the compressive strength of concrete.

4.4.2 Effect of variation of Nano silica

In this subsection the graphs have been drawn for a fixed coir fiber contents and the effect of variation in percentage of nano silica in the mix is studied.

Fig 4.8 shows the 7 days compressive strength of concrete for w/b ratio of 0.47. The compressive strength of the conventional concrete (without any replacement) is observed to be 24.8 MPa whereas 0.25 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 7 % and 10 % respectively and for 0.5 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 13% and 18 % respectively but 0.75 % coir fiber addition and 15 % fly ash replacement, the compressive strength is lesser than the control mix whereas it increases by 7 % if nano silica increases from 2 % to 3 % in the mix.

Fig 4.9 shows the 7 days compressive strength of concrete for w/b ratio of 0.45. The compressive strength of the conventional concrete (without any replacement) is observed to be 29.9 MPa whereas 0.25 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 7 % and 9 %

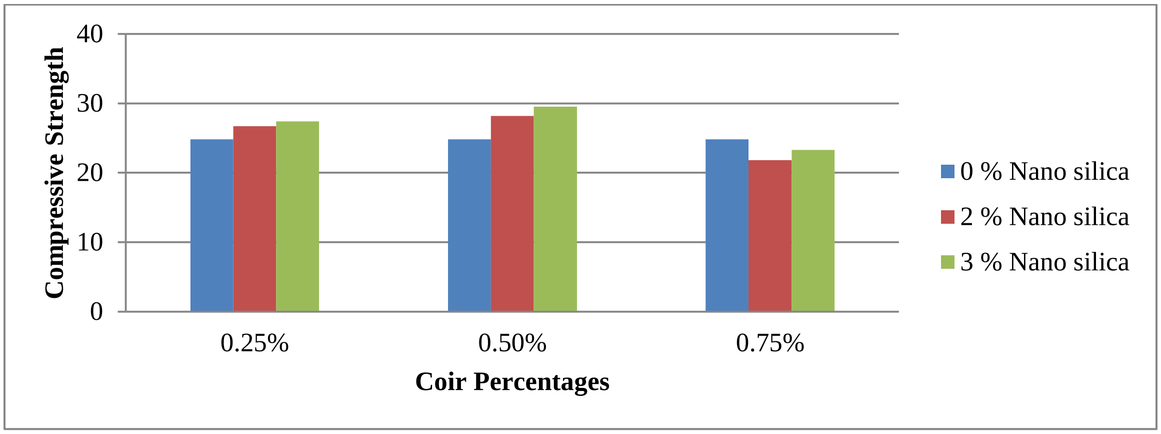


Fig. 4. 8 **7 days compressive strength for the w/b ratio of 0.47**

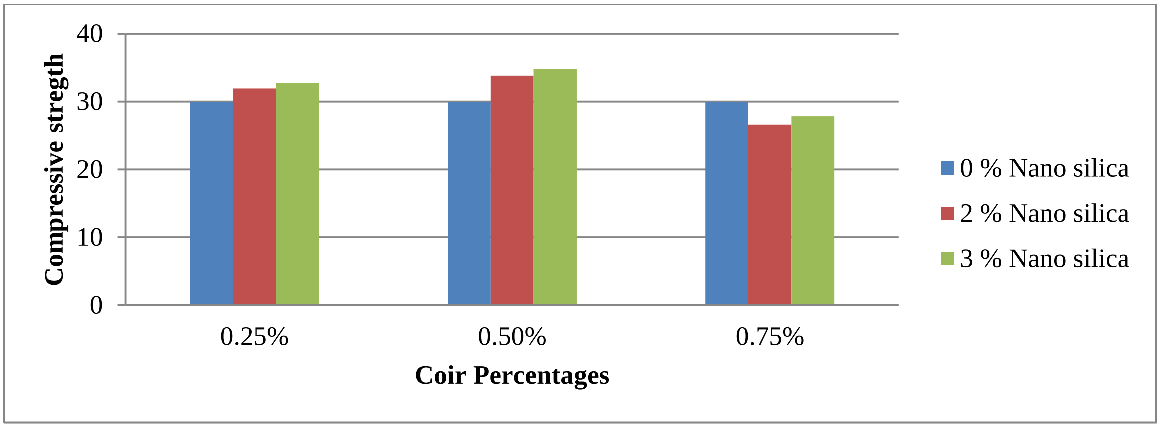


Fig. 4. 9 7 days compressive strength for the w/b ratio of 0.45

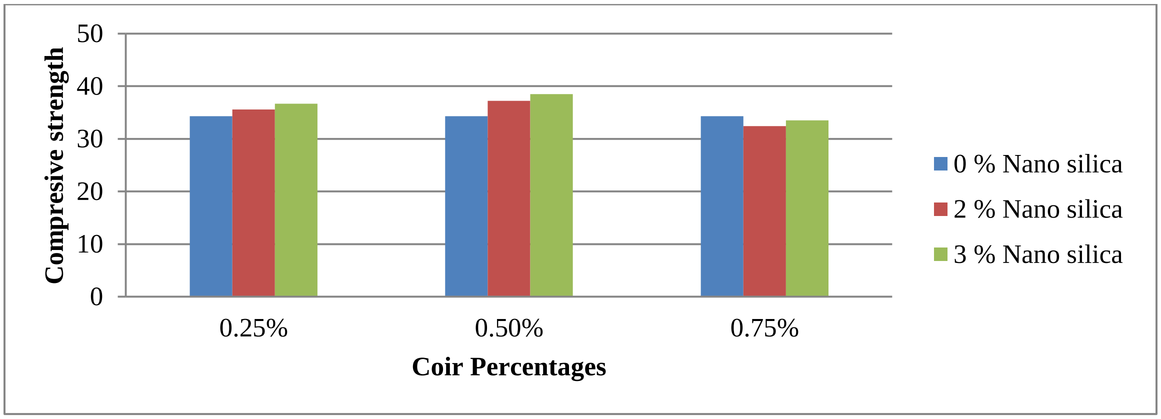


Fig. 4. 10 7 days compressive strength for the w/b ratio of 0.42

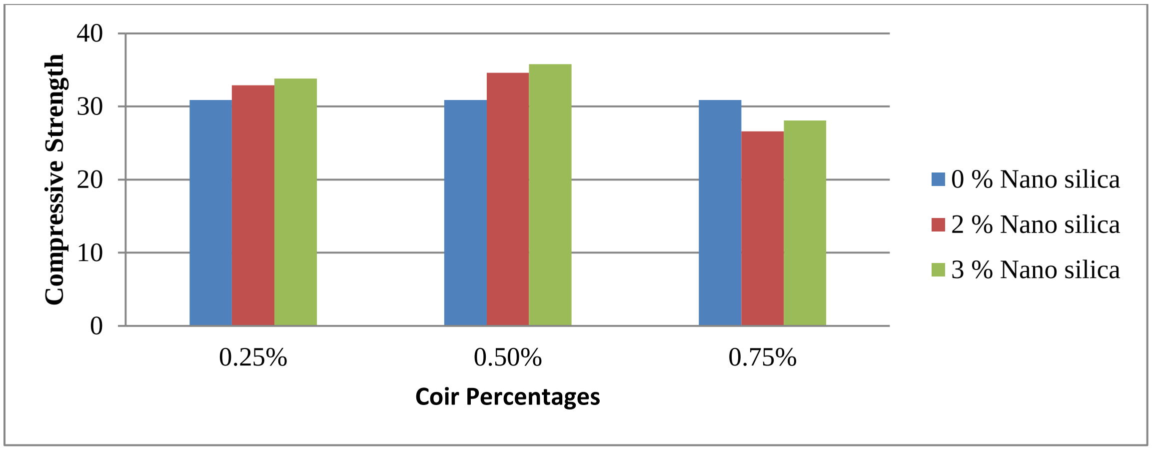


Fig. 4. 11 28 days compressive strength for the w/b ratio of 0.47

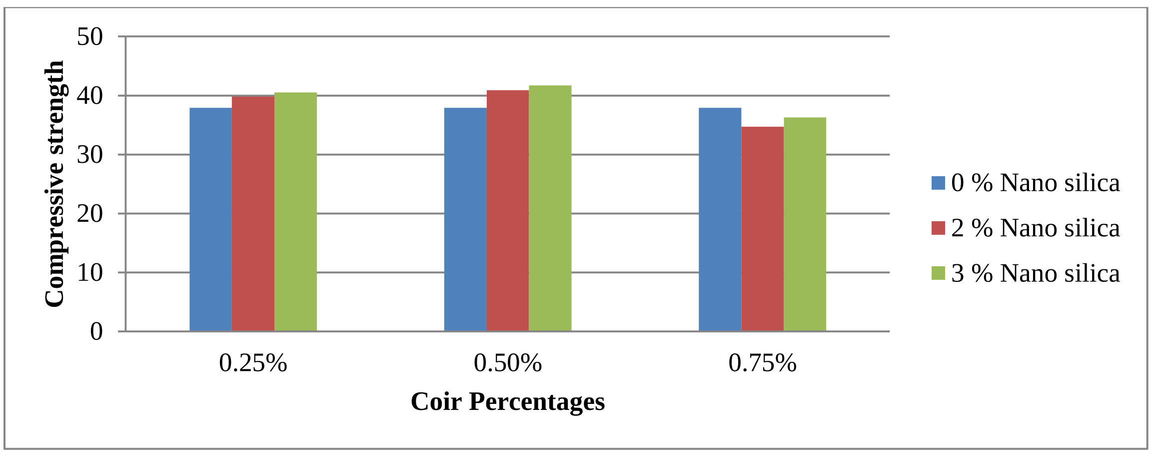


Fig. 4. 12 28 days compressive strength for the w/b ratio of 0.45

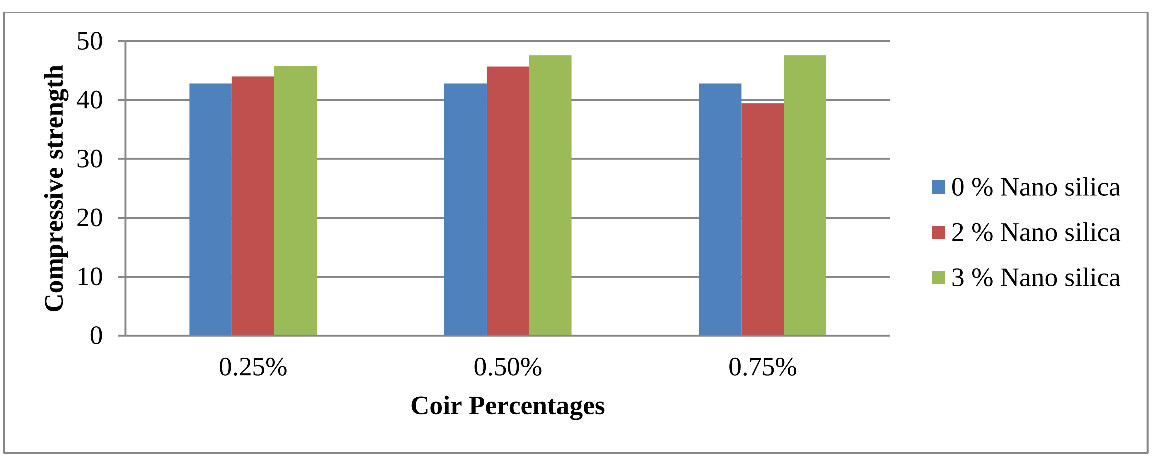


Fig. 4. 13 28 days compressive strength for the w/b ratio of 0.42

respectively and for 0.5 % coir addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 12 % and 16 % respectively but for 0.75 % coir addition and 15 % fly ash replacement, the compressive strength is lesser than the control mix whereas it increases by 4 % if nano silica increases from 2 % to 3 %.

Fig 4.9 shows the 7 days compressive strength of concrete for w/b ratio of 0.45. The compressive strength of the conventional concrete (without any replacement) is observed to be 29.9 MPa whereas 0.25 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 7% and 9 % respectively and 0.5 % coir fiber addition and 15 % Fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 12% and 16 % respectively but 0.75 % coir fiber addition and 15 % fly ash replacement, the compressive strength is lesser than the conventional concrete whereas it increases by 4 % if nano silica increases from 2 % to 3 %.

Fig 4.10 shows the 7 days compressive strength of concrete for w/b ratio of 0.42. The compressive strength of the conventional concrete (without any replacement) is observed to be 34.3MPa whereas 0.25 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 4% and 7 % respectively and 0.5 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 8% and 12 % respectively but 0.75 % coir fiber addition and 15 % fly ash replacement, the compressive strength is lesser than the conventional concrete whereas it increases by 3 % if nano silica increases from 2 % to 3 %.

Fig 4.11 shows the 28 days compressive strength of concrete for w/b ratio of 0.47. The compressive strength of the conventional concrete (without any replacement) is observed to be 30.9 MPa whereas 0.25 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 6% and 9 % respectively whereas 0.5 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 12% and 16 % respectively but 0.75 % coir fiber addition and 15

% fly ash replacement, the compressive strength is lesser than the conventional concrete whereas it increases by 6 % if nano silica increases from 2 % to 3 %.

Fig 4.12 shows the 28 Days compressive strength of concrete for w/b ratio of 0.45. The compressive strength of the conventional concrete (without any replacement) is observed to be 37.9 MPa whereas 0.25 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 5% and 7 % respectively and 0.5 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 8% and 10 % respectively but 0.75 % coir fiber addition and 15 % fly ash replacement, the compressive strength is lesser than the conventional concrete whereas it increases by 5 % if nano silica increases from 2 % to 3 %.

Fig 4.13 shows the 28 days compressive strength of concrete for w/b ratio of 0.42. The compressive strength of the conventional concrete (without any replacement) is observed to be 42.8MPa whereas 0.25 % coir fiber addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 2% and 7 % respectively and 0.5 % coir addition and 15 % fly ash replacement, the increment in the compressive strength of concrete due to addition of 2 % and 3 % nano silica is 6% and 11 % respectively but 0.75 % coir fiber addition and 15 % fly ash replacement, the compressive strength is lesser than the conventional concrete whereas it increases by 5 % if nano silica increases from 2 % to 3 %.

From the discussion of results for 7 and 28 days compressive strength it is seen that the improvement in the compressive strength is higher after the 7 days as compare to the 28 days, which shows that the nano silica improves the early age strength which is also explained by previous researchers. The increment in the early age strength indicates that nano silica is more reactive during the early age because of presence of high silica continent. It can also be concluded that the value of compressive strength is higher for 0.5 % coir fiber with 3 % nano silica in the mix. Hence it can be said that 0.5 % of coir fiber with 3 % nano silica is the optimum percentage for the mix as it helps to bind the mix together.

4.4.3 Summary

From the observations and discussions in preceding subsection, it can be concluded that the coir fiber can be used only up to the 0.5 % by the weight of the fine aggregate along with replacement of cement with 2% and 3 % nano silica and 15 % fly ash. Also it can further be concluded that 3 % nano silica in the mix gives maximum strength for all the water to binder ratios when compared with 2 % nano silica content at 7 days as well as 28 days curing period. It is also observed that the rate of increment of compressive strength is decreased as the w/b ratio decreased from 0.47 to 0.45 and 0.42. Hence, it can be concluded that the optimum dosage of coir fiber and nano silica is 0.5 % and 3 %, respectively for achieving the maximum compressive strength after 7 and 28 days curing.

4.5 ABRASION RESISTANCE TEST RESULT

The average weight loss of the three specimens was considered as weight loss due to the abrasion of the concrete. Table 4.4 shows the initial and final weight and weight loss due the abrasion resistance of the concrete for w/c ratio 0.47, 0.45 and 0.42.

4.6 DISCUSSION ON THE ABRASION RESISTANCE TEST RESULT

Figures 4.14, 4.15 and 4.16 show 28 days abrasion resistance of concrete for w/b ratios 0.47, 0.45 and 0.42, respectively. Abrasion resistance test performed for determine the effect of coir fiber and nano silica on the durability properties of concrete after the 28 days curing period.

Fig 4.14 shows the abrasion resistance of concrete for w/b ratio of 0.47 after 28 Days. The weight loss of the conventional concrete (without any replacement) due to abrasion is observed to be 0.99 % whereas 2 % nano silica and 15 % fly ash replacement, the decrement in the abrasion resistance of concrete due to addition of 0.25 %, 0.5 % and 0.75 % coir fiber is 9 %, 17 % and 21 %, respectively. For 3 % nano silica and 15 % fly ash replacement, the decrement in the abrasion resistance of concrete due to addition of 0.25 %, 0.5 % and 0.75 % coir fiber is 4 %, 12 % and 18 %, respectively.

Table 4. 5 Abrasion resistance test result

Type	Intial weight (gm)	Final weight (gm)	Wt. Loss (%)
w/ b ratio = 0.47			
A1	320.97	317.8	0.99
A2	323.25	319.96	1.08
A3	313.05	309.42	1.16
A4	275.19	271.89	1.2
A5	293.53	290.52	1.03
A6	312.82	309.35	1.11
A7	303.14	299.59	1.17
w/ b ratio = 0.45			
B1	324.77	321.89	0.89
B2	289.73	286.98	0.95
B3	301.86	298.45	1.13
B4	291.11	287.57	1.22
B5	313.79	310.95	0.91
B6	302.73	299.72	0.99
B7	330.99	327.12	1.17
w/ b ratio = 0.42			
C1	335.54	332.9	0.80
C2	327.33	324.59	0.84
C3	301.07	298.31	0.92
C4	328.64	325.28	1.02
C5	328.48	325.83	0.82
C6	317.16	314.33	0.89
C7	313.51	310.64	0.92

Fig 4.15 shows the abrasion resistance of concrete for w/b ratio of 0.45 after 28 Days. The weight loss of the conventional concrete (without any replacement) due to abrasion is observed to be 0.89 % whereas 2 % nano silica and 15 % Fly ash replacement, the

decrement in the abrasion resistance of concrete due to addition of 0.25 %, 0.5 % and 0.75 % coir fiber is 6 %, 16 % and 27 %, respectively. For 3 % nano silica and 15 % Fly ash replacement, the decrement in the abrasion resistance of concrete due to addition of 0.25 %, 0.5 % and 0.75 % coir fiber is 3 %, 11 % and 20 %, respectively.

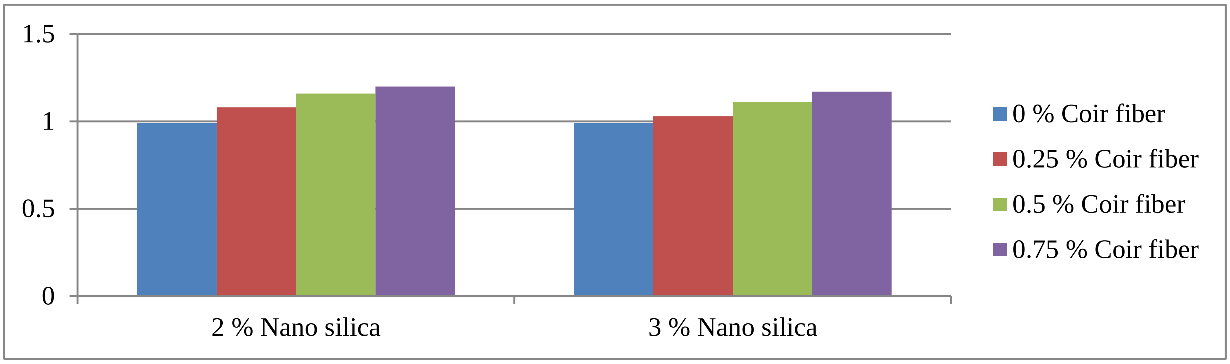


Fig. 4. 14 Abrasion Resistance of concrete for w/b ratio of 0.47

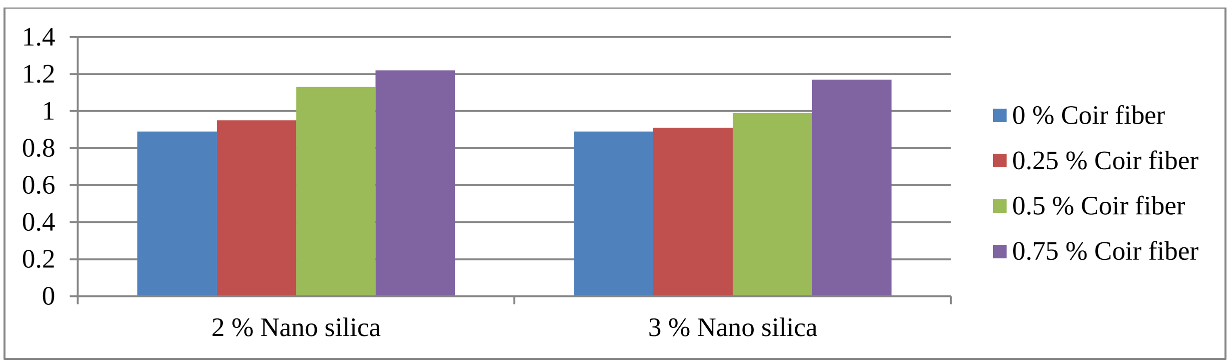
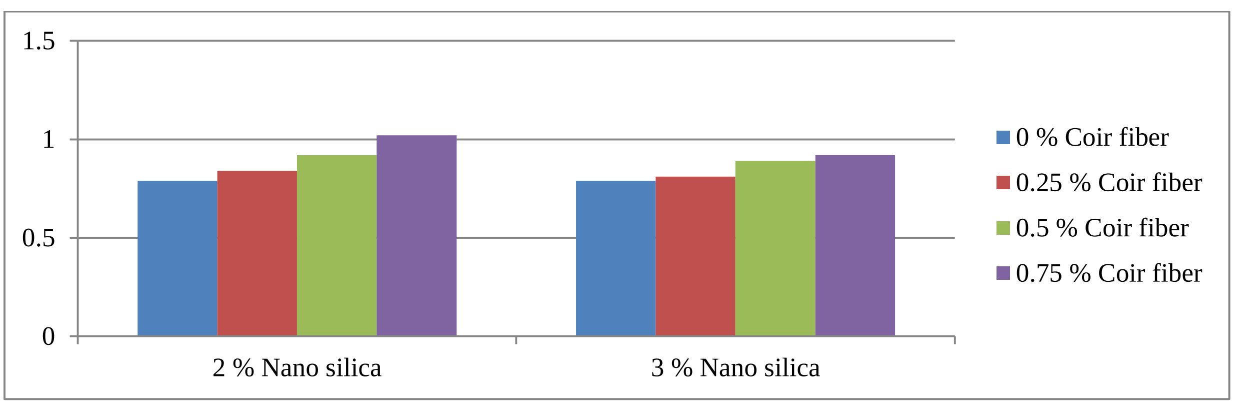


Fig. 4. 15 Abrasion Resistance of concrete for w/b ratio of 0.45



: **Fig. 4. 16 Abrasion Resistance of concrete for w/b ratio of 0.42**

Fig 4.16 shows the abrasion resistance of concrete for w/b ratio of 0.42 after 28 Days. The weight loss of the conventional concrete (without any replacement) due to abrasion is observed to be 0.80 % whreas 2 % nano silica and 15 % fly ash replacement, the decrement in the abrasion resistance of concrete due to addition of 0.25 %, 0.5 % and 0.75 % coir fiber is 6 %, 15 % and 26 %, respectively. For 3 % nano silica and 15 % fly ash replacement, the decrement in the abrasion resistance of concrete due to addition of 0.25 %, 0.5 % and 0.75 % coir fiber is 2 %, 12 % and 16 %, respectively.

From the observations and discussions in that section, it can be concluded that as the percentages coir fibre in the concrete increases, loss in weight of concrete sample is also increases as compare to the conventional concrete sample. It shows that coir fiber may not be able to fill the voids completely. It was also observed that if the nano silica increases from 2 % to 3 % the loss in weight decreases. It was also seen that, as water to binder ratio decrease, the rate of weight loss is also decreasing. It indicates that the as the water to binder ratio decreases makes concrete more durable. Finally it is concluded that, 0.25 % coir fiber with 3 % nano silica is the optimum dosage because this resulting concrete sample having approximate equal abrasion resistance as compare to the conventional concrete.

CHAPTER 5

CONCLUSION

5.1 GENERAL

In the present study, the effect of coir fiber and nano silica on the compressive strength and abrasion properties of the concrete was determined. This chapter deals with the main conslusions of the present study.

After completing the present study, the following conclusions can be drawn:

1. As the percentage of coir fiber increases in the mix, the dosage of the super plasticizer is also increase in order to achieving a constant slump between 50 to 75 mm. Thus, it can be concluded that addition of coir fiber decreases the workability leading to required higher dosage of super plasticizer dosage (%).
2. The percentage of the coir fiber in the concrete affects the compressive strength of concrete. As the percentage of coir fiber increases, the compressive strength of the concrete increases up to 0.5 % however the percentage of coir fibers increases to 0.75 % there is a sharp decline in the compressive strength as compared to the control sample. This behavior is similar for all water to binder ratios (0.47, 0.45, and 0.42) after 7 days as well as 28 days. Thus it can be concluded that up 0.5 % of coir fiber in the mix is the optimum percentage.
3. For higher water to binder ratios, the strength increase for coir fiber percentage of 0.5 % is more due to the fact that higher water to binder ratios has higher water content which makes it easier to mix the ingredients resulting in formation of more homogeneous concrete mix.
4. Keeping the same coir percentage, if the percentage of nano silica is increased in the concrete mix, the compressive strength of the concrete improves by approximate 7 %, 4 % and 3 % for the water to cement ratio 0.47, 0.45 and 0.42, respectively. The rate of increment in the 7 days compressive strength is higher than the 28 days compressive strength, thereby concluded that nano silica addition in concrete improves the early age strength.

5. The value of compressive strength is the highest for 3 % nano silica and 0.5 % coir fiber in the mix. A further increment in coir fiber percentage leads to coarser mix making it harder to place and proper bonding is not achieve. Thus it can be concluded that the optimum dosage of coir fiber and nano silica is 0.5 % and 3 %, respectively which improves the properties of the concrete.
6. As the percentage of coir fiber increased in the concrete, the Abrasion resistance of the concrete (due to addition of 0.25 %, 0.5 % and 0.75 % coir fiber and replacement of cement with 2 % and 3 % nano silica and 15 % fly ash) decrease as compare to the control mix. which shows that coir fiber may not be able to fill the voids completely. But 3 % nano silica in the mix gives minimum abrasion resistance for all the water to binder ratios when compared to 2 % nano silica content at 28 days curing period which shows that nano silica fill the voids and makes the concrete more homogeneous. Thus it can be concluded that the optimum dosage of coir fiber and nano silica is 0.25 % and 3 %, respectively which provides approximate equal abrasion resistance as compare to the conventional concrete sample.

From the discussion and conclusions of the present study, it can be concluded that the addition of 0.5 % coir fiber with 3 % nano silica improve the compressive strength of the concrete but abrasion resistance is decreases when compared with the control specimen. Since, the results provided by 0.5 % coir fiber and 3 % nano silica were adequate, it can be can be considered as the optimum dosage.

5.2 FUTURE SCOPE

- In order to completely fig out the behavior of nano silica and coir fiber, it is important to study the mineralogical and rheological properties of the resulting concrete.
- The study can be extended to find the effect of amorphous nano silica and other variations in colloidal nano silica and Fly ash in the concrete containing coir fibers.

- Further work can also carried out, for understanding the effect of coir fiber and nano silica on the other properties of concrete like flexural strength, split tensile strength and other durability properties.

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