

**USE OF WOOD CHIPPING AS PARTIAL REPLACEMENT
OF FINE AGGREGATE IN CONCRETE**

A Dissertation Submitted

In Partial Fulfillment of the Requirements

For the degree of

**MASTERS OF ENGINEERING
IN
STRUCTURAL ENGINEERING**

Submitted by:

SOURAV MEHTA

(ROLL NO. 801724029)

UNDER THE SUPERVISION OF

DR. RAFAT SIDDIQUE

Senior Professor



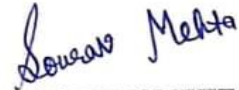
**DEPARTMENT OF CIVIL ENGINEERING
THAPAR INSTITUTE OF ENGINEERING AND TECHNOLOGY**

PATIALA – 147004

JULY, 2019

DECLARATION

The author hereby declare that this dissertation entitled "*USE OF WOOD CHIPPING AS PARTIAL REPLACEMENT OF FINE AGGREGATE IN CONCRETE*", in whole or part had not been used to obtain any degree in this, or any other institute, except where references have been given in text, it is entirely the author's own work. The author confirms that the library may lend or copy this upon request for academic purpose.



(SOURAV MEHTA)

ROLL NO. – 801724029

CERTIFICATE

This is to certify that the work presented in dissertation entitled "*USE OF WOOD CHIPPING AS PARTIAL REPLACEMENT OF FINE AGGREGATE IN CONCRETE*", submitted by Mr. SOURAV MEHTA in partial fulfillment of the requirements for the award of degree of **Master in Engineering** in Structural Engineering at **Thapar Institute of Engineering and Technology, Patiala**, is a bonafide work carried out by student under our supervision and guidance. The matter embodied in this report has not been submitted anywhere for reward of any other degree.


Dr. RAFAT SIDDIQUE

Senior Professor

Department of Civil Engineering
Thapar Institute of Engineering
And Technology, Patiala

ACKNOWLEDGEMENT

This acknowledgement is intended to be thanks giving to all those people who have been involved directly or indirectly with my thesis work. First and foremost, I would like to express my thanks and indebtedness to my guide Dr Rafat Siddique, Sr. Professor of Civil Engineering, Thapar Institute of Engineering & Technology, Patiala for his deep involvement, invaluable and continuous motivation throughout this work. I am highly obliged to him for being there always whenever I needed him.

I would like to thank Dr. Prem Pal Bansal Head, Civil Engineering Department, Thapar Institute of Engineering & Technology, Patiala who has been a constant source of inspiration for me throughout this work.

The cheerful support of my friends and colleagues is sincerely appreciated. Special words of appreciation go to Sh. Manreet Sidhu, Sh. Hitesh Kumar, Sh. Ram Simran, Sh. Virender Singh and other laboratory colleagues who helped me in my experimental work. I am also thankful to all the staff members of the Civil Engineering Department for their full cooperation and help.

Above all, I thank my parents, whose love and affectionate blessing have been a constant source of inspiration in making this manuscript a reality. I render my gratitude to the almighty who bestowed self-confidence, ability, and strength in me to complete this work.

Sourav Mehta
(801724029)

ABSTRACT

Due to growing environmental awareness, as well as stricter regulation on managing industrial waste, the world is increasingly turning to researching properties of industrial waste and finding solution on using its valuable component parts so that it might be used as secondary raw material in various other industries.

Although wood saw dust is still today considered waste and is categorized in industrial waste catalogues in most countries, but it is not that kind of waste neither by its physical and chemical properties nor according to data on its use as valuable martial for different purposes. Moreover in early time till the arrival of refrigeration, it was frequently used in houses to obtain ice all through summer.

Considering the specificity of physical and chemical properties of wood saw dust and a series of possibilities for their use in other industrial branches and in the field of civil constructions, this report demonstrates the possibilities of using saw wood dust as partial replacement of fine aggregate in concrete.

This report presents an investigation of different properties like fresh properties, hardened properties and durability properties of concrete using different percentage of wood chipping as partial replacement of fine aggregate at different water cement ratio after pretreatment with water and sodium silicate. Secondly it represents fresh properties, hardened properties and durability properties of concrete using constant percentage (5%) of wood chipping as partial replacement of fine aggregate and silica fume as partial replacement of cement at different percentage. The results shows that the concrete using wood saw dust as replacement of fine aggregate there is large reduction in weight of concrete.

TABLE OF CONTENT

DECLARATION.....	i
ACKNOWLEDGEMENT.....	ii
ABSTRACT.....	iii
TABLE OF CONTENT.....	iv
LIST OF FIGURES.....	viii
LIST OF TABLES.....	xi
LIST OF ABBREVIATIONS.....	xv
CHAPTER 1.....	1
INTRODUCTION.....	1
1.1 GENERAL.....	1
1.2 CONCRETE FORMED BY USING INDUSTRIAL WASTE AS REPLACEMENT...	2
1.3 KEY PARAMETER AND INGREDIENT USED.....	3
1.3.1 General.....	3
1.3.2 Matrix.....	3
1.3.3 Particle Packing.....	3
1.3.4 Cement.....	4
1.3.5 Coarse-Aggregate.....	5
1.3.6 Fine-Aggregate.....	5
1.3.7 Timber Waste.....	6
1.3.8 Silica-Fume.....	9
1.3.9 Sodium-Silicate.....	11
CHAPTER 2.....	13

LITERATURE REVIEW OF WOOD SAW DUST AS PARTIALA REPLACEMENT OF FINE-AGGREGATE	13
2.1 EFFECT OF WOOD CHIPING ON DIFFERENT PROPERTIES OF CONCRETE ..	13
2.1.1 Workability	13
2.1.2 Density	15
2.1.3 Compressive-Strength.....	16
2.1.4 Split-Tensile-Strength	20
2.1.5 Flexure-Strength	22
2.1.6 Elastic Modulus	23
CHAPTER 3.....	26
EXPERIMENTAL PROGRAM.....	26
3.1 PRELIMINARY TESTING.....	26
3.2 MATERIALS AND THEIR PROPERTIES.....	26
3.2.1 Fine-Aggregate	26
3.2.2 Coarse-Aggregate	28
3.2.3 Cement	29
3.2.4 Wood Chipping.....	30
3.2.5 Silica-Fume	32
3.2.6 Sodium-Silicate.....	32
3.3. PREPARATION OF MATERIAL FOR CASTING	33
3.3.1 Mix-Design as per IS 10262:2009	33
3.3.2 Casting And Curing of Samples	38
3.3.3 Testing Program.....	38
CHAPTER 4.....	50

RESULTS AND DISCUSSIONS	50
4.1 FRESH-PROPERTIES OF CONCRETE RESULTS.....	50
4.1.1 Workability	50
4.1.2 Density of Fresh-Concrete	53
4.2 HARDENED PROPERTIES OF CONCRETE RESULTS	57
4.2.1 Compressive-Strength.....	58
4.2.2 Split-Tensile Strength	63
4.3 DURABILITY RESULTS OF CONCRETE	68
4.3.1 Water Penetration Test.....	68
4.3.2 Rapid-Chloride Permeability Test (RCPT).....	70
4.3.3 Water Sorptivity Test.....	72
4.4 SCANNING ELECTRON MICROSCOPY AND ENERGY DISPERSIVE SPECTROSCOPY	77
4.4.1 SEM Analysis of Sample Containing 5 % Wood Chipping	77
4.4.2 SEM Analysis of Sample Containing 10 % Wood Chipping	77
4.4.3 SEM Analysis of Sample Containing 5 % Wood Chipping and 12% Silica Fume as Replacement of Cement.....	78
4.4.4 SEM Analysis of Sample Containing 5 % Wood Chipping After Sodium Silicate treatment	79
CHAPTER 5.....	81
OBSERVATIONS AND CONCLUSIONS.....	81
5.1 GENERAL.....	81
5.2 CONCLUSIONS.....	81
5.2.1 Workability	81
5.2.2 Density of Fresh Concrete	81

5.2.3 Compressive Strength	82
5.2.4 Split Tensile Strength.....	82
5.2.5 Water Penetration Test.....	82
5.2.6 RCPT.....	83
5.2.7 Sorptivity.....	83
5.3 SCOPE OF FUTURE STUDY	83
REFERENCES	84

LIST OF FIGURES

Figure 1.1: Particle packing.....	4
Figure 1.2: Coarse-aggregate	5
Figure 1.3: Formation of wood chipping	8
Figure 1.4: Wood Chipping.....	8
Figure 3.1: Fine-aggregate (sand)	26
Figure 3.2: Coarse-aggregate	28
Figure 3.3: Wood chipping.....	30
Figure 3.4: Sieve-analysis of wood chipping	31
Figure 3.5: Raw material of wood chipping.....	36
Figure 3.6: Sieving of raw material from 4.75mm sieve.....	37
Figure 3.7: Pre-treatment of saw dust with water	37
Figure 3.8: Slump-value of concrete	40
Figure 3.9: Density of fresh concrete	40
Figure 3.10: Casting of cubes of concrete	41
Figure 3.11: Compressive-strength of cube	42
Figure 3.12: Split-tensile-strength of cylinder	43
Figure 3.13: 100 mm x 50 mm cylinder A and Epoxy coated sample B	44
Figure 3.14: Sorptivity test arrangement.....	45
Figure 3.15: Water penetration test	46
Figure 3.16: Water penetrated sample.....	46
Figure 3.17: Vacuum desiccator bowl.....	48
Figure 3.18: Full arrangement of R.C.P.T.....	48
Figure 4.1: Workability of wood replacement after pre-treatment	51

Figure 4.2: Workability of wood replacement after pre-treatment	51
Figure 4.3: Workability of wood as F.A. replacement & silica-fume.....	52
Figure 4.4: Workability after wood replacement after pre-treatment with sodium-silicate...	53
Figure 4.5: Density of wood replacement without pre-treatment	54
Figure 4.6: Density of wood replacement after pre-treatment	55
Figure 4.7: Density of wood replacement after pre-treatment	55
Figure 4.8: Density of Wood as F.A replacement & Silica-fume.....	56
Figure 4.9: Density of wood replacement after pre-treatment	57
Figure. 4.10: Compressive-strength after wood replacement without pre-treatment.....	58
Figure 4.11: Compressive-strength after wood replacement after pre-treatment with water.	59
Figure 4.12: Compressive-strength after wood replacement after pre-treatment with water.	60
Figure. 4.13: Compressive-strength after wood as F.A replacement & Silica-fume.....	61
Figure 4.14: Compressive-strength after wood replacement after pre-treatment with sodium-silicate.....	62
Figure 4.15: Split-tensile-strength after wood replacement without pre-treatment	63
Figure 4.16: Split-tensile-strength after wood replacement after pre-treatment with water ..	64
Figure 4.17: Split-tensile-strength after wood replacement after pre-treatment with water ..	65
Figure 4.18: Split-tensile-strength after wood as F.A replacement & silica-fume.....	66
Figure 4.19: Split-tensile-strength after wood replacement after pre-treatment with sodium-silicate.....	67
Figure 4.20: Water sorptivity values after wood replacement after pre-treatment with water	74
Figure 4.21: Water sorptivity after wood as F.A replacement & silica-fume	76
Figure 4.22 SEM of Sample Containing 5 % Wood Chipping.....	77
Figure 4.23 SEM of Sample Containing 10 % Wood Chipping.....	78
Figure 4.24 SEM of Sample Containing 5 % Wood Chipping & 12% S.F.....	79

Figure 4.25 SEM of Sample Containing 5 % Wood Chipping after treatment with Sodium silicate..... 80

LIST OF TABLES

Table 1.1: Chemical composition of concrete.....	4
Table 1.2: Chemical-properties of wood chipping.....	9
Table 1.3: Chemical-composition of silica-fume.....	10
Table 1.4: Chemical-properties of liquid sodium-silicate.....	11
Table 1.5: Physical-properties of liquid sodium-silicate.....	12
Table 2.1: Slump test results (Mohammed et al., 2014).....	13
Table 2.2: Slump test results (Priya et al., 2018).....	14
Table 2.3: Density (Mohammed et al., 2014).....	15
Table 2.4: Compressive-strength (Mohammed et al., 2014).....	17
Table 2.5: Compressive-strength (Anandh et al., 2018).....	18
Table 2.6: Compressive-strength (Ahmed et al., 2018).....	19
Table 2.7: Compressive-strength (Sawant et al., 2018).....	20
Table 2.8: Split-tensile-strength (Mohammed et al., 2014).....	20
Table 2.9: Split-tensile-strength (Ahmed et al., 2018).....	21
Table 2.10: Split-tensile-strength (Sawant et al., 2018).....	22
Table 2.11: Modulus of Elasticity (Mohammed et al., 2014).....	24
Table 2.12: Modulus of Elasticity (Ahmed et al., 2018).....	25
Table 3.1: Physical-properties of fine-aggregate.....	27
Table 3.2: Sieve analysis of fine-aggregate.....	27
Table 3.3: Physical-properties of coarse-aggregate.....	28
Table 3.4 Sieve-analysis of coarse-aggregate (20mm).....	29
Table 3.5: Sieve-analysis of coarse-aggregate (10 mm).....	29

Table 3.6: Properties of the cement	30
Table 3.7: Physical-properties of wood chipping	30
Table 3.8: Sieve-analysis of saw wood dust	31
Table 3.9: Physical-properties of silica-fume provided by the supplier	32
Table 3.10: Chemical-properties of silica-fume provided by the supplier	32
Table 3.11: Chemical-properties of sodium-silicate (Grade 52) provided by the supplier. ..	32
Table 3.12: Mix proportion M25	34
Table 3.13: Concrete mix proportions	35
Table 3.14: Specimens description	38
Table 3.15: Tests and Codes	39
Table 3.16: Time and tolerances for the measurements of the mass of the specimen (ASTM C1585 – 04).....	45
Table 3.17 Chloride ion penetrability based on the charge passed (ASTM 1202)	47
Table 4.1: Slump-value for different wood replacement after pre-treatment with water w/c=0.5	50
Table 4.2: Slump-value for different wood replacement after pre-treatment with water w/c=0.44	51
Table 4.3: Slump-value for different replacement and different silica-fume replacement....	52
Table 4.4: Slump-value for different wood replacement after pre-treatment with sodium- silicate (w/c = 0.44)	52
Table 4.5: Density of fresh-concrete for different wood replacement without pre-treatment (w/c = 0.5).....	53
Table 4.6: Density of fresh-concrete for different wood replacement after pre-treatment with water (w/c = 0.5).....	54
Table 4.7: Density of fresh-concrete for different wood replacement after pre-treatment with water (w/c = 0.44).....	55

Table 4.8: Density of fresh-concrete for different wood replacement and different silica-fume replacement.....	56
Table 4.9: Density of fresh-concrete for different wood replacement after pre-treatment with sodium-silicate (w/c = 0.44)	57
Table 4.10: Average Compressive-strength of concrete for different wood replacement without pre-treatment (w/c = 0.5).....	58
Table 4.11: Average Compressive-strength of concrete for different wood replacement after pre-treatment with water (w/c = 0.5)	59
Table 4.12: Average Compressive-strength of concrete for different wood replacement after pre-treatment with water (w/c = 0.44)	60
Table 4.13: Average Compressive-strength of concrete for different wood replacement and different silica-fume replacement	61
Table 4.14: Average Compressive-strength of concrete for different wood replacement after pre-treatment with sodium-silicate (w/c = 0.44).....	62
Table 4.15: Average Split-tensile-strength of concrete for different wood replacement without pre-treatment (w/c = 0.5)	63
Table 4.16: Average split-tensile-strength of concrete for different wood replacement after pre-treatment with water (w/c = 0.5)	64
Table 4.17: Average split-tensile-strength of concrete for different wood replacement after pre-treatment with water (w/c = 0.44)	65
Table 4.18: Average split-tensile-strength of concrete for different wood replacement and different silica-fume replacement	66
Table 4.19: Average Split-tensile-strength of concrete for different wood replacement after pre-treatment with sodium-silicate (w/c = 0.44).....	67
Table 4.20: Penetration value of water in concrete for different wood replacement after pre-treatment with water w/c =0.5	68

Table 4.21: Penetration value of water in concrete for different wood replacement and different silica-fume replacement	69
Table 4.22: Penetration value of water in concrete for different wood replacement after pre-treatment with sodium-silicate.....	69
Table 4.23: RCPT results of concrete for different wood replacement after pre-treatment with water.....	70
Table 4.24: RCPT results of concrete for different wood replacement and different silica-fume replacement.....	71
Table 4.25: RCPT results of concrete for different wood replacement after pre-treatment with sodium-silicate.....	71
Table 4.26: Water Sorptivity test at different wood replacement level.	72
Table 4.27: Water Sorptivity test at different wood replacement level & different S.F.....	74

LIST OF ABBREVIATIONS

OPC	Ordinary Portland cement
GPa	Giga Pascal
MPa	Mega Pascal
F.A	Fine Aggregate
C.A	Course Aggregate
N	Newton
mm	Millimeter
ml	Milliliter
SS	Sodium Silicate
S.F	Silica Fume
CH	Calcium Hydroxide
CSH	Calcium Silicate Hydrate
w/c	Water/ Cement
min	Minutes
sec	Seconds

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Concrete is the greatest extensively used material in the world. Humans were using concrete in their pioneering architectural feats since 3000 BC. Egyptians used the initial forms of concrete to shape pyramids. They mixed grass and mud to form bricks and used lime and gypsum to make mortars. Greeks used the same material but as this material could easily dissolve in water, they added volcanic ash from the Pozzuoli town (that's how the term pozzolana came). Using this material they had made wonderful structures like the Colosseum, the largest stadium ever built or the Pantheon in Rome, the world's largest nonreinforced concrete dome that is still standing even after more than 2000 years of its construction. With the fading of the Roman Empire, concrete use became rare until the technology was redeveloped around the 1950s with the invention of Portland-cement, which is the essentially used in modern day concrete.

Concrete is employed in entirely altogether major and minor technology comes. The ingredients that are used for formation of concrete give sturdiness and strength to concrete. These constituents are sand, cement, aggregate, water in certain water-cement quantitative relation for higher performance of concrete. Usage of waste product (wood chipping) in situ of sand up to an exact amount with all alternative constituents transforms the properties of concrete. However, usually concrete could be a combined mixture of binding-material, filler-material & water that syndicates the entire mass. The main aim of concrete combine design is to achieve most sturdiness and compressive-strength with none compromise with the standard. Engineers and Scientists are more making an attempt to extend its boundaries with the assistance of ingenious chemical-admixtures and varied supplementary binding & filler-materials in conjunction with reformed producing techniques. Currently many technologies are employed in the sector of concrete technology that transforms concrete properties.

Rising population has created a crucial need for speeded housing and infrastructural development in developing countries like India. However the rising costs of construction material, diminishing material sources and environmental considerations have seriously affected

ability of both public and private organization to encounter this challenge. It has therefore become necessary to examine non-traditional sources of materials for use in civil engineering building. The usage of waste material like plastic waste, risk husk ash, and wood chipping in construction would facilitate to decrease concluded dependence on ancient materials like as cement, sand and crushed stones whose exploitation has caused in harmful environmental consequences.

Universally the wood industries turn out an oversized quantity of waste product. Wood is produced from milling, cutting and drilling actions once wood is scratch from either wood logs or whereas getting ready ended merchandise. Wood dirt is separate from wooden ash (i.e. the rest produced after the burning of timber and its goods) and it contains of terribly small particles generated throughout sanding or different machining operation, the physical and Chemical-properties of wood dirt differ considerably counting on several factors like topographic positions of the log that's consumed for wooden product and industrial processes. For instance, hardwoods unremarkably turn out lot of dirt than that of softwoods, and therefore the leaves and bark sometimes turn out a lot of wood powder than the inner element of the tree. In some cases, wood byproduct includes some extents of pollution and needs further process so as to fulfill finish market specifications that affects the choice for the likelihood to recycle the wood byproduct. The formation of energy from burning saw dust wood byproduct could bring about to challenges coupled to the Carbon-Dioxide generation and therefore the atmospheric phenomenon. An enormous amount of green housing gases may even be discharged throughout the storage of wood and wood chipped, notably if they decompose rapidly.

So it becomes significant for countries like India to consume the waste wood and prevent it from increasing the pollution in the counties. And engineers discover a solution for it by using wood saw dust in concrete as replacement of fine-aggregate and make the concrete light weight as well it would solve both the problems one replacement of natural sources which are exploiting day by day and second use of waste material so that we can protect the environment.

1.2 CONCRETE FORMED BY USING INDUSTRIAL WASTE AS REPLACEMENT

As we have seen in the past many researcher have tried different forms of manufacturing waste as replacement of fine-aggregate and they got success in these researches. The industrial waste like leftover Foundry sand, Copper Slag, Palm oil clinker, Fly Ash F class, Steel Slag,

plastic waste and Rice Husk are earlier recycled as partial-replacement of fine-aggregate and these unlike material possess or enhances different kinds of properties like some enhances the compressive-strength and other increases the durability of concrete and many more properties. And I have decided to replace wood chipping as partial-replacement of fine-aggregate so that we can see its feasibility as replacement and to get to know about its impact on various properties like compressive-strength, Split-Tensile-strength, Unit weight of Fresh concrete, workability of concrete and soaking up of water test.

1.3 KEY PARAMETER AND INGREDIENT USED

1.3.1 General

In this study an effort was made to use wood byproducts for creating lightweight concrete by exchanging natural-sand. And it is composed of cement, aggregate, sand, silica-fume, wood sawdust, Sodium-Silicate and water. The difference between concrete containing wood chipping and convectional concrete mix design is lies specifically in specific gravity of sand and the specific gravity of wood sawdust there is a lot of difference between their specific gravity and due to which the weight of concrete containing wood is very less as compare to convectional concrete. Convectional concrete has much denser matrix than a concrete containing wood. Optimizing the packing density of granular constitutes results in a dense matrix and thus improve both physical and durability properties.

1.3.2 Matrix

The matrix phase in concrete is specified to consist of free water, cement, supplementary cementations materials and the filler portion of the aggregates. The matrix, thus, consists of both chemically reactive and inert materials.

1.3.3 Particle Packing

Particle packing is a fundamental necessity for making good strength concrete. And the concrete made using wood makes more porous concrete due the spongy-quality shown by wood; therefore it is light in weight. Compatibility and acceptable flow in the fresh state of concrete is a big task concerning packing of the concrete, which could be solved with the introduction of large quantities of fine particles having the similar size as that cement which can be silica fume as shown in figure1.1.

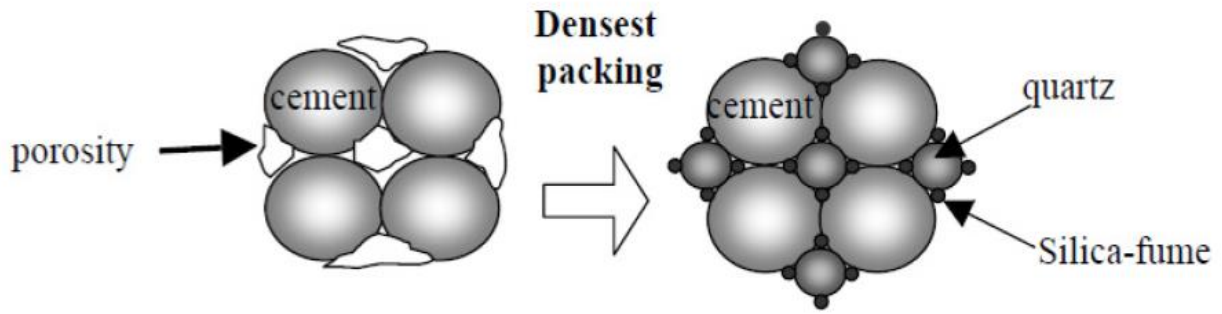


Figure 1.1: Particle packing

1.3.4 Cement

Cement could be a binder used for building that sets, solidifies, stick to other ingredients, and binds them along. Cement isn't used on its own, however in its place to bind natural-sand and gravel along. As per IS 456: 2000 (Clause 8.2.4.2) cement content in concrete mustn't exceed 450 kg/m³. Portland-cement is the commonest variety of cement usually used everywhere in the world as a basic element of concrete. It's a fine-powder, shaped by heating sedimentary rock and clay minerals in a very oven to make clinker, grinding the clinker, and adding two to three share of mineral. A bound kind of Portland-cement is out there, the foremost common, referred to as standard Portland-cement (OPC) and is gray in color. Its name is occupied from its resemblance to Portland-stone that was extracted on the Isle of Portland in Dorset, England. It absolutely was termed by Joseph Aspdin who gotten a patent for it in 1824.

The cement generally is categorized into three grades, namely 33 grade, 43 grade and 53 grade. And I have used grade 43 in my thesis. The chemical configuration of the ordinary Portland-cement is as follows:-

Table 1.1: Chemical composition of concrete
Chemical Configuration of Ordinary Portland-cement:

The main ingredients are :		
Lime	CaO	59-64%
Silica	SiO ₂	18-24%
Alumina	Al ₂ O ₃	02-07%

1.3.5 Coarse-Aggregate

Aggregate is that the constituent of a material that repels compressive stress and contributes to the greater part of the material. For effective filling, mixture must be a lot of smaller than the ended item; however has a large vary of sizes. For instance, the particles of stone wont to build concrete actually embrace each sand and gravel. Mixture commonly occupies around 70th to 80th of the amount of concrete and thus be expected to own a big impact on concrete's properties.

The nominal maximum size of aggregate would be as maximum as possible within the parameters defined but never greater than one-fourth part of the thickness of the member (*As per IS 456: 2000 (Clause 5.3.3)*). For maximum work, 20 mm aggregate is fit, wherever there is not any limit to the flow of concrete into section, 40 mm or greater size might be tolerable. In concrete components with tinny section, narrowly spread out reinforcement or minor cover, thought would be certain to the use of 10 mm nominal maximum size. Generally for regular works 60% of 20 mm size coarse-aggregate and 40% of 10 mm size coarse-aggregate are mixed together and then they are used.



20 mm Coarse Aggregate



10 mm Coarse Aggregate

Figure 1.2: Coarse-aggregate

1.3.6 Fine-Aggregate

Aggregate whose particle passes from 4.75 mm IS sieve is named as fine-aggregate s. Most regularly used fine-aggregate are natural-sand (quarry or sand of river, sea sand and sand of pit) and crushed-stone in powdered form.

1.3.6.1 Sand

It contains of minor angular or rounded particles of silica reliant upon the source from which it is obtained. It consists of following:-

(a) Pit or Quarry sand: - it is founded as deposited in soil and is to be dug out. And their particles are usually sharp or angular. It ought to be not containing organic matter and clay. It's usually measured to be the most effective fine-aggregate to be used in mortar and concrete.

(b) River sand: - it is generally founded from the beds of rivers. It could be fine or coarse. Fine sand gained from beds of rivers is often found mixed with silt and clay so it should be sweep away before use. But coarse sand is usually clean and wonderful for use particularly for plastering purposes.

(c) Sea Sand: - it comprises of fine rounded particles of brown color and it is taken from sea shores. Sea sand generally comprises salts and however using that in concrete and mortar causes breakdown (disintegration) of the work in which it is used. In R.C.C work these salts will attack reinforcement if salt percentage is high, this salt may cause efflorescence. It should be used locally after thorough washing.

1.3.6.2 Crushed-stone

It is gathered by devastating the waste stones of pits to the particular size of sand. Sand gathered by the crushing of a good quality stone is wonderful fine-aggregate . Mortar made with this sand is usually used in ashlar work (Good quality of work).

1.3.7 Timber Waste

Wood Saw dirt is also identified as wooden powder or wooden dirt. It is the byproduct of cutting, drilling, grinding and sanding of wood. It formed as a small irregular chips or small trash of wood during chopping of logs of wooden into different sizes. It can also be referred as the residue of certain insects, animals and birds that sleep in wood, like the pisiform bird and ant etc. The dimensions of wooden chipping atoms depends on the varieties of wood from which the wooden saw dirt is gained and additionally on the dimension of the saw teeth .About 15-20 % you look after the overall volume of the wood is reduced as waste produced.

1.3.7.1 Production of saw dust

Double waste items, dirt and chips, structure at the working surface during carpentry tasks, for instance, sawing, processing and sanding. These procedures both break lignified wood cells and break out entire cells and gatherings of cells. Breaking of wood cells makes dust, while breaking out of entire gatherings of wood cells makes chips. The more cell-breaking that happens, the better residue particles are framed. For instance, sawing and processing are blended cell breaking and chip making forms, while sanding is solely cell breaking.

1.3.7.2 Common uses of saw dust

A key use of wood waste is in particle-board; coarse-sawdust can be used for wood-pulp. Wooden saw dirt have a range of different sensible uses, comprising usage as the khaad, as a bio gas, or as an alternate to clay cat-litter. Till the arrival of refrigeration, it turned into frequently used in ice-houses to maintain ice-frozen all through summer. It's been used in innovative presentations, and as scatter in small rail-road and other fashions. It is also every so often used to soak up liquid spills, allowing the spill to be without problems accumulated or swept-aside. As such, it becomes formerly common on barroom floors. And wood noticed dirt may be used as fuel in winters which harms the environment badly.

1.3.7.3 Problems with timber waste

Timber waste has long been a hard problem for communal landfills and lumbering operations. Grinding it to reduce its volume is expensive and tremendously harmful to the environment; and while grinding reduces the volume you are still left with the same amount of timber waste. Usually, utilization of the waste wood saw dirt is now become the major concerns for the government and to the public as well because it's burning produce so much of pollutant which harm the human body and their lungs get affected very badly.

1.3.7.4 Raw material

The raw materials of wood chips may be softwood, waste-wood, and residual wood from agriculture, landscaping, logging and sawmills. Wood chips can even be made from residual biology materials together with tree crowns, branches and undersized trees. Biology operations offer the raw-materials required for woodchip production. Virtually any tree may

be regenerate into woodchips, but the shape and quality of the wood used to turn out woodchips depends totally on the market, For example Softwood species tend to be a lot of handy to be used as woodchips than hardwood species because they are less dense and quicker growing.



Figure 1.3: Formation of wood chipping

1.3.7.5 Properties of wood chipping

Physical and Chemical-properties of saw wood chipping are significant in finding their helpful uses, and vary significantly depending on many factors. These properties are influenced by species of tree, tree growing regions, conditions and methods.

1.3.7.5.1 Chemical properties

The saw dust comprise of chippings from several hardwoods and softwood. The sawdust is sieved through 4.75 mm.



Figure 1.4: Wood Chipping

Table 1.2: Chemical-properties of wood chipping

Sr.No.	Components	Percentage (By weight)
1	Silicon-dioxide (SiO ₂)	85
2	Aluminum oxide (Al ₂ O ₃)	2.45
3	Iron oxide (Fe ₂ O ₃)	2.02
4	Magnesium oxide (MgO)	0.23
5	Calcium oxide (CaO)	3.75
6	Loss of Ignition (LOI)	4.65

1.3.7.6 Advantages of using wood chipping as fine-aggregate

- It is used to form light weight structure.
- Advantage of wood chipped concrete is high strength to weight ratio.
- Better heat and sound insulation.
- Affect the cost in positive manner.

1.3.7.7 Disadvantages of using wood chipping as fine-aggregate

- It decreases the compressive and Split-tensile strength of concrete.
- Wood chipping needs a pretreatment before to be used in concrete.

1.3.8 Silica-Fume

Silica-fume is additionally mentioned to as small silicon-dioxide or condensed silicon-dioxide fume. It is formed from the residue from the manufacture of silicon and silicon-alloys. It includes of massive quantities of very fine-amorphous particle of silicon-dioxide (SiO₂) that usually makes up quite 90% of silicon-dioxide fume constituents. The fineness of silica-fume in forms of the specific-area whose range can be around 20000 m²/kg as compared with 400 m²/kg to 800 m²/kg for fly ash and 300m²/kg to 500m²/kg for ordinary Portland-cement. A classic silica-fume displays most particles smaller than that of 1 micron and they have a diameter of about 0.1 micron.

Fresh-concrete comprising of silica-fume is a lot of cohesive and fewer liable to segregation than concrete which does not have the silica-fume. Concrete comprising of

silica-fume displays significant less bleeding. The impact is produced principally by high extent of silica-fume to be wetted, free water left within the mixture for bleeding is very less. Moreover bleeding is reduced by silica-fume by physically blocking the voids which are present in the fresh-concrete. When silica-fume is used it doesn't affect the unit weight significantly.

Silica-fume has been acknowledged as a pozzolanic admixture that's effective in raising the mechanical properties to an excessive extent. With the help of silica-fume together with superplasticizer it's comparatively easier to achieve high compressive-strength within the laboratory.

Adding the silica-fume in the concrete will increase the durability of the concrete with the decrease of the porosity, and by advancing pore-structure which interns resulting in decrease the diffusion of harmful-ions, decreases lime content which ends up in a more resistant to the sulfate-attack. Development within the durability will enhance the flexibility of silica-fume concrete in defensive the embedded steel from corrosion.

Table 1.3: Chemical-composition of silica-fume

Constituents	Percent (%)
Silicon-dioxide(SiO ₂)	87-95
Aluminum-oxide(Al ₂ O ₃)	0.5-0.7
Magnesium-oxide(MgO)	0.6-1.5
Iron-oxide(Fe ₂ O ₃)	0.3-0.9
Calcium-oxide(CaO)	0.1-0.4
Sodium-oxide(Na ₂ O)	0.3-0.6
Potassium-oxide(K ₂ O)	0.3-1.2
Carbon (C)	0.4-1.3
Sulfur (S)	0.2-0.4

1.3.9 Sodium-Silicate

Sodium-Silicate is also recognized as liquid glass material or water glass material. IUPAC name of Sodium-Silicate is Sodium Meta-silicate. This material is existing in aqueous solution and in solid-form. The chemical composition of Sodium-Silicate is Na_2SiO_3 . The reaction between Sodium-Carbonate and Silicon-dioxide gives the product Sodium-Silicate along with Carbon-Dioxide.

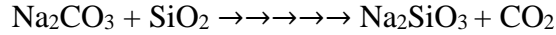


Table 1.4: Chemical-properties of liquid sodium-silicate

Liquid Sodium-Silicate (Grade 52)		
Property	Minimum	Maximum
Gravity(degree-Baume at 20°C)	51.5	52.5
Specific gravity (at 20°C)	1.551	1.568
Sodium-Monoxide(wt. % Na_2O)	13.60	14.20
Silica (wt.% SiO_2)	32.85	33.85
Total-Solids (wt. %)	46.45	48.05
Weight-Ratio ($\text{SiO}_2/ \text{Na}_2\text{O}$)	2.35	2.45
Viscosity (centipoise at 20 °C)	1375	2200

The Sodium-Silicate acts as the self-healing material due to their reaction with concrete. Sodium-Silicate reduces the mobility of water in cement. The Sodium-Silicate is readily available to react with Calcium-Hydroxide which is existing in the cement and forms Calcium-

Silicate-Hydroxide. It involves in increasing the hydration of cement, thereby High strength of concrete is achieved.it is the very quick reaction with Ca^{2+} that allows silicate to be used as a cement accelerator. Generally it is white in color.

Table1.5: Physical-properties of liquid sodium-silicate

Properties of Sodium-silicate	
Chemical-formula	Na_2SiO_3
Appearance	White-Opaque-Crystals
Density	2.61g/cm^3
Melting-Point	$1,088^\circ\text{C}(1,990^\circ\text{F})$
Solubility in Water	$22.2\text{g}/100\text{ml}(25^\circ\text{C})$ $160.6\text{g}/100\text{ml}(80^\circ\text{C})$
Solubility	Insoluble-in-alcohol
Refractive index (nD)	1.52

CHAPTER 2

LITERATURE REVIEW OF WOOD SAW DUST AS PARTIAL REPLACEMENT OF FINE-AGGREGATE

2.1 EFFECT OF WOOD CHIPING ON DIFFERENT PROPERTIES OF CONCRETE

Different researchers have studied different types of concrete with semi substitution of fine-aggregate. Some of the major studies of the behavior of concrete with saw dust chipping as semi replacement of fine-aggregate are explained below:

2.1.1 Workability

Mohammed et al. (2014) tested the workability of the concrete comprising saw dust as semi-replacement of fine-aggregate and slump test was conducted and the test shows the patterns of increase in workability as the substitution of the wood chipping goes on increasing and as the w/c ratio of concrete is increasing. The wood absorbs more water as compared to the sand. The reason behind the increase in workability is the property of wood to show the sponge-quality. The soaked surface dry-wood easily loses its water-content in the course of mixing thereby leading to rise in slump value.

Table 2.1: Slump test results (Mohammed et al., 2014)

w/c ratio	Saw dust replacement (%)	Slump
0.37	0	30
	10	110
	15	150
	20	180
	30	210
0.41	0	50
	10	135
	15	175

	20	210
	30	240
0.57	0	72
	10	175
	15	220
	20	245
	30	260

Kanna et al. (2018) found out the workability of concrete containing wood Saw dust at different substitution of fine-aggregate and observe that the workability of concrete increase as the substitution goes on increasing and the given the reason behind increasing is when wood absorbs the water it forms bulky kind of mixture which tends to increases the workability of concrete and second reason given was when wood absorbs the water it become bit fluffy and thus Slump-value increases.

Priya et al. (2018) reported the results of the workability test he reported that the workability goes on crumbling up to certain substitution and noted that it stars decreasing after particular replacement value. In his study he saw that the Slump-value increase up to 30% replacement of wood chipping as fine-aggregate after that the Slump-value stars get decreasing this is due to the factor when there is much wood it absorbs the extra water and make it bit stiff as a result the Slump-value decreases.

Table 2.2: Slump test results (Priya et al., 2018)

S.No.	Saw dust replacement (%)	Slump value
1.	0	75
2.	10	80
3.	20	86
4.	30	95
5.	40	86
6	50	83

Prasanna et al. (2017) they conducted the slump test for concrete and result of the workability tests same of that of the other researcher's studies i.e. increasing in workability with increase in the substitution of wood chipping to mixture. The maximum value of slump was 135mm for 15% replacement level as compare to that of conventional concrete which was 110mm the reason for increasing the workability is woods more water absorbing properties.

Oyedepo et al. (2014) tested the workability of the concrete containing wood as partial-substitution of fine-aggregate and slump test was conducted and he is the only person who says that the workability of concrete will drop first and then it will starts increasing after certain percentage of replacement and the results stated that up to 50% wood replacement of sand with a uniform mix at 0.65 w/c ratio the workability is showing the decreasing trend and reason given was due to rise in the surface-area as well as high soaking up of water of sawdust. And after this the rise in the Slump-value of the concrete mix at 75% and 100% sawdust substitution of sand is obtained reason for it was given as there a greater proportion of saw dirt in the mix tends to adhere collectively to form almost a uniform mix.

2.1.2 Density

Mohammed et al. (2014) conducted the density test of fresh-concrete and he shows the compactness of the fresh-concrete goes on decreasing as the wood replacement goes on increasing with fine-aggregate. The reduction in unit weight was because of specific gravity of wood chipping is considerable lesser as compare to that of specific gravity of sand.

Table 2.3: Density (Mohammed et al., 2014)

w/c ratio	Saw dust replacement (%)	Unit weight (kg/m ³)
0.37	0	1915.43
	10	1808.00
	15	1754.64
	20	1687.84
	30	1554.15
0.41	0	1889.96

	10	1733.99
	15	1649.64
	20	1562.11
	30	1402.16
0.57	0	1836.65
	10	1660.78
	15	1563.70
	20	1476.96
	30	1328.15

Suji. et al. (2016) done the unit weight test on fresh-concrete and he also displays that the compactness (unit-weight) of concrete reduce as the wood substitution goes on increasing and he displaced the same reason behind the decrease of unit weight that is the specific gravity of saw wood dust is considerable lesser as compare to that of sand used as fine-aggregate.

Ahmed et al. (2018) tested the compactness (unit-weight) of the concrete at different percentage of substitution of sand with saw wood and he shows that the results which interpret that the density decrease which also effect the weight of concrete as well as the thermal conductivity of concrete and thus it shows huge advantage in terms of replacement of fine-aggregate with saw dust.

Bederina et al. (2006) conducted the thermal conductivity test as well as the density test and he also shows the similar trend as that of the all previous researchers and he concluded that the density goes on decreasing in a parabolic manner and also stated that for a wood content of 100kg/m^3 the density is reduced by approximately 30%.

2.1.3 Compressive-Strength

Mohammed et al. (2014) reported the test results in which he replace the wood chipping 5%, 10%, 15%, 20%, 30% with the fine-aggregate at different-2 w/c ratio with specimens dimension 150 mm x 150 mm x 150 mm and stated the results that as the wood replacement goes on

increasing the compressive-strength of the concrete goes on decreasing and it can also be seen that as the w/c ratio decrease the compressive-strength increases and reason given was as wood saw dust causes a spongy-quality when they come in connection with water and can be compressed easily. And same is the reason for early crack-formation and week bonding of concrete.

Table 2.4: Compressive-strength (Mohammed et al., 2014)

w/c ratio	Wood-chipping replacement (%)	Compressive-strength cube (MPa)
0.37	0	50.45
	10	46.40
	15	39.67
	20	34.68
	30	31.61
0.41	0	47.28
	10	40.55
	15	35.16
	20	30.96
	30	26.48
0.57	0	42.92
	10	37.52
	15	29.86
	20	25.16
	30	23.32

Anandh et al. (2018) tested the sample to found out the compressive-strength of the concrete at 7 days 28 days he conducted his test to specimen dimension 100 x 100 x 100 mm sized cubes, he did for different replacement up to 20% with fine-aggregate and shows the same trend that the as the wood chipping content increase the compressive-strength decreases. The reason given was the concrete doesn't makes the proper bonding with other particles as wood's property of adhesion is less as compared to that of cohesion, which tends to harm the strength of concrete in very bad manner thus reduces it.

Table 2.5: Compressive-strength (Anandh et al., 2018)

S.No.	Saw dust replacement (%)	7 th day Compressive-strength (MPa)	28 th day Compressive-strength (MPa)
1.	0	19.73	30.1
2.	5	18.17	29.47
3.	10	16.2	25.9
4.	15	15.16	21.7
5.	20	12.57	18.47

Corinaldesi et al. (2016) has done the compressive test on the concrete contain wood shaving as replacement of the fine-aggregate and results were same as the previous researcher that the compressive-strength falls with surge in substitution of fine-aggregate in concrete the reason given was as there was a slightly lower volume mass of wood shaving than sand and second reason was due to the shape of the wood shaving particles which are flat and very thin and long shaped type of particles.

Ahmed et al. (2018) the testing was done for the specimen with or without the replacement of wood saw dirt as substitution of fine-aggregate in concrete at different time of curing. As expected the compressive-strength decrease as replacement increase and he is the only person who stated that the compressive-strength will also be effected by the quality of the saw dust if someone is using teak wood chipping will show more compressive-strength then the other types of wood. The reason he stated was saw dust particles are more porous and weaker than that of natural-sand that is the reason the compressive-strength of control concrete was results more than that of concrete containing wood saw dust.

Table 2.6: Compressive-strength (Ahmed et al., 2018)

S.No.	Saw dust Replacement (%)	28 th day Compressive-strength (MPa)
1.	0	40.1
2.	5	38.6
3.	10	36.5
4.	15	34.2

Coatanlem et al. (2006) tested the compressive-strength of concrete with partial-substitution of wood chipping and results were concluded that they shows the loss of compressive-strength as the replacement increase and the reasons he stated that wood contains much lesser silica content as compare to that of natural-sand and therefore it creates the binding problem in concrete and thus reduced in compressive-strength of concrete.

Narayanan et al. (2017) concluded that the compressive-strength of wood saw dirt up to 10% is nearly comparable to that of control mix. Weight of the saw-dirt concrete was lower than that of control concrete and also become more-economical and as the replacement goes increasing further the compressive-strength reduces drastically so he says that the optimizing substitution of sand with saw dust is up to 10% replacement.

Sawant et al. (2018) verified the compressive-strength of concrete at different substitution of fine-aggregate with wood chipping level from 5% to 25% and stated that there is decrease in the compressive-strength gradually. Still reasonable outcomes are gotten at 5% to 10% replacement. The reason given that water absorbs by wood tends to hydration of cement paste which governs the decrease in compressive-strength. And the outcomes are represented in the form of tables shown below. And in his studies he concluded that at the end of study the optimum percentage of replacement is 5%.

Table 2.7: Compressive-strength (Sawant et al., 2018)

Replacement level	Compressive-strength (N/mm ²)
Normal Mix	26.44
5	21.105
10	12.445
15	10.07
20	7.25
25	5.12

2.1.4 Split-tensile strength

Mohammed et al. (2014) reported the test results in which he replace the wood chipping 5%, 10%, 15%, 20%, 25% and 30% with the fine-aggregate at different-2 w/c ratio with specimens dimension 150mm x 300mm and stated the results that as the wood replacement surds to increase the Split-tensile strength of the concrete surds to decreasing and it can also be seen that as the w/c ratio decrease Split-tensile strength of the concrete goes on increases and reason given was as wood saw dust causes a spongy-quality when they come in connection with the water and can be compressed easily. And same is the reason for early crack-formation and week bonding of concrete.

Table 2.8: Split-tensile strength (Mohammed et al., 2014)

w/c ratio	Saw dust replacement (%)	Split-tensile -strength (MPa)
0.37	0	3.58
	10	3.26
	15	3.15
	20	3.04
	30	2.41
0.41	0	3.30
	10	2.91

	15	2.79
	20	2.59
	30	2.15
0.57	0	2.86
	10	2.65
	15	2.33
	20	2.16
	30	1.86

Ahmed et al. (2018) the testing was done for the specimen with or without the replacement of saw dirt as substitution of fine-aggregate in concrete at different time of curing. As expected the Split-tensile strength decrease as replacement increase and he is the only person who stated that the Split-tensile strength will also be effected by the quality of the saw dust if someone is using teak wood chipping will show more Split-tensile strength then the other types of wood. The reason he stated was saw dust particles are more porous and weaker than that of natural-sand therefore the Split-tensile strength of control concrete was obtained more as compared to the one containing wood saw dust.

Table 2.9: Split-tensile strength (Ahmed et al., 2018)

S.No.	Saw dust Replacement (%)	28 th day Split tensile strength(MPa)
1.	0	2.55
2.	5	2.32
3.	10	2.23
4.	15	1.90

Sawant et al. (2018) tested the Split-tensile strength of concrete at different substitution of fine-aggregate with wood chipping level from 5% to 25% and stated that here is drop in the Split-tensile strength progressively. Though reasonable outcomes are found at 5% to 10%

replacement. The reason given that water absorbs by wood tends to hydration of cement paste which governs the decrease in Split-tensile strength.

Table 2.10: Split-tensile strength (Sawant et al., 2018)

Replacement level (%) by weight	Split-tensile-strength
Nominal mix	4.33
5	3.53
10	2.02
15	1.13
20	1.07
25	0.91

Priya et al. (2018) conducted the test on different replacement of fine-aggregate with wood chipping from 0%, 10%, 20%, 30%, 40% and 50% and shows the results that the Split-tensile strength of concrete goes up upto 30 % replacement and then started decreasing and the reason he gave behind this is that water absorbs by wood tends to hydration of cement paste which governs the decrease in split-tensile-strength.

2.1.5 Flexure-Strength

Mohammed et al., 2014 reported the test results in which he replace the wood chipping 5%, 10%, 15%, 20%, 25% and 30% with the fine-aggregate at different-2 water-cement ratio. And stated the outcomes that as the wood replacement goes towards increasing the Flexure-strength of the concrete goes towards reducing and it can also be seen that as the w/c ratio decrease Flexure-strength of the concrete goes on increases and reason given was as wood saw dust causes a spongy-quality when they come in connection with the water and can be compressed without difficulty. And same is the reason for early crack-formation and week bonding of concrete.

Ahmed et al. (2018) the testing was done for the specimen with or without the replacement of sawdust as substitution of fine-aggregate in concrete at different time of curing. As expected the Flexure-strength decrease as replacement increase. He stated that the Flexure-strength will also be affected by the quality of the saw dust if someone using teak wood chipping will show more Flexure-strength then the other types of wood. The reason he stated was saw dust particles are more porous and weaker than that of natural-sand therefore the Flexure-strength of controller concrete was found more as equated to concrete containing wood saw dust.

Corinaldesi et al. (2016) done the Flexure-strength test on the concrete contain wood shaving as partial-substitution of the fine-aggregate and results displayed the Similar effect on flexural-strength as the outcomes for compressive-strength that is drop in the Flexure-strength with increase in substitution of fine-aggregate in concrete the reason given was as there was a marginally lesser volume mass of wood shaving than sand and second reason was due to the shape of the wood shaving particles which are flat and very thin and long shaped type of particles.

Sawant et al. (2018) tested the Flexure-strength of concrete at different substitution of fine-aggregate with wood chipping level from 5% to 25% and stated that there is rise in the Flexure-strength at 5% replacement and after that the Flexure-strength increase at 10% after furthermore replacement the Flexure-strength goes on decreasing. However bit reasonable outcomes are obtained at 10% replacement. The reason given that water absorbs by wood tends to hydration of cement paste which governs the decrease in compressive-strength.so according to him the optimum percentage of replacement is 10%.

2.1.6 Elastic Modulus

Mohammed et al. (2014) reported the test results in which he replace the wood chipping 5%, 10%, 15%, 20%, 25% and 30% with the fine-aggregate at different-2 w/c ratio and stated the results that as the wood replacement surds on increasing the Elastic modulus of the concrete surds on decreasing and it can also be seen that as the w/c ratio decrease the Modulus of flexibility increases and reason given was as wood saw dust causes a spongy-quality when they come in contact with the water and can be compressed without difficulty. And same is the reason for early crack-formation and week bonding of concrete.

Table 2.11: Modulus of flexibility (Mohammed et al., 2014)

w/c ratio	Saw dust Replacement (%)	Static-modulus of elasticity (GPa)
0.37	0	22.59
	10	19.99
	15	18.38
	20	17.37
	30	14.26
0.41	0	18.58
	10	16.04
	15	14.27
	20	13.40
	30	10.34
0.57	0	15.23
	10	12.73
	15	10.72
	20	9.58
	30	7.16

Ahmed et al. (2018) the testing was done for the specimen with or without the replacement of sawdust as substitution of fine-aggregate in concrete at different time of curing. As expected the Modulus of flexibility decrease as replacement increase The reason he stated was saw dust particles are more porous and weaker than that of natural-sand therefore the Modulus of control concrete was found more than that of concrete containing wood saw dust.

Table 2.12: Modulus of flexibility (Ahmed et al., 2018)

S.No.	Saw dust Replacement (%)	Modulus of Elasticity (MPa)
1.	0	21.87
2.	5	16.56
3.	10	14.03
4.	15	9.56

CHAPTER 3

EXPERIMENTAL PROGRAM

3.1 PRELIMINARY TESTING

The preliminary testing comprises the testing of the materials to be used in casting of the samples. This included the tests on cement, fine-aggregate, coarse-aggregate, wood chipping, sodium-silicate, silica-fume and examining the properties of material used in the casting work.

3.2 MATERIALS AND THEIR PROPERTIES

The different properties like soaking up of water, specific gravity and sieve size analysis of the cement, fine-aggregate, coarse-aggregate, wood dust, silica-fume and Sodium-Silicate were investigated before using them in the casting so as to ensure any change in the test results due to these properties. The material and the results of their properties investigated are as shown below:

3.2.1 Fine Aggregate

The sand with extreme size of aggregate of 4.75mm was used as fine-aggregate in the concrete. The fine-aggregate were tested as per Indian-Standard-Specification BIS: 383-1970. The properties of the fine-aggregate such as sieve size analysis are compared with those of standard recommendations as per BIS: 383-1970. The Physical-properties and sieve-analysis of fine-aggregate is given below:



Figure 3.1: Fine-aggregate (sand)

Table 3.1: Physical-properties of fine-aggregate

Name of Property	Observed Value
Maximum size of aggregate	4.75 mm
Specific Gravity	2.60
Net Soaking up of water	0.80
Fineness Modulus	2.51
Grade of Sand	Grade II

Table 3.2: Sieve analysis of fine-aggregate

TOTAL MASS TAKEN		800gm		
Sieve No.	Mass retained (gm)	Percentage retained (%)	Passing (%)	Cumulative retained (%)
4.75	00	00	100	00
2.36	101	12.625	87.375	12.625
1.18	171	21.375	78.625	34
600	68	8.5	91.5	42.5
300	200	25	75	67.5
150	217	27.125	72.875	94.625
Pan	43	5.375	94.625	100
				$\Sigma\%$ Retained =251.25

Fineness-Modulus = $251.25/100 = 2.51$

3.2.2 Coarse-Aggregate

Coarse-aggregate with maximum nominal size of 20mm and 4.75 mm retaining are used in study. The Physical-properties of the used coarse-aggregate were tested and the results are shown as below:

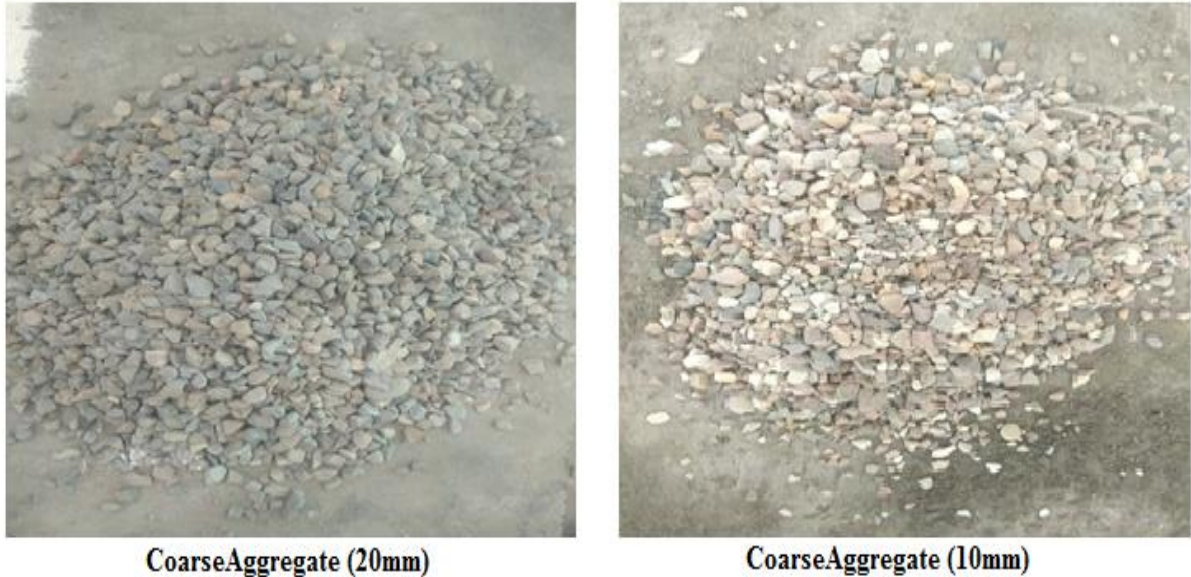


Figure 3.2: Coarse-aggregate

Table 3.3: Physical-properties of coarse-aggregate

Name of Property	Observed Value
Maximum size of aggregate	20mm
Specific Gravity	2.68
Net Soaking up of water	0.85
Fineness Modulus	7.18

Table 3.4 Sieve-analysis of coarse-aggregate (20mm)

IS Sieve	Mass retained (gm)	Mass retained (%)	Cumulative retained (%)	Passing (%)
20 mm	600	20	20	80
10 mm	2370	79	99	21
4.75 mm	15	0.5	99.5	99.9995
Pan	15	0.5	100	99.9995
			$\Sigma\%$ Retained =218.5	

Weight of the sample taken = 3000 g

Fineness-Modulus = $(218.5 \times 500) / 100 = 7.18$

Table 3.5: Sieve-analysis of coarse-aggregate (10 mm)

IS Sieve	Mass-retained (gm)	Mass-retained (%)	Cumulative retained (%)	Passing retained (%)
20 mm	0	0	0	100
10 mm	389	19.45	19.45	80.55
4.75 mm	1435.5	71.775	91.225	8.775
Pan	175.5	8.775	100	0
			$\Sigma\%$ Retained =110.675	

Weight of the sample taken = 2000 g

Fineness-Modulus = $(110.675 \times 500) / 100 = 6.10$

3.2.3 Cement

Cement is the one of the best binding material used in concrete. Different -2 grades of cement are present in market they are according to the strength. The properties of the cement investigated were Specific-Gravity, initial setting time, consistency etc. The below table gives the results of the properties and their obtained value:

Table 3.6: Properties of the cement

Name of the Property	Result
Grade of Cement	OPC 43
Specific Gravity	3.15
Initial-Setting Time (min)	112
Consistency of Standard Cement paste (%)	28
Final-Setting Time (min)	281

3.2.4 Wood Chipping

Wood Saw dirt is also known as wooden powder or wooden-dirt. It is the byproduct of drilling, cutting, grinding and sanding of wood. It formed as a small irregular chips or small trash of wood during chopping of logs of wooden into different sizes. It is also the byproduct residue of certain insects, animals and birds that sleep in wood, like the pisiform bird and ant etc. And different test are done on wood chipping that are shown in figure 3.3.



Figure 3.3: Wood chipping

Table 3.7: Physical-properties of wood chipping

Name of Property	Observed Value
Maximum size of aggregate	4.75 mm
Specific Gravity	0.288
Fineness Modulus	3.29

Table 3.8: Sieve-analysis of saw wood dust

TOTAL MASS TAKEN		200 gm.		
Sieve-No.	Mass-retained (gm.)	Percentage-retained (%)	Passing (%)	Cumulative retained (%)
4.75	00	00	100	00
2.36	39	19.5	81	19.5
1.18	59.5	29.75	70.25	49.25
600	50	25	75	74.25
300	32	16	84	90.25
150	12.5	6.25	93.75	96.5
Pan	7	3.5	96.5	100
				$\Sigma\%$ Retained = 329.75

Weight of the sample taken = 200gm.

Fineness-Modulus = $329.5/100 = 3.29$



Figure 3.4: Sieve-analysis of wood chipping

3.2.5 Silica-Fume

Silica-fume was obtained from Haryana ceramics Pvt. Ltd., Ambala city. The physical and chemical-properties of silica-fume as providing by the supplier are represented in Table 3.9 and Table 3.10 respectively.

Table 3.9: Physical-properties of silica-fume provided by the supplier

Characteristics	value
color	white
Specific-Gravity	2.25
Dv (50)	16.209 μm

Table 3.10: Chemical-properties of silica-fume provided by the supplier

SiO ₂	MgO	SO ₃	H ₂ O	K ₂ O	Na ₂ O	CaO	Si	Cl	Fe ₂ O ₃
92.25%	<1.5%	<1.1%	<0.4%	<2.25 %	<1.4%	<0.35 %	<0.5%	<0.06 %	<2%

3.2.6 Sodium-Silicate

Sodium-Silicate is also recognized as liquid glass material or water glass material. IUPAC name of Sodium-Silicate is Sodium Meta-silicate. This material is existing in aqueous solution and in solid-form. The chemical composition of Sodium-Silicate is Na₂SiO₃. The reaction between Sodium-Carbonate and Silicon-dioxide gives the product Sodium-Silicate along with Carbon-Dioxide.

Table 3.11: Chemical-properties of sodium-silicate (Grade 52) provided by the supplier.

Liquid-Sodium-Silicate (Grade 52)		
Property	Minimum	Maximum
Gravity(degree Baume at 20°C)	51.5	52.5

Specific gravity (at 20°C)	1.551	1.568
Sodium-Monoxide(wt.% Na ₂ O)	13.60	14.20
Silica (wt.% SiO ₂)	32.85	33.85
Total-Solids (wt.%)	46.45	48.05
Weight-Ratio (SiO ₂ / Na ₂ O)	2.35	2.45
Viscosity (centipoise at 20 °C)	1375	2200

3.3. PREPARATION OF MATERIAL FOR CASTING

3.3.1 Mix-Design as per IS 10262:2009

The concrete mix-design is conceded for a particular compressive-strength of concrete to achieve acceptable amount of workability so that the concrete can be easily transported, placed and compacted. The concrete mix-design as per Indian Standards IS: 10262-2009 is done for the casting of the specimens for different tests to be performed. The mix-design is done for M25 grade of concrete. The preliminary data of the constituent materials required for the mix design of concrete is found out as stated above. The amounts of the material required per-cubic meter volume of concrete are found out and the quantities per batch of the concrete were calculated by multiplying the calculated data with the batch volume. And the different materials quantities are calculated. The quantities of the materials required per cubic meter of concrete are as given below in the table:

M25 Mix Design Data:-

Characteristic Compressive-strength at 28 Days = 25 N/mm²

Maximum size of aggregate = 20mm

Type of Exposure = Mild

Concrete-Use = Concrete Structure

Table 3.12: Mix proportion M25

Name of the Material	Quantity (kg/m ³)
Cement	448
Fine-aggregate	796
Coarse-aggregate	944
Water	197
w/c ratio	0.44

Mix-Composition

The control mixtures with constant amount of cement content, fine and coarse-aggregate content were made to achieve maximum 28 days compressive-strength of 29.96 MPa. And to find out optimum content of wood chipping without compromising this strength different attempt were made which are described below:

Attempt First :- In the mix proportion of the different mixes, the content of fine-aggregate was varied with wood chipping in proportion of 0%, 5% and 10% replacement level without any pretreatment and at w/c ratio of 0.5 then it was seen that the strength of the concrete was decreased drastically therefore we found out other method for its usage.

Attempt Second: - In the mix proportion of the different mixes, the content of fine-aggregate was varied with wood chipping in proportion of 0%, 5%, 10%, 15% and 20% replacement level after pretreatment with the water for 24hours at w/c ratio 0.5 then it was seen that the strength of the concrete was decreased but not as much as it was in the mixture without pretreatment therefore to overcome the strength barrier we found out other method to use the wood chipping.

Attempt Third: - To overcome the decreased strength we have changed the w/c ratio of mixture from 0.5 to 0.44 and again the content of fine-aggregate was varied with wood chipping in proportion of 0%, 5% and 10% replacement level and the strength was still not up to the mark the we think of the other alternative and made one more attempt.

Attempt Fourth: - To achieve the desire strength we varied the content of fine-aggregate with wood chipping at 5% replacement level and also we varied the cement content with silica-

fume at different percentage level as 4%, 8% and 12% at w/c ratio of 0.44 and the results we good but still we thing there is a scope of improvement the we make a last attempt.

Attempt Fifth: - In this we varied the content of fine-aggregate with wood chipping in proportion of 0%, 5% and 10% replacement level with pretreatment with Sodium-Silicate of grade 52 and further treat that sample with water at w/c ratio of 0.44 and the results were good and can be justified.

Table 3.13: Concrete mix proportions

Mix No.	Cement (kg/m ³)	Fine-aggregate (kg/m ³)	Saw-dust (kg/m ³)	Coarse-aggregate (kg/m ³)	w/c ratio	Water (kg/m ³)
control	394	818	00	970	0.5	197
SD 5	394	777	41	970	0.5	197
SD 10	394	736	82	970	0.5	197
control	394	818	00	970	0.5	197
SD 5	394	777	41	970	0.5	197
SD 10	394	736	82	970	0.5	197
SD 15	394	695	123	970	0.5	197
SD 20	394	654	164	970	0.5	197
control	448	796	00	944	0.44	197
SD 5	448	756	40	944	0.44	197
SD 10	448	716	80	944	0.44	197
control	448	796	00	944	0.44	197
SD 5 and 4 SF	430	756	40	944	0.44	197
SD 5 and 8 SF	412	756	40	944	0.44	197

SD 5 and 12 SF	394	756	40	944	0.44	197
SD 5 and SS	448	756	40	944	0.44	197
SD 10 and SS	448	716	80	944	0.44	197

3.3.1.1 Process of formation of wood chipping

Step First :- First of all the raw material was collected from the local wood factories or wood shops and in this raw material the different size of the particles of the wood are present and which are larger than the size of the natural occurring sand.



Figure 3.5: Raw material of wood chipping

Step Second: - Now as we can see the size of the particle of raw material is different in shape and size and 50% of the quantity is greater than 4.75mm so to replace the saw dust with the fine-aggregate we need to sieve the material so that it can gain size of sand and properties of saw dust and thus replacement can be achieved.



Figure 3.6: Sieving of raw material from 4.75mm sieve

Step Third: - After sieving the material we have to treat it with water so that it can't affect the process of hydration of cement when used in concrete and so that it can absorb the water that is required for it to have the maximum strength and workability. The treatment process is done for 24 hours before it can be used in concrete and for the pretreatment the ratio of the quantity of saw dust and water is 1/10 means 1000gm of water is required for 100gm of wood dust.



Figure 3.7: Pre-treatment of saw dust with water

Step Fourth: - After pretreatment the excess water is removed from the wood chipping and it can be used in casting the specimen with partial-replacement of the fine-aggregate at different percentage replacement level.

3.3.2 Casting And Curing of Samples

In this unit the setup used for obtaining different test on concrete are discussed below the tests will be discussed are Workability, Density test for fresh concrete, compressive-strength, split-tensile-strength, sorptivity, permeability and Rapid-Chloride-Permeability-Test.

The specimens of different sizes were casted as per the requirements of the testing methodology. The casting of the specimens involved the weighing of the materials, dry mixing of the constituent materials i.e. cement, fine-aggregate, coarse-aggregate, saw dust and silica-fume and then water was added to the dry mix. The type of mixing was obtained was machine mixing. The mould was properly oiled before pouring the concrete mix into them. The top surface of the samples was removed off to obtain the smooth surface finishing. The samples were taken out from the mould after the completion of 24 hours. And then they were then placed into the curing tank for 7, 28, 56 days. The surface of the specimens taken out from the curing tank was wiped off with cloth before testing. The description of the type and size of the specimens is as given in table 3.14:

Table 3.14: Specimens description

Name of the test	Type of specimen	Size of Specimen (mm)
Compressive-strength	Cube	150 x 150 x 150
Split-tensile-strength	Cylinder	300 x 150 (L x D)
Permeability Test	Cube	150 x 150 x 150
Sorptivity	Cylinder	50 x 100 (L x D)
RCPT	Cylinder	50 x 100 (L x D)

3.3.3 Testing Program

The different tests performed on the casted specimens and standards followed for the testing procedure are as given below:

Table 3.15: Tests and Codes

TEST	CODE
Compressive-strength	BIS 516-1959
Split-tensile-strength	IS 5816-1999
Penetration Test	DIN 1048 Part 5
Sorptivity	ASTM C1585-2004
RCPT	ASTM C 1202-12

The above tests were performed at different-curing periods i.e. 7, 28, 56 days of curing.

3.3.3.1. Workability

Workability of the concrete refers as the ease by which the concrete can be mixed, transported and placed in the specimen at any given place after mixing of all the elements of the concrete. While selecting the suitable concrete for any work workability of concrete plays a very important and vital role. The workability of the concrete depends upon the surface-area of the elements of the concrete like aggregate area; shape and size of the aggregate, smooth and rounded aggregate will possess more workable concrete and it also depends upon the water-content in the concrete as well as the w/c ratio of the concrete. The amount of workability of concrete required depends upon the type of the concreting work undertaken. For general works the Slump-value up to 50mm is sufficient but for pumping of concrete at a height, larger amount of slum value is required that is 75 to 100mm.

The workability of the concrete can be raised by raising the w/c ratio which in turn may result in the decreased strength of the concrete. To increase the workability of the concrete without increasing the water content, certain chemical compounds or mineral admixtures are added into the concrete to attain the desired workability which is known as the super plasticizers. The Figure 3.8 shows the slum value of concrete.



Figure 3.8: Slump-value of concrete

3.3.3.2 Density test for fresh concrete

Casting: - To calculate the density of fresh-concrete a cylinder is used whose dimension is 17cm height and 15cm diameter. As we know Compactness (unit-weight) of the concrete is calculated by dividing the weight of the fresh-concrete to the volume of the concrete. After casting the concrete the concrete is poured in the cylinder in three layers with 25 blows in each layer and the weight of the cylinder is measured and noted as W1. Now the concrete is taken out and weight of the empty cylinder is measured and noted it as W2. Then the weight of concrete is measured by subtracting $W1 - W2$. And volume of the cylinder is measured and noted as V. Then to calculate the density these two are divided.

$$\text{Density} = \frac{\text{Weight of the concrete}(W1-W2)}{\text{Volume of the concrete (V)}}$$



Figure 3.9: Density of fresh concrete

3.3.3.3 Compressive-strength of concrete

Casting: - The three cubes of size 150 x 150 x 150 mm were casted for 1 replacement level to check the compressive-strength of concrete. The quantities of the different materials like coarse-aggregate, fine-aggregate, cement, silica-fume and wood chipping were weighted independently. And then all are put in the mixer and the dry mixing is done for 1 to 2 minutes after that the 50 to 70% of the water was added to the mixture and then it is allowed to mixed for 2 to 3 minutes and then the remaining water were added in the mixture and mixture get started the process is allowed going for further 2 to 3 minutes. Before pouring the prepared concrete in the cube the cube were oiled properly and then the concrete is filled in the cubes. After filling the cubes to remove the voids and to get maximum compaction the vibrating machines is used and cubes are filled properly. After casting the specimen are kept indoor for 24 hours. Next day the specimens are taken out from the mould and the specimen are kept in curing tank for 7day, 28days and 56days compressive-strength test



Figure 3.10: Casting of cubes of concrete

Testing: - The compressive-strength of concrete is tested on the Compression-testing-machine (CTM) whose load carrying capacity 5000 KN and it gives us the maximum compressive load taken by concrete cube before failure. The compressive-strength is finding out by dividing the maximum compressive load with average cross section area. Cube sample of size 150 mm were casted and tested for compressive-strength as per Indian-standard-specifications of IS: 516-1959. On the day of the testing the sample are carried from the curing tank and kept outside for about 30 to 60 minutes. Then the samples are placed in between the two plates of Compression-testing-machine (CTM). Before placement of samples the plates should be cleaned thoroughly so that the load can be distributed evenly. The face which was at the top side during the casting is placed in the machine as front face according to IS: 516 -1959. Then the test is

done at the loading rate of 5 kN/s as per IS: 516 -1959. Then the failure load is taken from the machine.



Figure 3.11: Compressive-strength of cube

3.3.3.4 Split-tensile-strength

Casting: - The three cylinders of size 150 x 300 mm were casted for 1 replacement level to check the Split-tensile strength of concrete. The quantities of the different materials like coarse-aggregate, fine-aggregate, cement, silica-fume and wood chipping were weighted separately. And then all are put in the mixer and the dry mixing is done for 1 to 2 minutes after that the 50 to 70% of the water was added to the mixture and then it is allowed to mixed for 2 to 3 minutes and then the remaining water were added in the mixture and mixture get started the process is allowed going for further 2 to 3 minutes. Before pouring the prepared concrete in the cylinder the cylinder were oiled properly and then the concrete is filled in the cylinders. After filling the cylinders to remove the voids and to get maximum compaction the vibrating machines is used and cylinder are filled properly. After casting the specimen are kept indoor for 24 hours. Next day the samples are removed from the mould and the samples are kept in curing tank for 7day, 28days and 56days Split-tensile strength test.

Testing: - The Split-tensile strength of concrete is tested on the Compression-testing-machine (CTM) whose load carrying capacity 5000 KN. The load was applied along the length of the cylindrical sample till failure. The rate of loading should lie between 1.2 to 2.4 N/mm²/min as

per IS: 5816 (1999) it gives us the maximum compressive load taken by concrete cylinder before failure. On the day of the testing the sample are carried from the curing tank and they were kept outside for around 30 to 60 minutes. Then the samples are placed in between the two plates of Compression-testing-machine (CTM) Before placement of samples the plates should be cleaned thoroughly so that the load can be distributed evenly. Then the failure load is taken from the machine. The Split-tensile strength was measured using the formula:

$$T = (2P/\pi DL)$$

Where T = Split-tensile strength of concrete in MPa

P = Maximum-applied-load as indicated by the machine in KN

D = Diameter of the cylindrical-specimen in 'm'

L = Length of the cylindrical-specimen in 'm'



Figure 3.12: Split-tensile strength of cylinder

3.3.3.5 Durability-test

Durability of the concrete can be defined as the resistance of the concrete to weathering action and chemical-attack during its design life. And the Durability of concrete depends on the easiness with which the fluid can move through it. Concrete which act more resistive to the movement of fluid termed as the durable concrete. The durability of the concrete can be tested by sorptivity, permeability and Rapid-Chloride-Permeability-Test.

3.3.3.5.1 Water-sorptivity-test

Casting: - For sorptivity test, the cylinder of size 100 x 200 mm were casted and then they are cured in the tank for 7 and 28 days. After that the sample are need to cut down in size 100 (diameter) x 50mm (length) as described in the ASTM C1585-04. Now the samples are placed in environmental compartment at temperature 50°C and relative humidity of 75 % for 3 days. After that, the samples were stored in a container for 15 days. Then side surfaces of the sample are coated with help of epoxy and the rest surface which is exposed to air is sealed with the tape as shown in Figure 3.13.



Figure 3.13: 100 mm x 50 mm cylinder A and Epoxy coated sample B

Testing: - The surface which is left free earlier is now exposed to the water. The concrete specimens are placed in the water up to depth of 1 to 3mm from the top of the supporting sticks placed in the pan as shown in Figure 3.14. The specimens were placed on the supports along with that stopwatch was started. The mass of the specimen was recorded at the time intervals as given in Table 3.16. At each measurement, wiping out any surface water was done with a dampened cloth. After taking a measurement, place back the specimen at the supports. The process is repeated for 7 days at interval shown in the code.

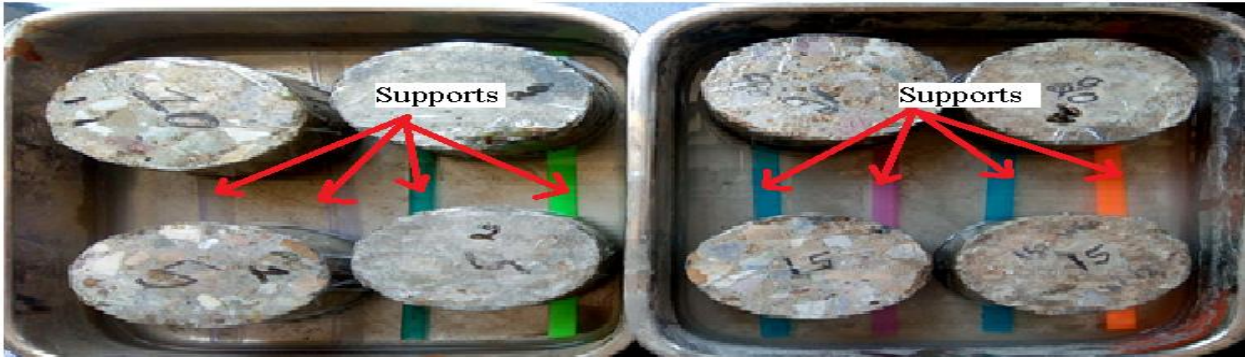


Figure 3.14: Sorptivity test arrangement.

Table 3.16: Time and tolerances for the measurements of the mass of the specimen (ASTM C1585 – 04).

Time	Tolerance in time
60-seconds	2-seconds
5-minutes	10-seconds
10-minutes	2-minutes
20-minutes	2-minutes
30-minutes	2-minutes
60-minutes	2-minutes
Every hour up to 6-hours	5-minutes
Once a day up to 3-days	2-hours
Day 4 to 7, three measurements 24-hours apart	2-hours
Day 7 to 9, one measurement	2-hours

3.3.3.5.2. Water penetration test

Casting: - For water penetration test the sample prepared is cube of standard size that is 150 x 150 x 150mm are required after casting of the cubes they are kept for curing for 28days in the curing tanks and on the day of testing they are taken out from the tank as rested for 30 to 60 minute.

Testing: - The sample is put in the water penetration test assembly, three cubes can be tested in one go. Once the sample is placed in the test cells, the hydrostatic pressure required to be maintained at 5 kg/cm² and the same pressure is maintained continually for 72 hours.



Figure 3.15: Water penetration test

After 72 hours the sample is taken out from the assembly and placed in the UTM and split into two parts by applying point load through two iron rods in the middle of the sample placed above and below as shown in the Figure 3.16 and the depth of penetration of water is measured with the help of a scale. Also the drop in the level of water in the water tube of the penetration apparatus is calculated.



(A) Sample Broken from Middle



(B) Penetration value

Figure 3.16: Water penetrated sample

3.3.3.5.3. Rapid-Chloride-Permeability-Test

Casting: - For Rapid chloride permeability check, the cylinder of size one hundred x two hundred millimeter samples were casted. And after the casting of the samples they are remained in a curing tank and cured within tank for 7 and 28 days. After that these samples are impeded in size 100 Diameter and 50mm Length as per the code ASTM C1202-12. Concrete starts Swelling 2 to 2.5 times in chloride-ion-penetration as compared to that with water penetration. Consequently test gives the estimation of electrical conductance of concrete and gives the value of resistance against chloride ion penetration. The table 3.17 shows the chloride-ion-penetration on the bases of charge passed in the concrete samples. This test gives the quantity of the electric current passed with in the concrete slice of 2-in. (50mm) thick slices of 4-in. (100 mm) nominal diameter cylinders for a time period of 6 hour. One surface of the sample is dipped in a sodium chloride solution and other surface of sample is immersed in a sodium hydroxide solution. And a potential difference of 60 VDC was kept across the ends of the samples. The total charge passed, in coulombs, was related to the resistance of the specimen to chloride ion penetration.

Table 3.17 Chloride ion penetrability based on the charge passed (ASTM 1202)

Charge passed (Coulomb)	Chloride Ion Penetrability
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very Low
<100	Negligible

Testing: -Before putting the samples into the RCPT arrangement the Specimens were placed in the vacuum desiccator's bowl shown in Figure 3.17 and the vacuum was upheld in the desiccators bowl for Three hours for the removal of air from the samples. It was done therefore that it totally shelters the samples and not any air was permitted to enter. And then the vacuum was again continued for extra one hour. Then these samples were kept in the gasket to infuse water for further 18 hours. The samples are collected from the desiccator, and then they are dried out and sited in gasket. After that the samples are wiped with towel and put in the arrangement of the R.C.P.T.



Figure 3.17: Vacuum desiccator bowl

The liquids (3% sodium chloride and 0.3% sodium hydroxide solutions) were filled in the two cells. And after that the Power supply of 60V is set up, and first present reading was noted. Temperatures of the sample and solutions were maintained at 20 to 25°C at the time of the test was started (when the power supply was turned on). The values for the current were noted after 6hour duration of the test.



Figure 3.18: Full arrangement of R.C.P.T

3.3.3.5.4 Scanning Electron Microscope (SEM)

SEM is a very important test for the study of concrete element in at microscopic level. This test is conducted to analyze composition (wood-chipping, natural-sand, CSH gel, calcium hydroxide and cement) topography and the morphology of the concrete at different magnification. We have conducted this test at 5 different magnification level for knowing the clear idea of both bigger size particle as well as the smaller size particle. This test is done with the help of Energy Dispersive spectroscopy.

A size of nearly 6 to 8 mm square and 2 to 3 mm thick sample was used for analyzing SEM's properties. To increase the signal of the image, coating of gold has been done on the sample which can conduct the electricity through it.

In this study we have taken the 4 types of samples for determining the microscopic properties of the concrete contain saw wood dust as the partial substitution of fine- aggregate. And the 4 different Combinations are First 5% replacement of wood-chipping at 0.44 w/c ratio after pretreatment with water. Second 10% replacement of wood-chipping at 0.44 w/c ratio after pretreatment with water. Third 5% replacement of wood-chipping at 0.44 w/c ratio and 12% substitution of cement with silica-fume. Fourth and last one 5% substitution of wood-chipping at 0.44 w/c ratio after pretreatment with sodium-silicate.

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter will show the outcomes and the reasons why these results are coming. Different tests are conducted on different sample with different shapes and sizes. And different properties like fresh, durable and hardened properties of concrete are found out and their results are discussed below.

4.1 FRESH-PROPERTIES OF CONCRETE RESULTS

Fresh-properties tests are conducted when the concrete is in the form of paste before the initial setting of the concrete. In this study I have conducted two Fresh-properties test on the concrete. One is the workability (easy of mixing) of the concrete and the second one is the Density (unit weight) of fresh concrete.

4.1.1 Workability

The workability (easy of mixing) of the different concrete mixes at different level of fine-aggregate replacement with the wood chipping after pretreatment with water at dissimilar water-cement ratios were tested and the outcomes of w/c ratio 0.5 are displayed in the table number 4.1.

Table 4.1: Slump-value for different wood replacement after pre-treatment with water w/c=0.5

Different wood replacement (%)	Slump-value (mm)
0	88
5	97
10	105
15	113
20	126

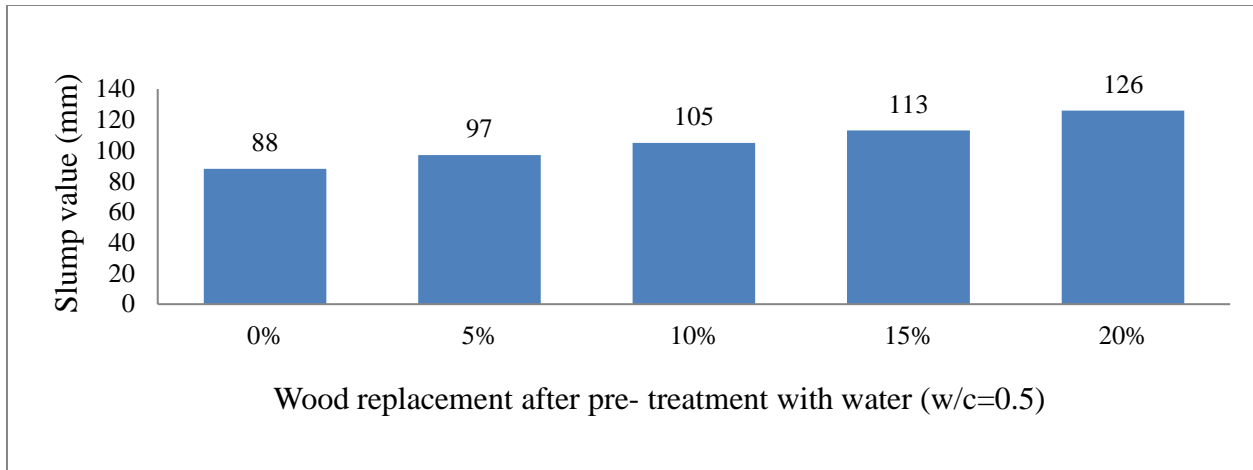


Figure 4.1: Workability of wood replacement after pre-treatment

The results of wood replacement at w/c ratio 0.44 are displayed in the table number 4.2.

Table 4.2: Slump-value for different wood replacement after pre-treatment with water w/c=0.44

Different wood replacement (%)	Slump-value (mm)
0	84
5	92
10	103

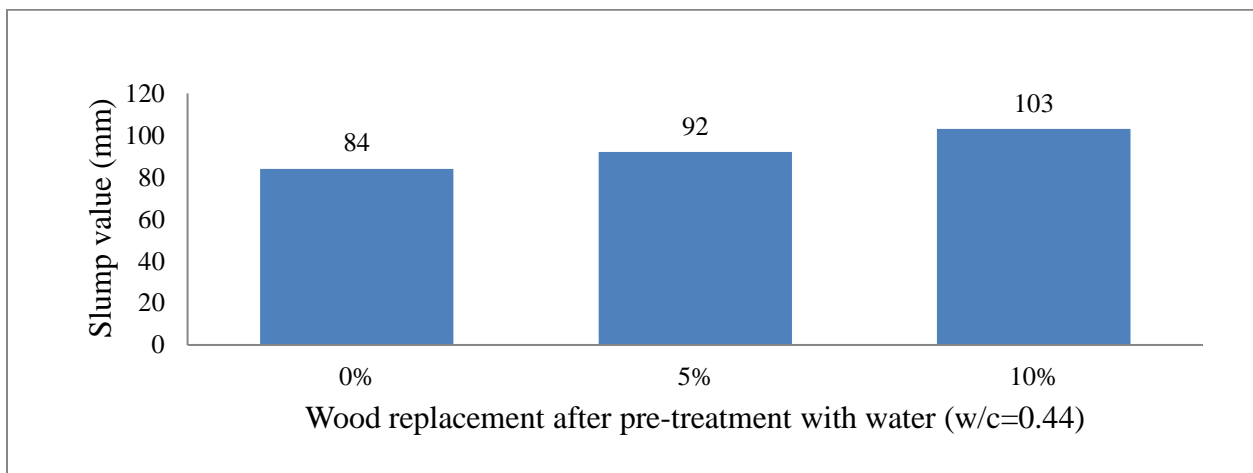


Figure 4.2: Workability of wood replacement after pre-treatment

The workability (easy of mixing) of the different concrete mixes at different level of fine- aggregate replacement with the wood chipping after pretreatment with water and also when

cement is exchanged with silica-fume at different percentage level were tested and the outcomes of this test are shown in the table number 4.3.

Table 4.3: Slump-value for different replacement and different silica-fume replacement

Different wood replacement (%) and Silica-fume replacement of Cement	Slump-value (mm)
0 Wood & 0 S.F	84
5 Wood & 4 S.F	91
5 Wood & 8 S.F	88
5 Wood & 12 S.F	85

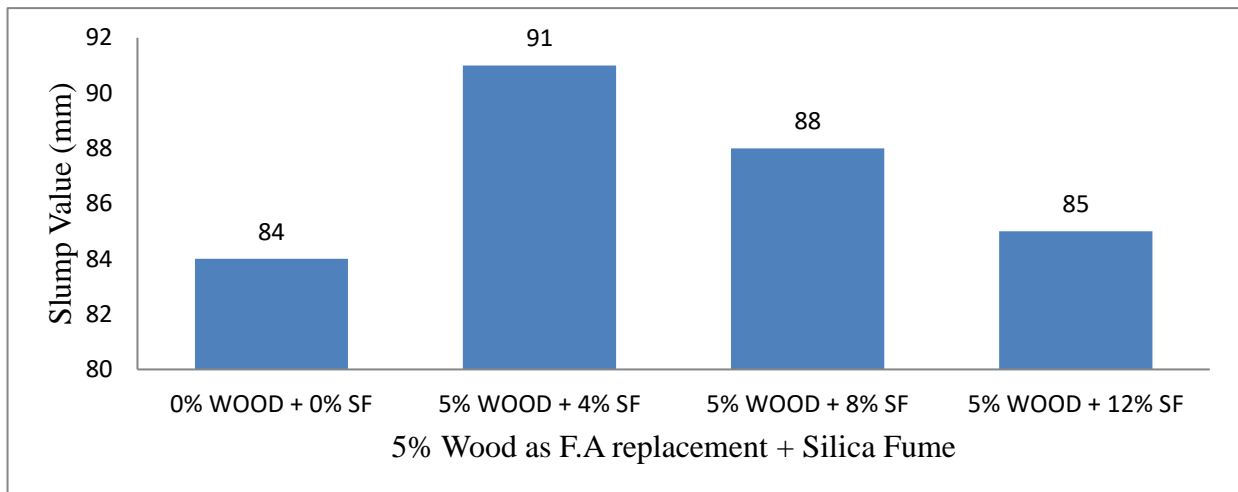


Figure 4.3: Workability of wood as F.A. replacement & silica-fume

The workability (easy of mixing) of the different concrete mixes at different level of fine-aggregate replacement with the wood chipping after pretreatment with Sodium-Silicate grade 52 liquid forms were tested and the outcomes of these test are shown in the table number 4.4.

Table 4.4: Slump-value for different wood replacement after pre-treatment with sodium-silicate (w/c = 0.44)

Different wood replacement (%)	Slump-value (mm)
0	84
5	96
10	115

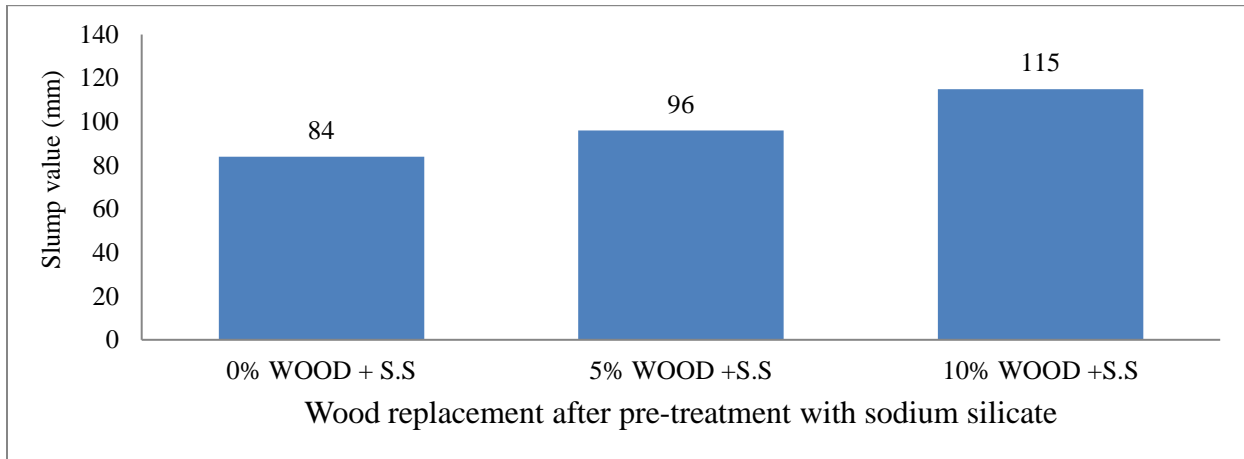


Figure 4.4: Workability after wood replacement after pre-treatment with sodium-silicate

Discussion: it can be seen that as the wood-substitution as fine-aggregate goes on increasing the Slump-value is raised. The increase in Slump-value is due to the spongy characteristics show by wood when interacted with water. The wood loses its water when compaction is done in slump cone test and thus workability goes on increasing. But as shown in table 4.2 workability decreases as w/c ratio decreases. And the workability (easy of mixing) also decreases as the silica-fume is substituted with cement at different replacement level due to small size of the particle of silica fume which filled the voids and doesn't allow water to penetrate in void so workability reduces.

4.1.2 Density of Fresh-Concrete

The Compactness of fresh-concrete of the different concrete mixes at changed level of fine-aggregate replacement with the wood chipping without any pretreatment and the water-cement ratios were ($w/c = 0.5$) tested and the outcomes are shown in the table number 4.5.

Table 4.5: Density of fresh-concrete for different wood replacement without pre-treatment ($w/c = 0.5$)

Different wood replacement (%)	Density (gm./cm ³)
0	2.40
5	2.09
10	2.02

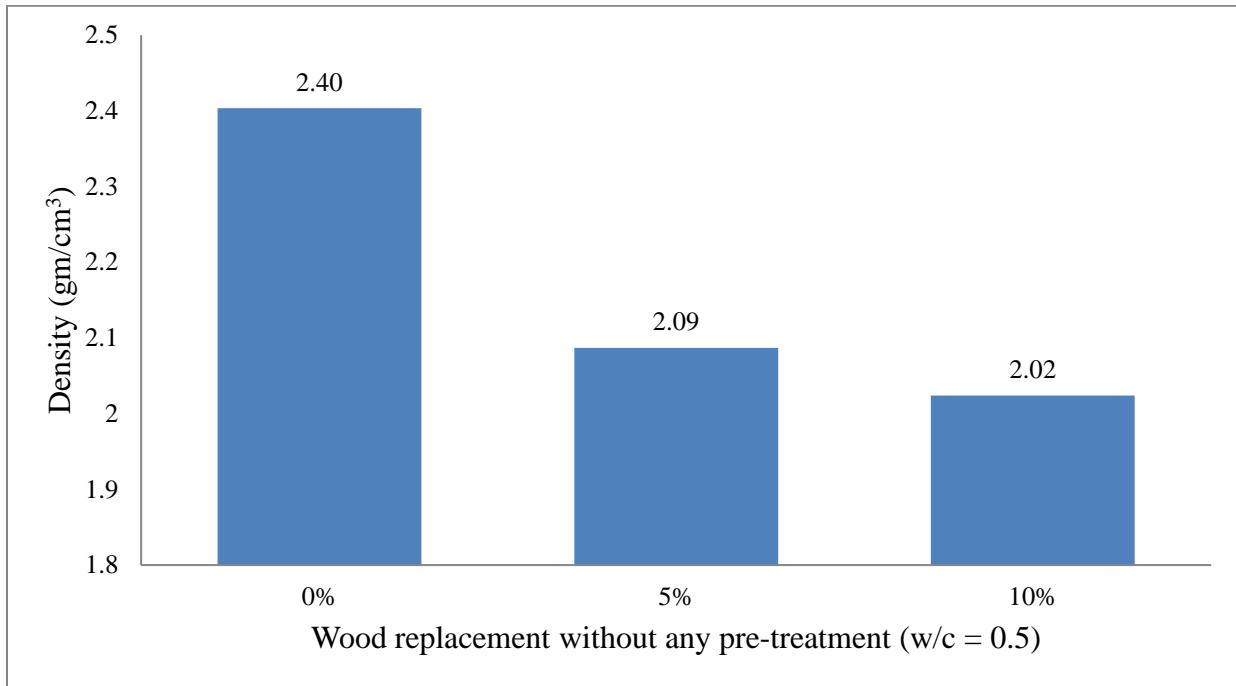


Figure 4.5: Density of wood replacement without pre-treatment

The Compactness of fresh-concrete of the different concrete mixes at different level of fine-aggregate replacement with the wood chipping after pretreatment with water at changed water-cement ratios were tested and the results for (W/C =0.5) are displayed in the table number 4.6.

Table 4.6: Density of fresh-concrete for different wood replacement after pre-treatment with water (w/c = 0.5)

Different wood replacement (%)	Density (gm./cm ³)
0	2.40
5	2.11
10	2.06
15	1.99
20	1.90

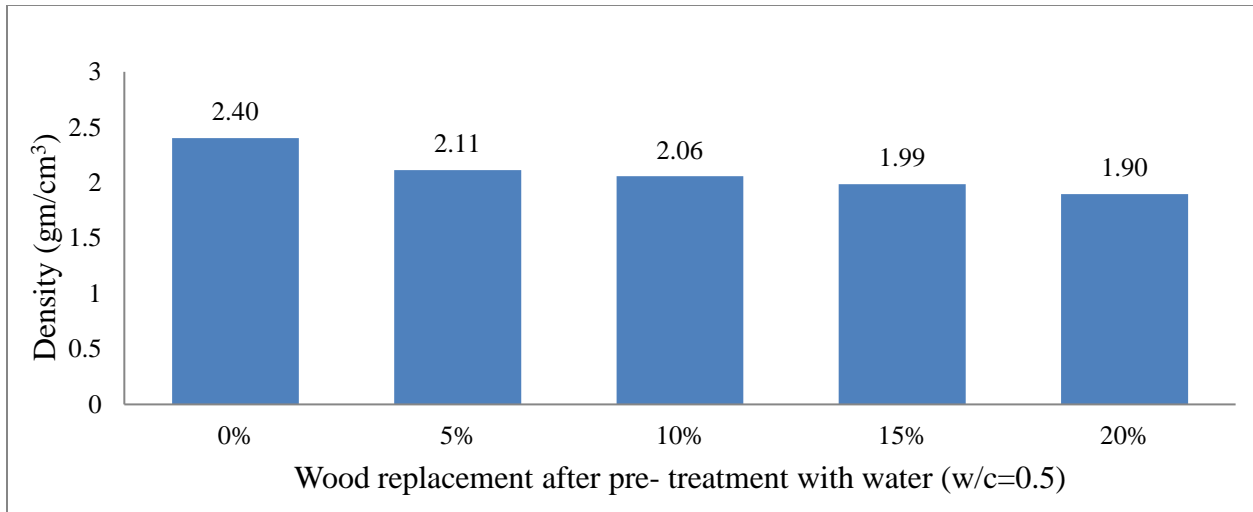


Figure 4.6: Density of wood replacement after pre-treatment

The Compactness of fresh-concrete of the different concrete mixes at changed level of fine-aggregate replacement with the wood chipping after pretreatment with water at different water-cement ratios were tested and the results for (w/c =0.44) are displayed in the table number 4.7.

Table 4.7: Density of fresh-concrete for different wood replacement after pre-treatment with water (w/c = 0.44)

Different wood replacement (%)	Density (gm./cm ³)
0	2.37
5	2.10
10	2.04

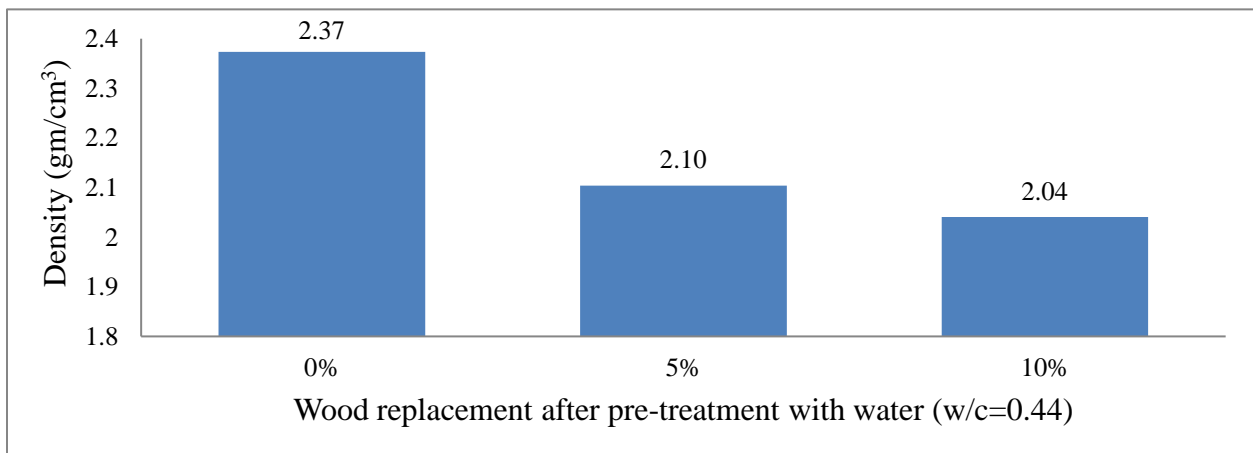


Figure 4.7: Density of wood replacement after pre-treatment

The Compactness of fresh-concrete of the different concrete mixes at changed level of fine-aggregate replacement with the wood chipping after pretreatment with water and also when cement is exchanged with silica-fume at different percentage level were tested and the outcomes of this test are shown in the table number 4.8.

Table 4.8: Density of fresh-concrete for different wood replacement and different silica-fume replacement

Different wood replacement (%) and silica-fume replacement of cement	Density (gm./cm ³)
0 Wood & 0 S.F	2.37
5 Wood & 4 S.F	2.13
5 Wood & 8 S.F	2.15
5 Wood & 12 S.F	2.19

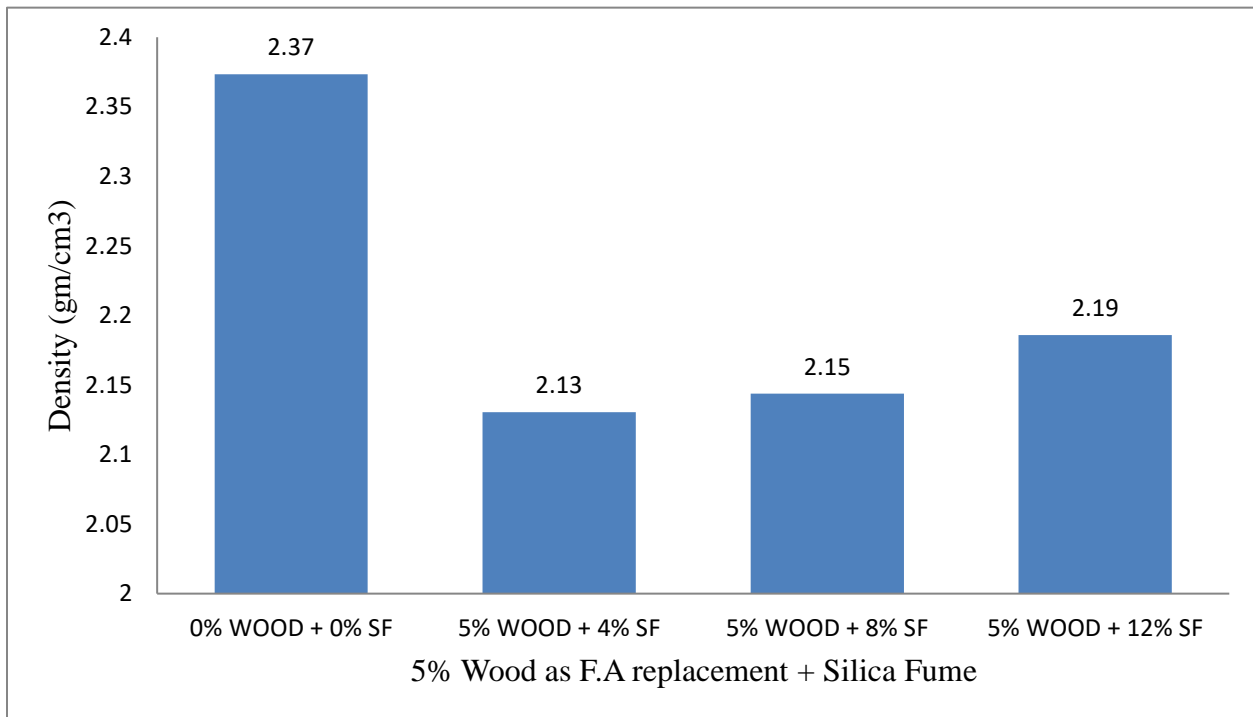


Figure 4.8: Density of Wood as F.A replacement & Silica-fume

The Compactness of fresh-concrete of the different concrete mixes at different level of fine-aggregate replacement with the wood chipping after pretreatment with Sodium-Silicate grade 52 liquid forms were tested and the outcomes of these test are exhibited in the table number 4.9.

Table 4.9: Density of fresh-concrete for different wood replacement after pre-treatment with sodium-silicate (w/c = 0.44)

Different wood replacement (%)	Density (gm./cm ³)
0	2.37
5	1.95
10	1.84

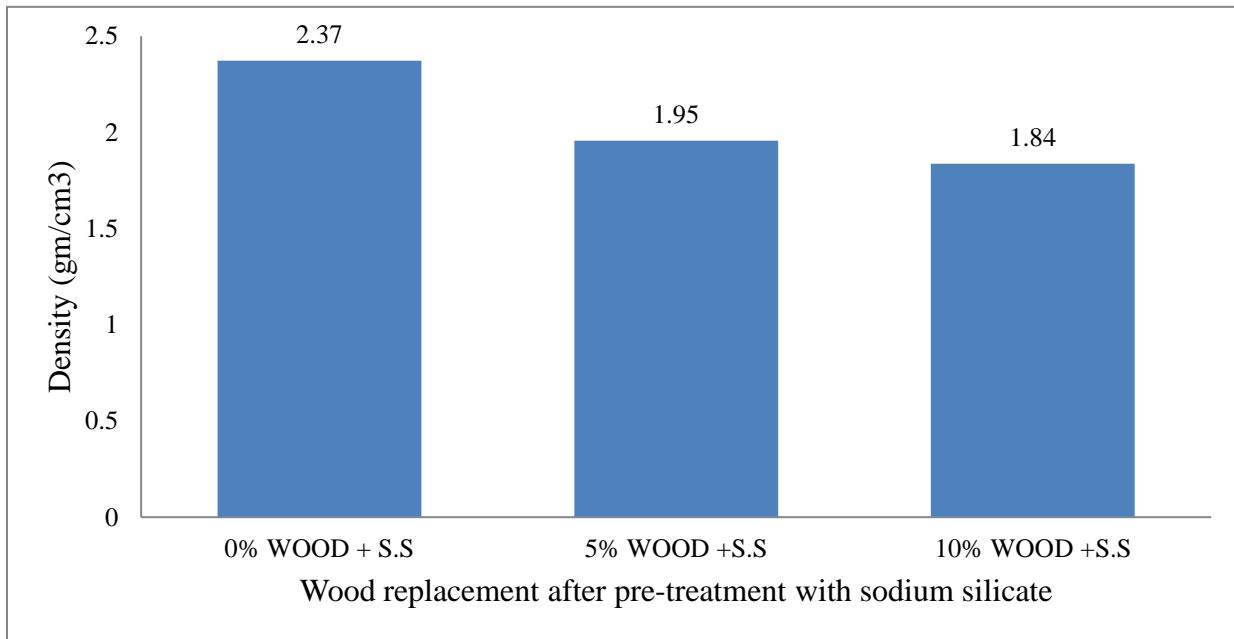


Figure 4.9: Density of wood replacement after pre-treatment

Discussion: It can be seen that as the wood-substitution as fine-aggregate moves to increasing the density of fresh-concrete goes on decreasing in every case and it can also be seen if wood is pretreated with the Sodium-Silicate the Compactness decrease more as compared to the wood pretreated with water. The reason for decrease in the density lies in the difference of the specific gravity of the wood chipping and the specific gravity of natural-sand.

4.2 HARDENED PROPERTIES OF CONCRETE RESULTS

The hardened property of concrete are found out on concrete after its final setting and after it's curing for 7days, 28days and 56days. The different hardened properties tests are compressive-strength of concrete, Split-tensile strength of concrete.

4.2.1 Compressive-Strength

The average compressive-strength of the concrete on changed percentage of replacement of wood as fine-aggregate at different w/c ratio are found out and the outcomes are denoted in tables below:

1. The compressive-strength of concrete without any pretreatment at w/c ratio of 0.5 is represented in table 4.10.

Table 4.10: Average Compressive-strength of concrete for different wood replacement without pre-treatment (w/c = 0.5)

Different wood replacement (%)	7days	28days	56days
0	19.89	28.84	29.82
5	15.35	19.57	20.60
10	7.23	8.09	9.29

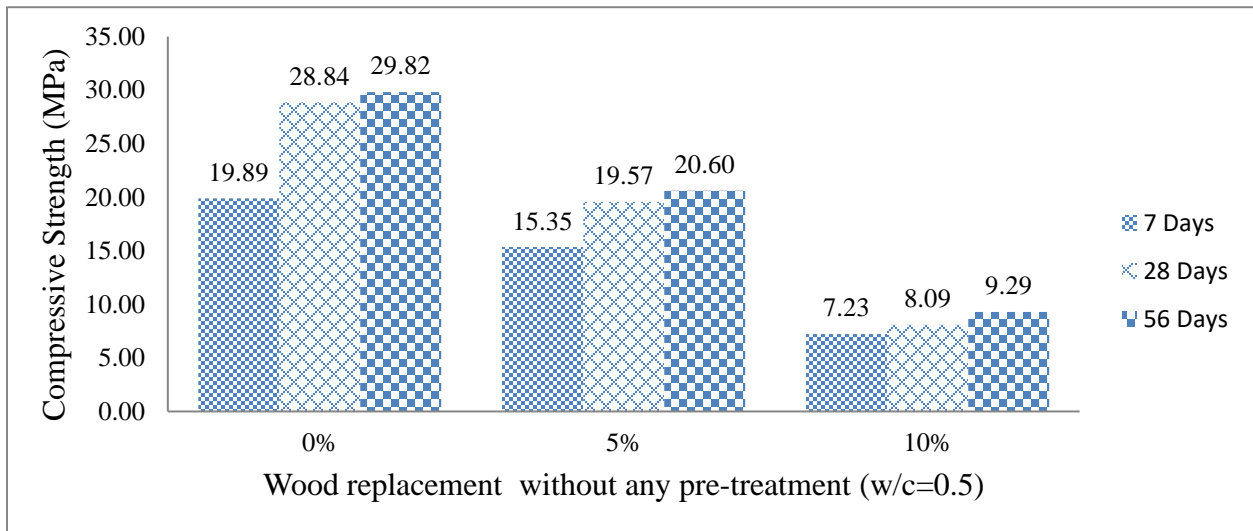


Figure. 4.10: Compressive-strength after wood replacement without pre-treatment

Discussion: It has been observed that the effect of substitution of fine-aggregate with wood chipping without any pre-treatment on compressive-strength of concrete shows different trends at 7,28 & 56 days of curing. The compressive-strength of concrete at 7,28 & 56 days of curing decreases rapidly with substitution of saw wood at 5 % replacement of fine-aggregate , and it is also seen that the compressive-strength of concrete further decrease with replacement of 10% wood chipping. The reason for the reduction in strength is due to dehydration of concrete due to

absorption of water by wood present in concrete, so concrete can't get enough water to make proper bond.

2. The compressive-strength of concrete after pretreatment with the water at w/c ratio of 0.5 is represented in table 4.11.

Table 4.11: Average Compressive-strength of concrete for different wood replacement after pre-treatment with water (w/c = 0.5)

Different wood replacement (%)	7days	28days	56days
0	19.89	28.84	29.82
5	19.24	27.01	28.09
10	14.31	20.09	21.73
15	10.99	15.33	16.51
20	7.45	10.39	11.27

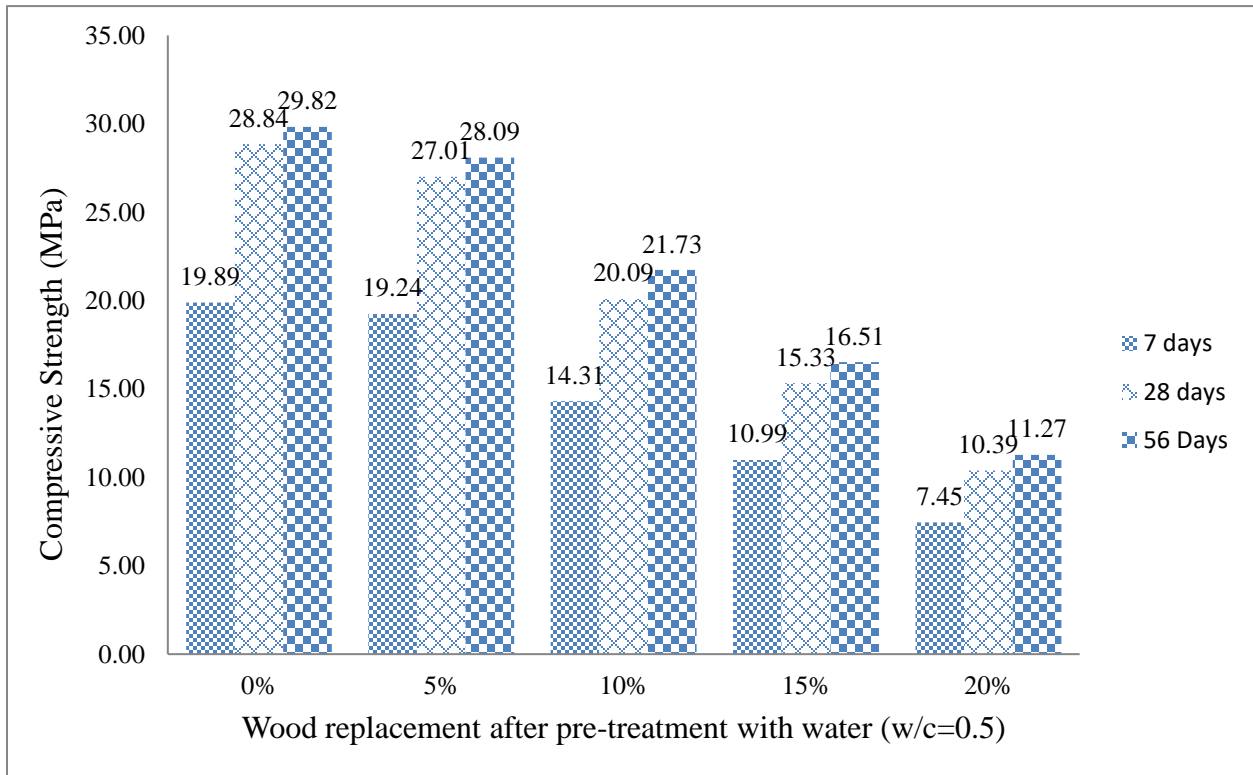


Figure 4.11: Compressive-strength after wood replacement after pre-treatment with water

Discussion: From above the bar chart table it can be experienced that the compressive-strength of concrete with replacement of saw wood dust wood with pre-treatment with water for 24 hours, the compressive-strength increases as compared to the compressive-strength without

any treatment. And it can also be realized that the compressive-strength shows the reductions trend as the replacement of wood goes on increasing from 5% replacement to 20 % replacement. The reason behind it is that wood saw dust causes a spongy-quality when they come in connection with water and they can be compressed easily. And same is the reason for early crack-formation and weak bonding of concrete matrix with saw wood dust on the exertion of load. And the other one reason is that the particles of natural-sand are much stronger than the particles of wood chipping particles. And the wood chipping particles are much porous too. Thus the compressive-strength of wood chipping concrete was seen to be lesser than the control concrete.

3. The compressive-strength of concrete after pretreatment with water at w/c ratio of 0.44 is represented in table 4.12.

Table 4.12: Average Compressive-strength of concrete for different wood replacement after pre-treatment with water (w/c = 0.44)

Different wood replacement (%)	7days	28days	56days
0	21.31	29.95	31.09
5	20.02	27.24	28.65
10	14.36	20.19	21.83

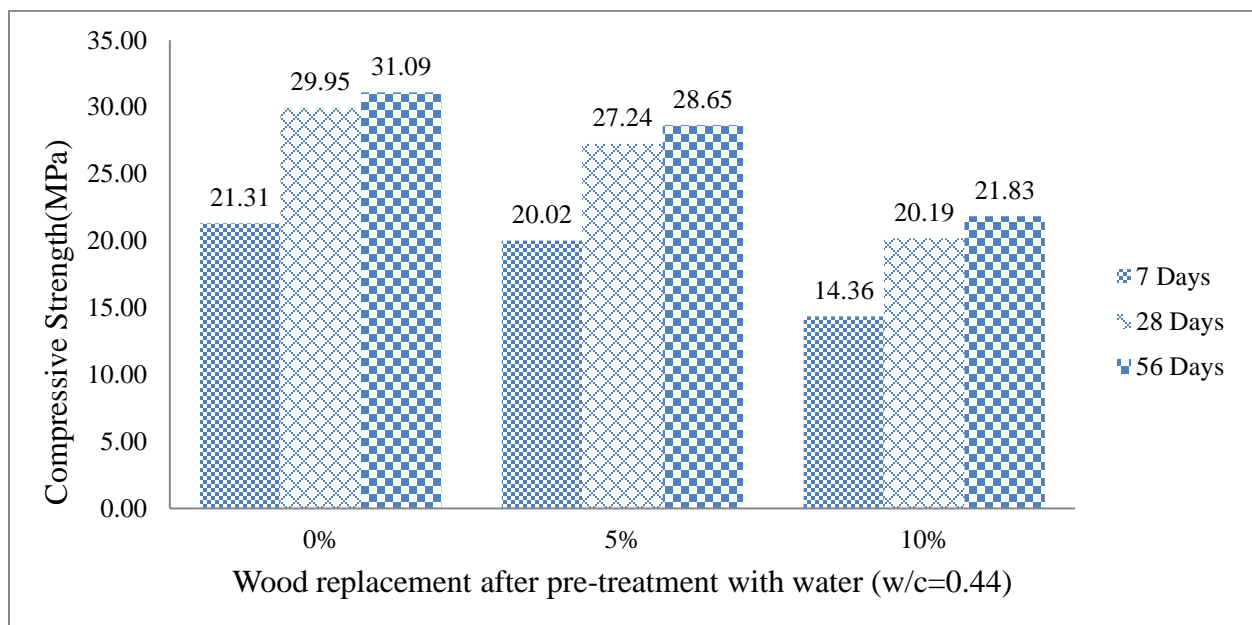


Figure 4.12: Compressive-strength after wood replacement after pre-treatment with water

Discussion: From the above bar chart it can be predicted that the compressive-strength enhances as the w/c ratio decreases from 0.5 to 0.44. But here also we can observe that the compressive-strength of control mix is larger than that of 5% replacement and 5% replacement has greater compressive-strength as compared to the 10 % replacement. The reason behind it is decrease in w/c ratio tends to higher the cement content of the mixtures leading to increase in strength

4. The compressive-strength of concrete for different wood replacement and different silica-fume replacement are represented in table 4.13.

Table 4.13: Average Compressive-strength of concrete for different wood replacement and different silica-fume replacement

Different wood replacement (%) and silica-fume replacement of cement	7days	28days	56days
0 Wood & 0 S.F	21.31	29.95	31.09
5 Wood & 4 S.F	20.11	27.26	28.70
5 Wood & 8 S.F	20.48	27.46	28.81
5 Wood & 12 S.F	20.58	27.56	28.91

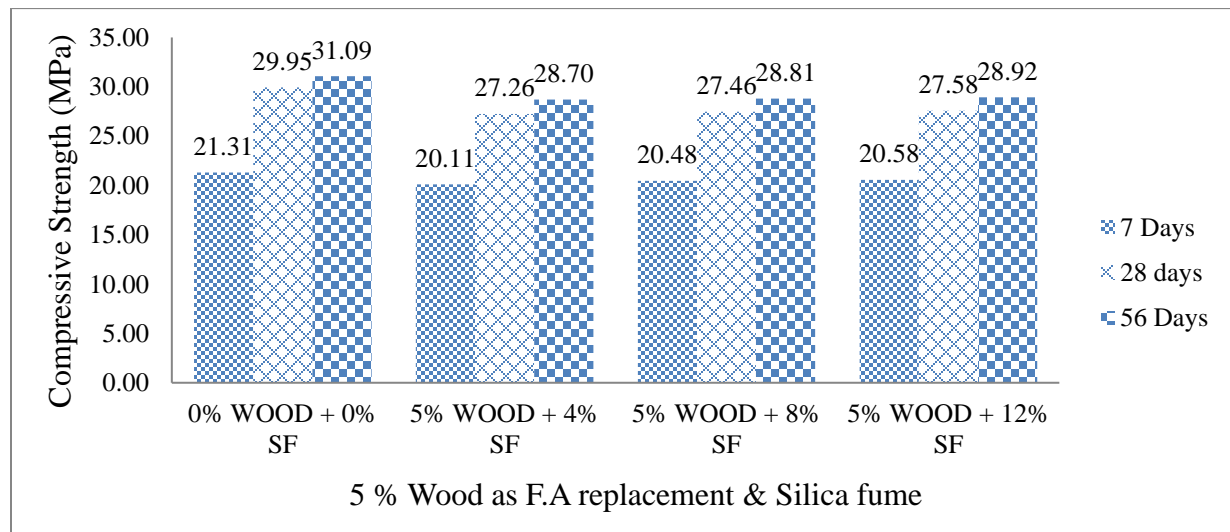


Figure. 4.13: Compressive-strength after wood as F.A replacement & Silica-fume

Discussion: From the above table it can be observed that with same percentage of wood replacement (5%) with fine-aggregate and additional exchange of cement with silica-fume with different % (4%, 8% & 12%) the compressive-strength shows increasing trend but it increase very slowly the reason behind the increase of the compressive-strength is Because of its physical and chemical-properties, it is an exact reactive pozzolan. Silica-fume particles are far smaller

than the cement particles (approx. 1/100). This smaller size makes it very effective filler and subsequently enhances the packing density. Other reason can be Silica-fume can be regarded as a water replacement in terms of water demand. A certain portion of water is essential to fill the void space even in a pure cement paste binder to make flow possible. With the addition of silica-fume, further water reduction is possible since it can take the place of the water in the void space hence strength can be increased.

Another reason can be during the hydration of cement, Calcium-Hydroxide (CH) is produced and with that silica-fume reacts and produces more of the Calcium-Silicate-Hydrate (CSH) gel, which has much higher strength compared to CH. Thus the pore system earlier filled with CH would now fill with stronger CSH gel, particularly in the critical, Interfacial-Transition-Zone (ITZ), which results in a remarkable increase in strength.

5. The compressive-strength of concrete after pretreatment with Sodium-Silicate at w/c ratio of 0.44 is represented in table 4.14.

Table 4.14: Average Compressive-strength of concrete for different wood replacement after pre-treatment with sodium-silicate (w/c = 0.44)

Different wood replacement (%)	7days	28days	56days
0	21.31	29.95	31.09
5	19.97	27.69	29.97
10	16.37	20.36	22.04

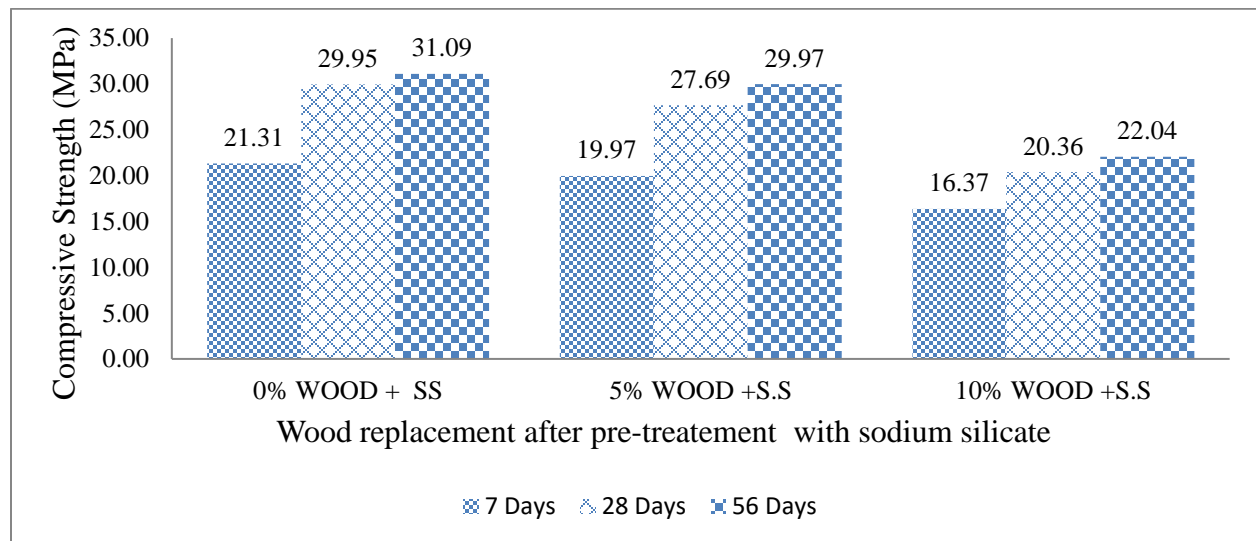


Figure 4.14: Compressive-strength after wood replacement after pre-treatment with sodium-silicate

Discussion: As we can see that the compressive-strength enhances from the previous all replacement after pre-treatment of wood with sodium-silicate. Sodium-Silicate provide silica content to the wood which was not present in wood before treatment and second reason is Sodium-Silicate act as the self-healing material due to their reaction with concrete. Third reason can be chemical reaction Sodium-Silicate is readily available to react with Calcium-Hydroxide which is present in the cement and forms Calcium-Silicate-Hydroxide. It involves in increasing the hydration of cement, there by High strength of concrete is achieved.

4.2.2 Split-Tensile Strength

The average Split-tensile strength of the concrete on different percentage of replacement of wood as fine-aggregate at different w/c ratio are found out and the results are represented in tables below:

1. The Split-tensile strength of concrete without any pretreatment at w/c ratio of 0.5 is represented in table 4.15.

Table 4.15: Average Split-tensile strength of concrete for different wood replacement without pre-treatment (w/c = 0.5)

Different wood Replacement (%)	7days	28days	56days
0	2.30	2.98	3.15
5	1.52	1.67	1.93
10	1.28	1.45	1.59

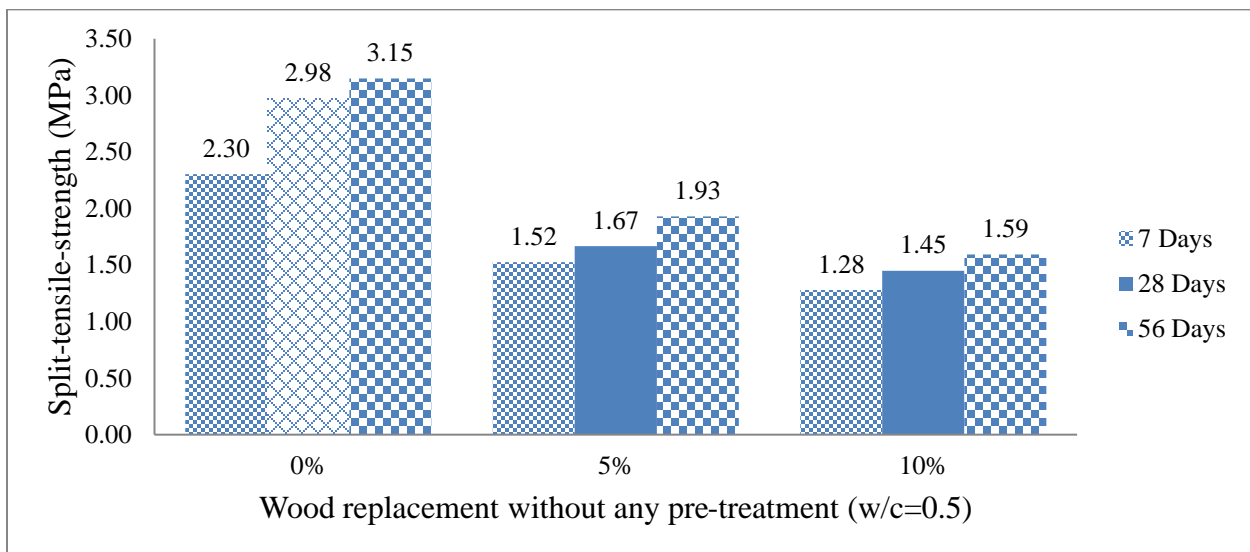


Figure 4.15: Split-tensile strength after wood replacement without pre-treatment

Discussion: It has been observed that the result of exchange of fine-aggregate with wood chipping without any pre-treatment, on Split-tensile strength of concrete shows different trends at 7,28 & 56 days of curing. The Split-tensile strength of concrete at 7,28 & 56 days of curing decreases rapidly with substitution of saw wood at 5 % substitution of fine-aggregate , and it is also observed that the Split-tensile strength of concrete further decrease with replacement of 10% wood chipping . The cause for the reduction in strength is due to dehydration of concrete due to absorption of water by wood present in concrete, so concrete can't get enough water to make proper bond.

2. The Split-tensile strength of concrete after pretreatment with water at w/c ratio of 0.5 is represented in table 4.16.

Table 4.16: Average Split-tensile strength of concrete for different wood replacement after pre-treatment with water (w/c = 0.5)

Different wood replacement (%)	7days	28days	56days
0	2.30	2.92	3.15
5	2.31	2.86	2.96
10	1.71	1.98	2.20
15	1.47	1.72	1.85
20	0.93	1.31	1.44

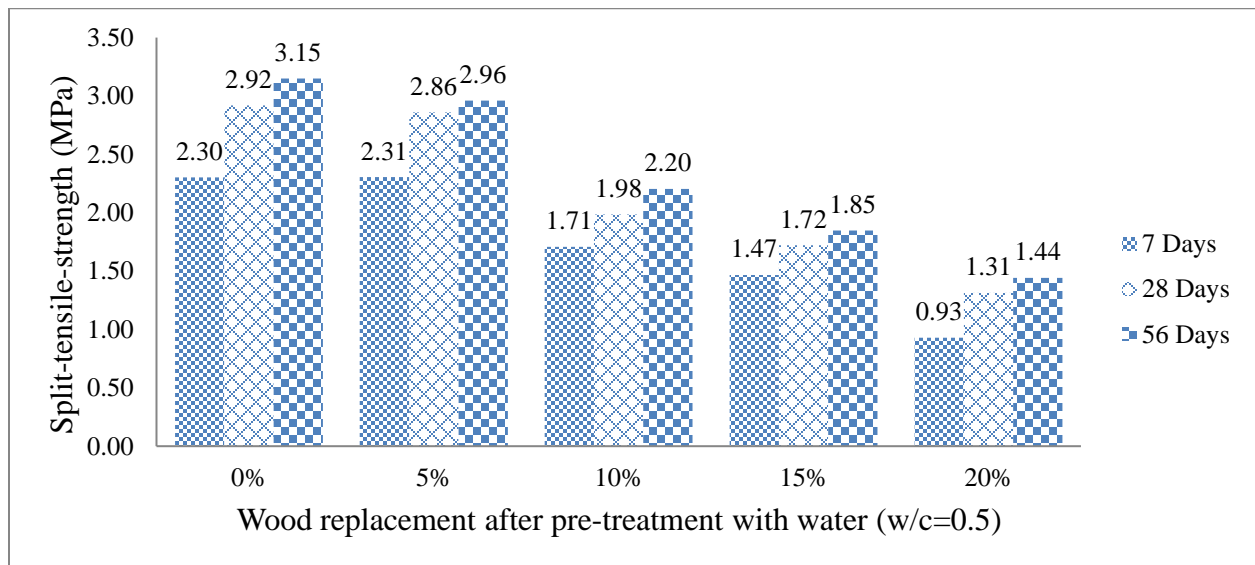


Figure 4.16: Split-tensile strength after wood replacement after pre-treatment with water

Discussion: It has been observed that the result of exchange of fine-aggregate with wood chipping without any pre-treatment, on Split-tensile strength of concrete shows different trends at 7,28 & 56 days of curing. The Split-tensile strength of concrete shows linear decreasing trend as the replacement goes on increasing from 5% to 20% replacement. The reason behind it is that Wood saw dust causes a spongy-quality when they come in contact with water and can be compressed easily. And same is the reason for early crack-formation and weak bonding of concrete-matrix and wood saw dust on application of load.

3. The Split-tensile strength of concrete after pretreatment with water at w/c ratio of 0.44 is represented in table 4.17.

Table 4.17: Average Split-tensile strength of concrete for different wood replacement after pre-treatment with water (w/c = 0.44)

Different wood replacement (%)	7days	28days	56days
0	2.45	2.96	3.19
5	2.26	2.82	2.97
10	1.90	2.09	2.21

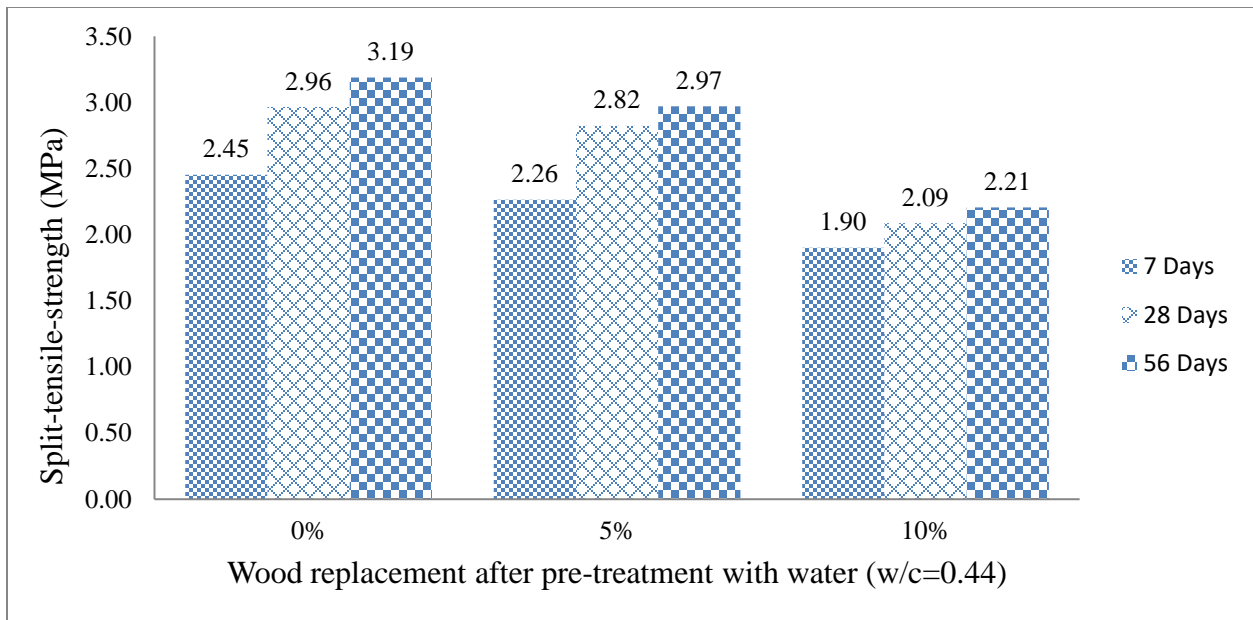


Figure 4.17: Split-tensile strength after wood replacement after pre-treatment with water

Discussion: From the above bar chart it can be predicted that the Split-tensile strength enhances as the w/c ratio decreases from 0.5 to .44. But here also we can predict that the Split-tensile strength of control mix is better than that of 5% replacement and 5% replacement has greater

compressive-strength as compared to the 10 % replacement. The reason behind it is decrease in water–cement ratio tends to higher the cement content of the mixtures leading to increase in strength.

4. The Split-tensile strength of concrete for Different Wood Replacement and Different Silica-fume Replacement are represented in table 4.18.

Table 4.18: Average Split-tensile strength of concrete for different wood replacement and different silica-fume replacement

Different wood replacement (%) and silica-fume replacement of cement	7days	28days	56days
0 Wood & 0 S.F	2.45	2.96	3.19
5 Wood & 4 S.F	2.28	2.84	2.97
5 Wood & 8 S.F	2.33	2.87	2.99
5 Wood & 12 S.F	2.37	2.91	3.04

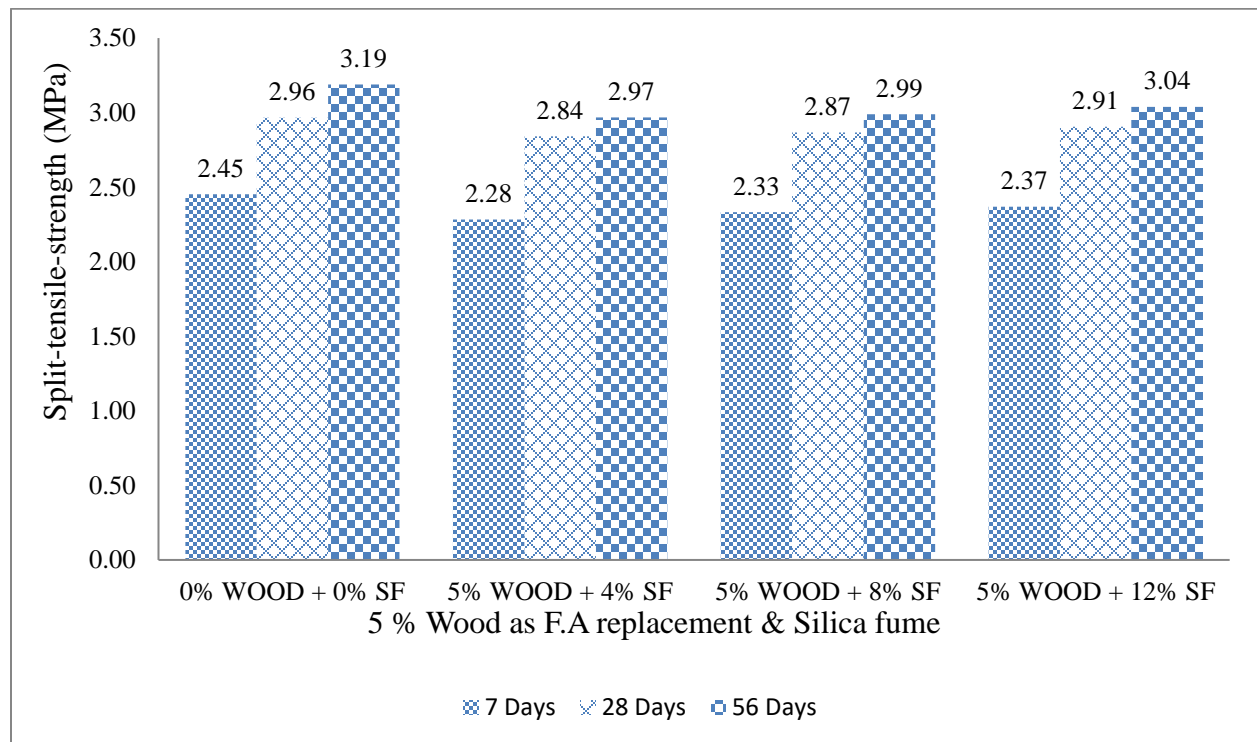


Figure 4.18: Split-tensile strength after wood as F.A replacement & silica-fume

Discussion: From the above table it can be observed that with same percentage of wood replacement (5%) with fine-aggregate and additional exchange of cement with silica-fume with different %(4%, 8% & 12%) the Split-tensile strength shows increasing trend but it increase very

slowly the reason behind the increase of the Split-tensile strength is because of its physical and chemical-properties, it is an exact reactive pozzolan. Silica-fume particles are far smaller than the cement particles (approx. 1/100). This smaller size makes it very effective filler and subsequently enhances the packing density.

5. The Split-tensile strength of concrete after pretreatment with Sodium-Silicate at w/c ratio of 0.44 is represented in table 4.19.

Table 4.19: Average Split-tensile strength of concrete for different wood replacement after pre-treatment with sodium-silicate (w/c = 0.44)

Different wood replacement (%)	7days	28days	56days
0	2.45	2.96	3.19
5	2.31	2.90	3.01
10	1.92	2.29	2.36

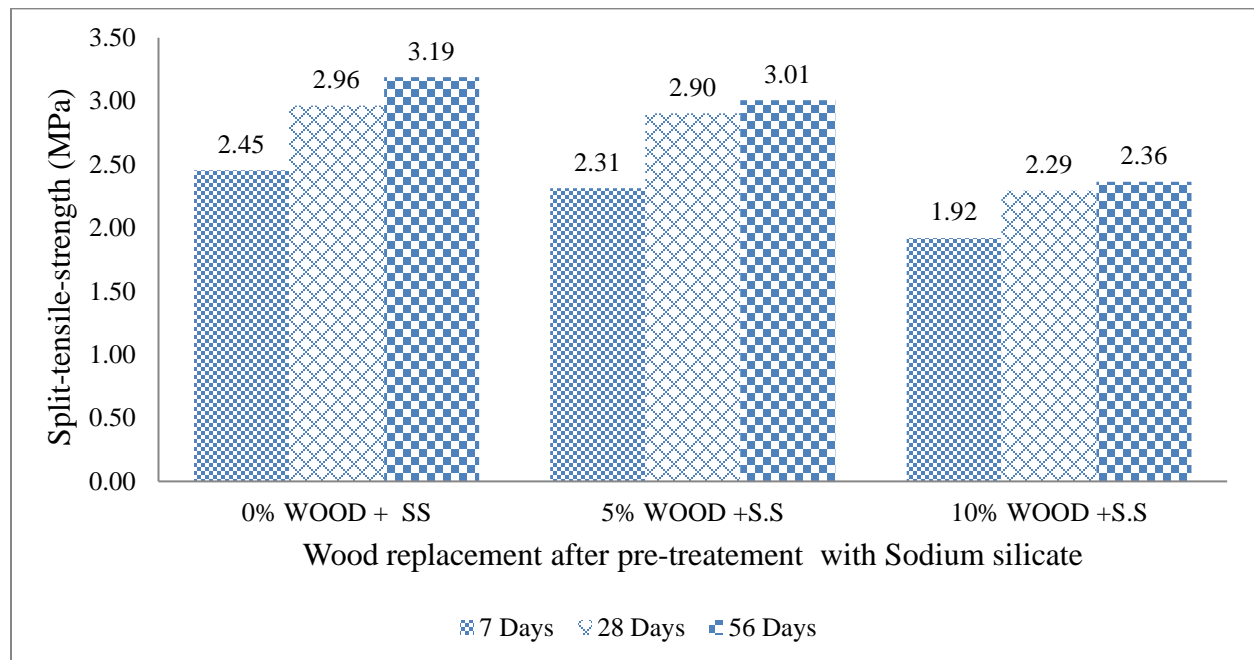


Figure 4.19: Split-tensile strength after wood replacement after pre-treatment with sodium-silicate

Discussion: As we can see that the Split-tensile strength increases from the previous all replacement after pre-treatment of wood with sodium-silicate. Sodium-Silicate provide silica content to the wood which was not present in wood before treatment and second reason is Sodium-Silicate act as the self-healing material due to their reaction with concrete. Third reason

can be chemical reaction Sodium-Silicate is readily available to react with Calcium-Hydroxide which is present in the cement and forms Calcium-Silicate-Hydroxide. It involves in increasing the hydration of cement, there by High strength of concrete is achieved.

4.3 DURABILITY RESULTS OF CONCRETE

The durability test on concrete are done to measure the performance of the concrete subjected to different atmospheric conditions and attack of different alkalis and acids or any other chemical compound. The different tests are conducted to assess the durability of the concrete which is shown below:

4.3.1 Water Penetration Test

It is one of the durability test conducted on the concrete this test is done to know the resistance of the concrete against the water. This test is conducted for a period of three days and water is allowed to penetrate in to the concrete cube (150 x 150 x 150) at a pressure of 5 kg/cm². The initial and final readings of the water level in the tube is noted and after 3 days the sample is broken as split tensile form and the depth of the water penetration is calculated through help of a scale. The different observation taken for the different sample with changed percentage of wood chipping replacement at changed w/c ratio and the results are described as below:

1. Penetration Value of water in concrete formed with replacement wood after Pretreatment with water at different w/c ratio is given in table 4.20.

Table 4.20: Penetration value of water in concrete for different wood replacement after pre-treatment with water w/c =0.5

Wood replacement (%)	Initial reading	Final reading	Difference in the water level	Depth of penetration (mm)
0	33.8	29.1	4.7	15
5	31.5	25.5	6	29
10	34.5	27.9	6.6	38
15	33.5	26.4	7.1	48
20	28.6	20.1	8.5	56

Discussion: It can be observed that as the wood-replacement goes on increasing the water penetration value of concrete also goes on increasing. And the reason for increase in penetration depth is due to the soaking behavior of the wood saw dust thus as the wood increases it absorbs more and more water in it and the depth of penetration shows increasing trend.

2. Penetration Value of water in concrete for Different Wood Replacement and Different Silica-fume Replacement are represented in table 4.18.

Table 4.21: Penetration value of water in concrete for different wood replacement and different silica-fume replacement

Different Wood Replacement (%) and Silica-fume Replacement of Cement	Initial reading	Final reading	Difference in the water level	Depth of penetration (mm)
0 Wood & 0 S.F	33.8	29.1	4.7	15
5 Wood & 4 S.F	28.4	22.6	5.8	28
5 Wood & 8 S.F	30	24.3	5.7	27
5 Wood & 12 S.F	25.7	20.3	5.4	23

Discussion: It can be seen that as at a constant replacement of wood (5%) if we vary cement percentage the penetration depth value decreases this is due to the particle size of the silica-fume is very less as compared to the cement-particle therefore it does not allow water to penetrate through it.

3. Penetration Value of water in concrete formed with replacement wood after Pretreatment with Sodium-Silicate is given in table 4.22.

Table 4.22: Penetration value of water in concrete for different wood replacement after pre-treatment with sodium-silicate

Wood Replacement (%)	Initial reading	Final reading	Difference in the water level	Depth of penetration (mm)
0	33.8	29.1	4.7	15
5	23.5	16.6	6.6	33
10	28.7	21.7	7	41

Discussion: It can be observed that as the wood replacement rises the depth of penetration also increases. And also we can see that if wood is pretreated with Sodium-Silicate shows more depth than the wood pretreated with water the reason for it is the wood soaking nature of water and after pretreatment its needs of water is not fulfilled so depth of penetration shows increasing trend.

4.3.2 Rapid-Chloride Permeability Test (RCPT)

It is also a type of durability test which is done to find out the chloride-ion-penetration of the concrete samples when these samples are subjected under the effect of chloride ions as per ASTM C1202-12 like situation in sea water. This test is done on concrete with changed percentage of wood replacement as fine-aggregate and the results are discussed below:

1. The RCPT test results for the concrete having wood saw dirt as partial-substitution of fine-aggregate after pretreatment with water are shown in table 4.23.

Table 4.23: RCPT results of concrete for different wood replacement after pre-treatment with water

Wood Replacement (%)	Current passed	Total charged passed (Coulombs)	Chloride-ion-permeability
0	118.5	2539	Moderate
5	254.3	5154	High
10	397.9	8227	High
15	500.8	2098	overflow
20	500.1	1819	overflow

Discussion: As it can be observed from the table that as the partial-substitution of wood increases as fine-aggregate it indicates the high chloride-ion-permeability. The reason for high and overflow permeability is due to the concrete-matrix form. Due to the presence of Spongy form of wood the concrete-matrix is not dense as that in case of conventional concrete. And particle packing of concrete is to optimum and dense.

2. The RCPT test outcomes of Concrete for Different Wood Replacement and Different Silica-fume Replacement are shown in table 4.24.

Table 4.24: RCPT results of concrete for different wood replacement and different silica-fume replacement

Different Wood Replacement (%) and Silica-fume Replacement of Cement	Current passed	Total charged passed (Coulombs)	Chloride-ion-permeability
0 Wood & 0 S.F	118.5	2539	Moderate
5 Wood & 4 S.F	132.5	2864	Moderate
5 Wood & 8 S.F	128.7	2732	Moderate
5 Wood & 12 S.F	125.9	2609	Moderate

Discussion: It can be observed in the table that at a constant replacement (5%) of wood chipping with fine-aggregate and varying the Silica-fume as a substitution cement the samples displayed extra resistance against chloride-ion transfer as compared to that of simple wood replacement goes on increasing. The reason for it is dense concrete-matrix formed due to filler effect of the silica-fume due to which it fill all the voids that are pending due to the use of wood chipping and obtained the optimum particle packing of the ingredient.

3. The RCPT test results for the concrete containing wood-chipping as partial-substitution of fine-aggregate after pretreatment with Sodium-Silicate are revealed in table 4.25.

Table 4.25: RCPT results of concrete for different wood replacement after pre-treatment with sodium-silicate

Wood Replacement (%)	Current passed	Total charged passed (Coulombs)	Chloride-ion-permeability
0	118.5	2539	Moderate
5	153.0	3345	Moderate
10	167.9	3591	Moderate

Discussion: As it can be seen from the table that as the partial-substitution of wood raises as fine-aggregate it indicates the slight higher chloride-ion-permeability. But this can also be seen that after pretreatment with Sodium-Silicate there is reduction in chloride-ion-permeability. The reason for reduction in permeability is Sodium-Silicate act as a binder to wood chipping and binds the wood with other elements of the concrete. And the second reason can be Sodium-Silicate give its silica content to the wood chipping which is less in silica particle content therefore which makes the concrete-matrix denser.

4.3.3 Water Sorptivity Test

This is the third test to find out the durability of the concrete. In this test we find out the how much amount of water is absorbed by the sample under hydraulic action with respect to the time. This test was done according to the recommendation as per ASTM C1585-04 on the sample of size 100 (diameter) x 50mm (length) which are cut down from a cylindrical sample of size 200mm (length) x 100mm (diameter). Three samples of each replacement level were tested and the average reading of the three samples was noted down.

1. The table 4:26. Shows Water Sorptivity Test outcomes of wood chipping as partial substitution of fine aggregate after pretreatment with water at a w/c ratio of 0.44.

Table 4.26: Water Sorptivity test at different wood replacement level.

Sample ID		Mass of the samples								
		Control	5% wood	I (mm)	10% wood	I (mm)	15% wood	I (mm)	20% wood	I (mm)
Time (in sec)	\sqrt{Ti} me (S ^{1/2})									
0	0	992.52	905.54	0	923.52	0	838.25	0	819.67	0
60	8	993.45	907.02	0.1826	925.55	0.2492	840.42	0.2677	822.89	0.3972
300	17	993.9	907.51	0.243	925.65	0.2627	841.88	0.4478	824.99	0.6562
600	24	994.03	907.94	0.296	925.89	0.2923	842.77	0.6315	827.04	0.9091

1200	35	994.56	908.32	0.3429	926.41	0.3565	843.37	0.6636	827.75	0.9967
1800	42	994.87	908.57	0.3738	926.99	0.4280	843.65	0.6636	829	1.1509
3600	60	995.5	908.99	0.4256	927.24	0.4589	843.99	0.7080	830.29	1.3099
7200	85	995.5	909.49	0.4872	927.94	0.5452	845.01	0.8338	833	1.6443
10800	104	995.5	910	0.5501	928.49	0.6131	846.22	0.9831	834.67	1.8502
14400	120	995.68	910.44	0.6044	928.67	0.6352	847.34	1.1212	836.07	2.0229
18000	134	995.87	910.56	0.6192	929.07	0.6846	847.96	1.1977	837.46	2.1944
21600	147	996.12	910.89	0.6599	929.27	0.7093	848.38	1.2495	837.69	2.2228
92220	304	996.67	912.01	0.7981	931.34	0.965	851.78	1.6689	841.95	2.7482
193200	440	996.9	913.23	0.9486	932.99	1.1681	853.66	1.9008	845.69	3.2096
268500	518	997.35	914.37	1.0892	933.78	1.2656	855.93	2.1808	847.93	3.4859
527580	726	998.48	915.54	1.2335	935.07	1.4247	857.89	2.4226	849.78	3.7141
622200	789	998.75	915.99	1.2890	937.02	1.6652	859.99	2.6816	852.49	4.0483
691200	831	999.58	917.78	1.5098	938.87	1.8934	863.59	3.1257	854.46	4.2913
Net gain in mass (in g)		7.06	12.24		15.35		25.34		34.79	

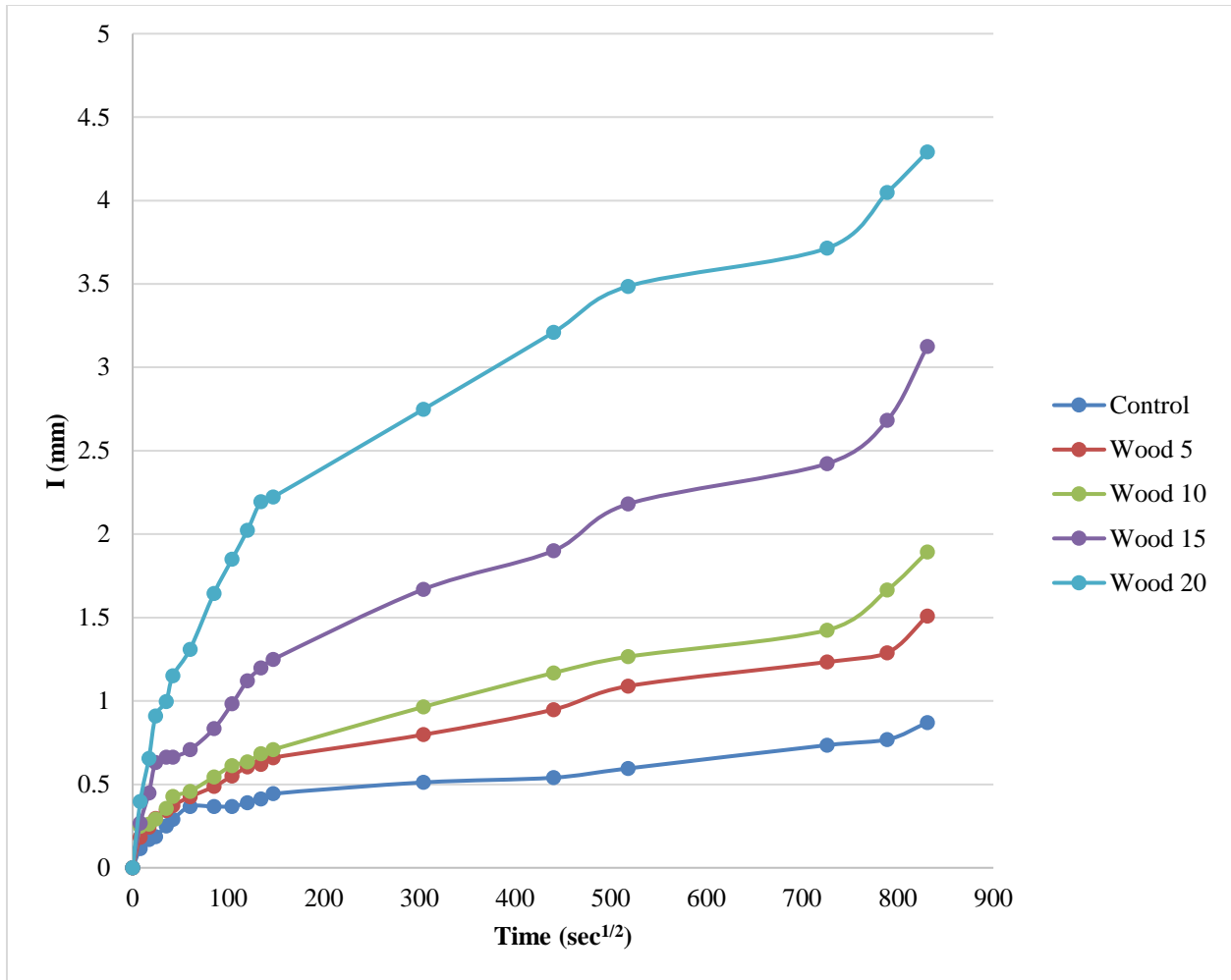


Figure 4.20: Water sorptivity values after wood replacement after pre-treatment with water

Discussion: From the table and also the curve it can be seen that as the percentage of substitution of wood chipping goes on increasing the soaking up of water value of concrete goes on increasing. And the wood with 20% replacement absorbs the most value. The reason for increasing is obvious wood absorbs more water and we have seen in water penetration test the wood contains more water has greater depth of penetration.

2. The table 4:27. Shows Water Sorptivity Test outcomes at constant 5% wood chipping as partial substitution of fine aggregate and cement replacement with varying Silica-fume content at a w/c ratio of 0.44.

Table 4.27: Water Sorptivity test at different wood replacement level & different S.F

Sample ID	Mass of the samples and respective I value							
	Control	I (mm)	5% wood	I (mm)	5% wood	I (mm)	5% wood	I (mm)

Time (in sec)	$\sqrt{\text{Time}}$ ($S^{1/2}$)			& 4% S.F		& 8% S.F		& 12% S.F	
0	0	992.52	0	954	0	943.12	0	953.24	0
60	8	993.45	0.1147	954.9	0.111	943.52	0.0493	954.19	0.1172
300	17	993.9	0.1702	955.56	0.1924	943.92	0.0987	954.56	0.1628
600	24	994.03	0.1862	956.12	0.2615	944.32	0.1480	954.86	0.1998
1200	35	994.56	0.2516	956.78	0.3429	944.59	0.1813	955.45	0.2726
1800	42	994.87	0.2898	957.2	0.3947	944.79	0.206	955.85	0.3219
3600	60	995.5	0.3675	957.5	0.4317	945.53	0.2973	956.26	0.3725
7200	85	995.5	0.3675	958.1	0.5057	946.52	0.4194	956.35	0.3836
10800	104	995.5	0.3675	958.6	0.5674	946.92	0.4687	956.47	0.3984
14400	120	995.68	0.3897	958.8	0.5921	947.32	0.5181	956.67	0.4231
18000	134	995.87	0.4132	959	0.6168	947.88	0.5871	956.93	0.4552
21600	147	996.12	0.4440	959.23	0.6451	948.12	0.6168	957.22	0.4909
92220	304	996.67	0.5119	961.22	0.8906	950.02	0.8511	958.3	0.6242
193200	440	996.9	0.5402	962.41	1.0374	951.56	1.0411	959.12	0.7253
268500	518	997.35	0.5957	963.23	1.1385	951.88	1.0805	959.42	0.7623
527580	726	998.48	0.7351	963.99	1.2323	952.33	1.1361	960.56	0.9029
622200	789	998.75	0.7684	964.45	1.289	952.56	1.1644	960.72	0.9227
691200	831	999.58	0.8708	964.91	1.3458	953.01	1.2199	961.34	0.9991
Net gain in mass (in g)		7.06		10.91		9.89		8.10	

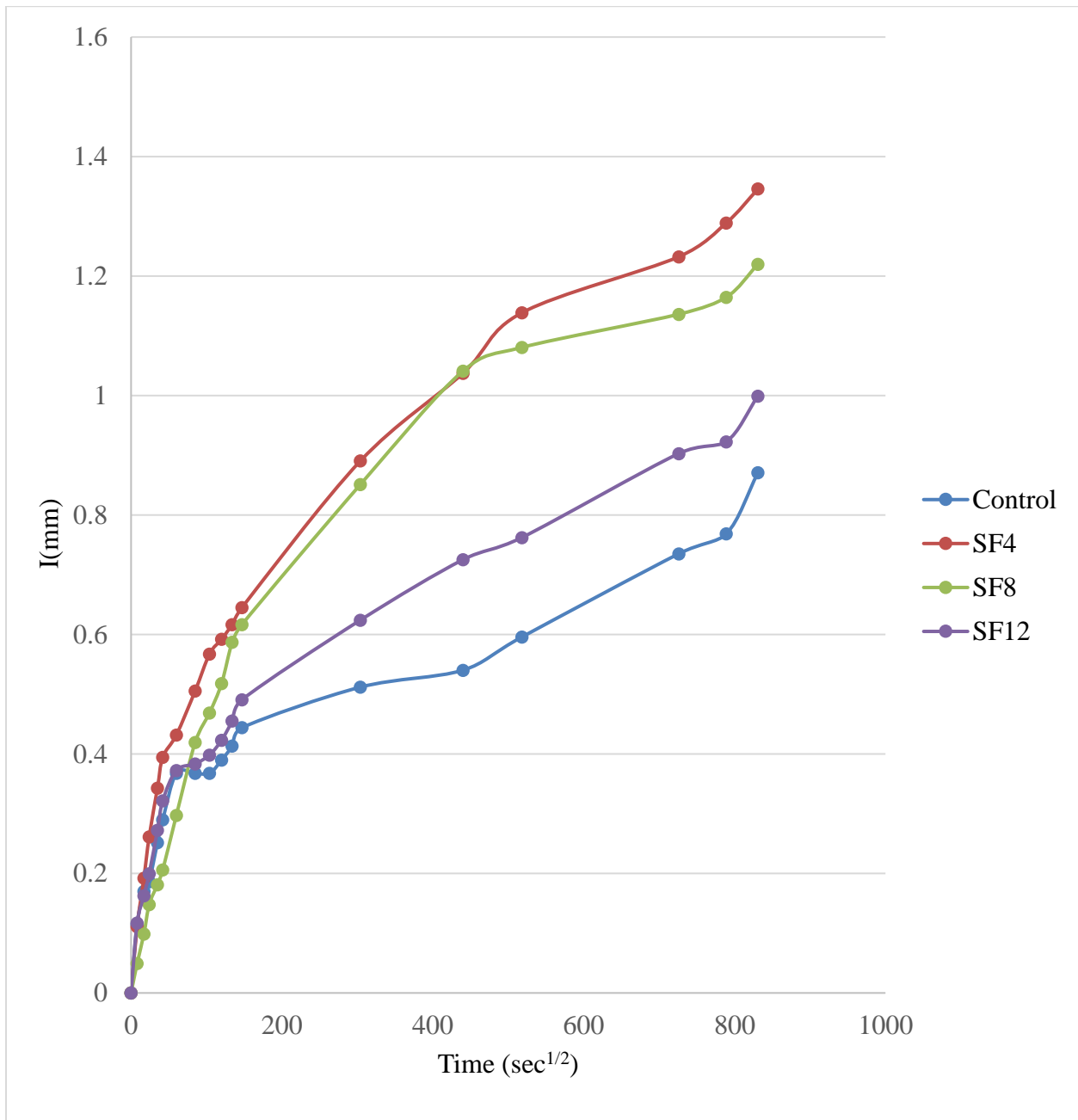


Figure 4.21: Water sorptivity after wood as F.A replacement & silica-fume

Discussion: It can be observed that at a constant replacement of wood that is at 5% and varying cement substitution with silica-fume the Soaking up of water value decrease as the substitution of cement increases from 4% to 12%. And the reason is that particle size of the silica-fume is much smaller than that of cement which itself fill the voids remaining after mixture and does not left the voids for water to fill it.

4.4 SCANNING ELECTRON MICROSCOPY AND ENERGY DISPERSIVE SPECTROSCOPY

4.4.1 SEM Analysis of Sample Containing 5 % Wood Chipping

Figure 4.22 shows the scanning electron microscopic (SEM) analysis of sample containing 5% saw wood dust as partial substitution of fine aggregate after the pretreatment with water at $w/c = 0.44$. At two different magnification level. And after seeing the picture the following observation were obtained and these are described in the discussion below the figure.

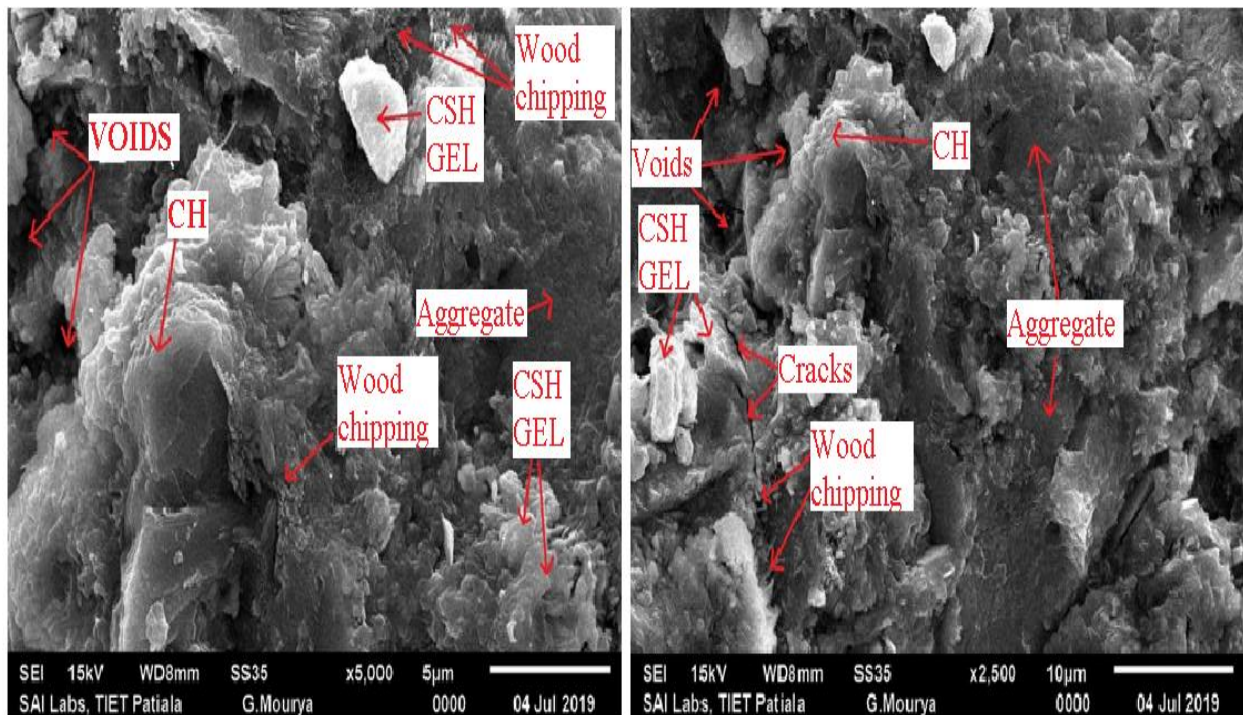


Figure 4.22 SEM of Sample Containing 5 % Wood Chipping

Discussion: - As we can see SEM image shows the formation of calcium silicate hydrate (CSH) and significant amount of formation of unreacted calcium hydroxide or portlandite (CH). It can also be seen that wood chipping has not taken part in the chemical reactions and near the wood chipping either there are cracks or the voids are left this could be the reason of decrease in the compressive and split tensile strength of concrete.

4.4.2 SEM Analysis of Sample Containing 10 % Wood Chipping

Figure 4.23 shows the scanning electron microscopic (SEM) analysis of sample containing 10 % wood chipping as partial substitution of fine aggregate after the pretreatment with water at w/c

= 0.44. At two different magnification level. And after seeing the picture the following observation were obtained and these are described in the discussion below the figure.

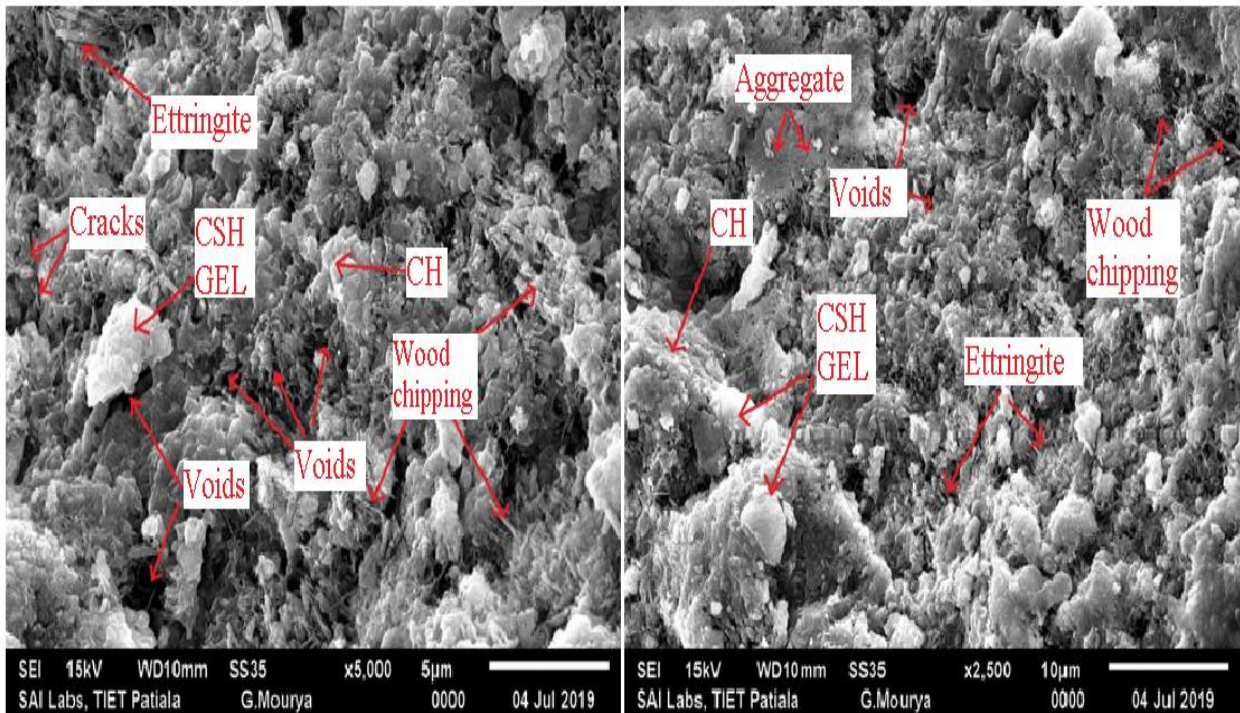


Figure 4.23 SEM of Sample Containing 10 % Wood Chipping

Discussion: - As it can be observed that 10 % wood replacement shows similar formation as that shown in 5 % wood but here due to the more wood the voids are much more than that of concrete contain 5 % wood and here we can observe that is formation of Ettringite as well this may be due to more wood content and this will harm the concrete as it can swell over a period of time which reduce the durability properties of concrete.

4.4.3 SEM Analysis of Sample Containing 5 % Wood Chipping and 12% Silica Fume as substitution of Cement

Figure 4.24 shows the scanning electron microscopic (SEM) analysis of sample containing 5% saw wood dust as partial substitution of fine aggregate after the pretreatment with water at $w/c = 0.44$ and 12 % Silica fume as partial substitution of cement. At two different magnification level. And after seeing the picture the following observation were obtained and these are described in the discussion below the figure.

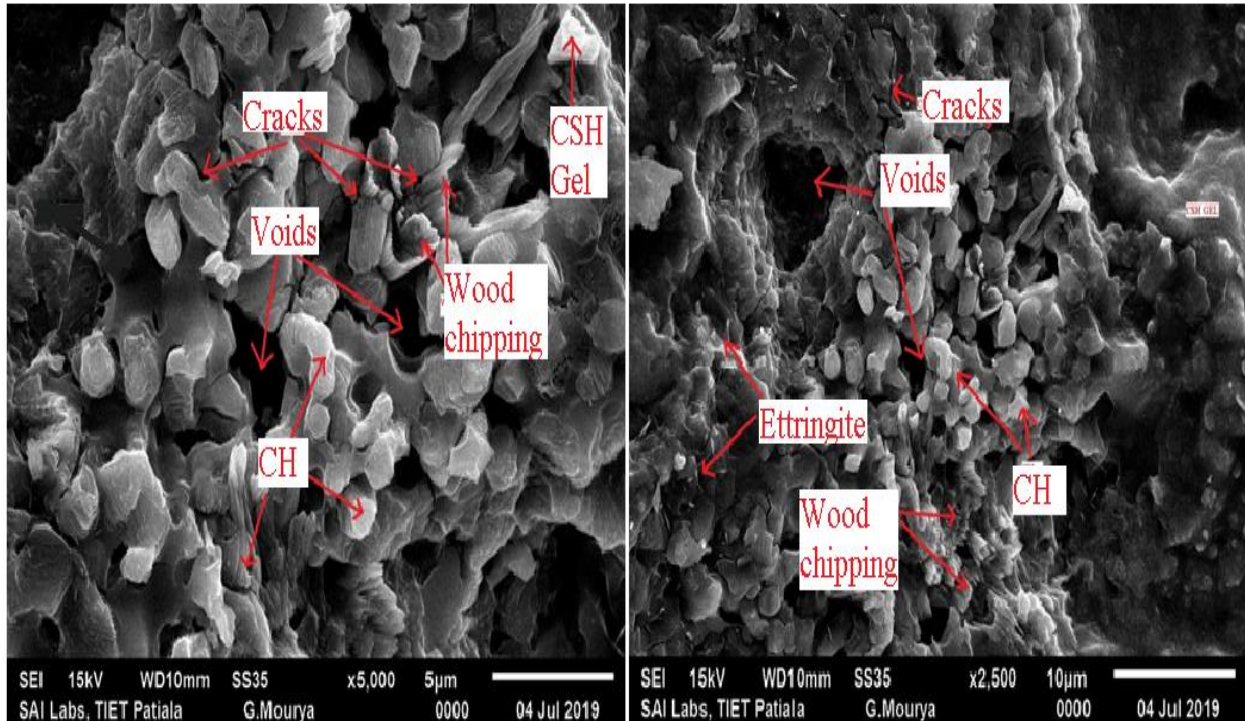


Figure 4.24 SEM of Sample Containing 5 % Wood Chipping & 12% S.F

Discussion: - As it can be observed that 5 % wood replacement as fine-aggregate and 12 % silica fume replacement as cement shows similar forms of reaction but it shows less number of voids left the reason is the voids are filled with the silica fume which is added as substitution of cement. And here we can observe that is formation of Ettringite is less as compare to 10 % wood.

4.4.4 SEM Analysis of Sample Containing 5 % Wood Chipping after Sodium Silicate treatment

Figure 4.25 shows the scanning electron microscopic (SEM) analysis of sample containing 5% saw wood dust as partial substitution of fine aggregate after the pretreatment with sodium silicate at $w/c = 0.44$. At two different magnification level. And after seeing the picture the following observation were obtained and these are described in the discussion below the figure 4.25.

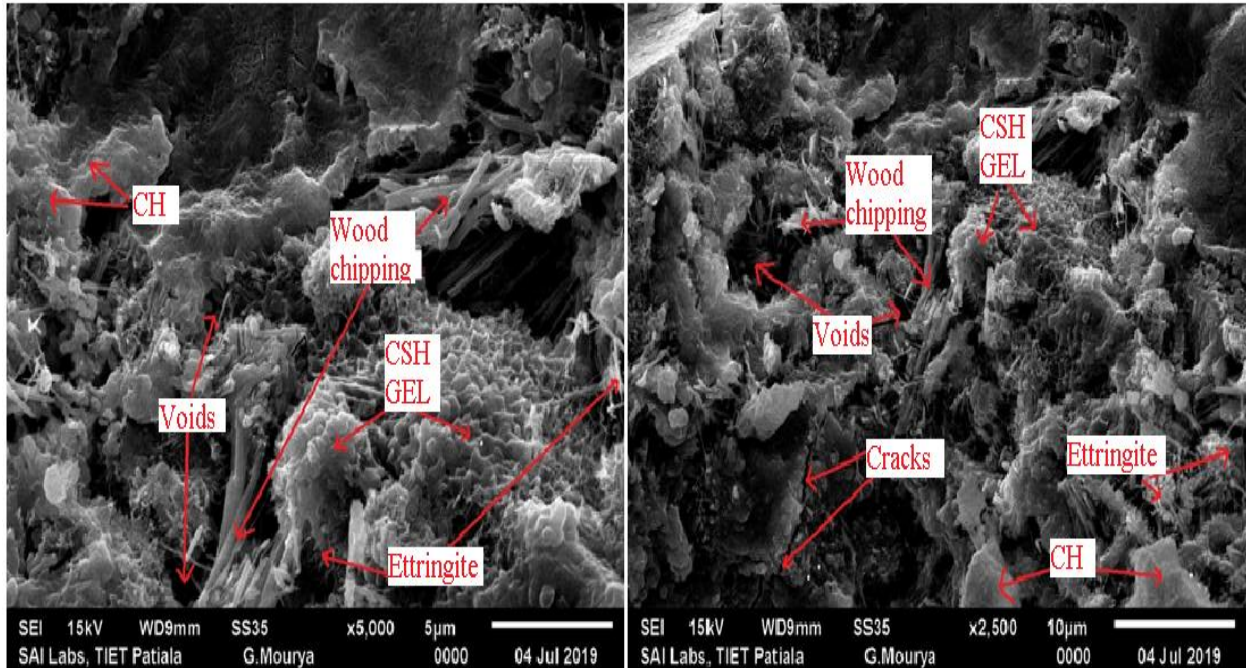


Figure 4.25 SEM of Sample Containing 5 % Wood Chipping after treatment with Sodium silicate

Discussion: - As we can see SEM image shows that there is much more formation of calcium silicate hydrate (CSH) as compared to all previous images this may be the reason for obtaining much more strength than the previous all cases and we can also see there is significant amount of formation of unreacted calcium hydroxide or portlandite (CH). It can also be seen that wood chipping has taken more part in the chemical reactions as compared to wood chipping after pretreatment with water.. And there is little formation of Ettringite also which can affect the durability properties after the passage of time.

CHAPTER 5

OBSERVATIONS AND CONCLUSIONS

5.1 GENERAL

This current study was done firstly to mix design the concrete comprising saw wood dust as partial substitution of fine aggregate based on its density and compressive strength criteria. Secondly, to observe the effect of replacement of wood saw dust as fine aggregate with sand on various others concrete properties like split tensile strength and durability of concrete.

5.2 CONCLUSIONS

After all the analization I have observed the following conclusions of different properties of concrete comprising wood saw dust as partial substitution of fine aggregate.

5.2.1 Workability

The workability of the concrete obtained by replacing wood saw dust as fine aggregate after pretreatment with water increase as the level of replacement increases at the water cement ratio of 0.5 but if we decrease the water cement ratio from 0.5 to 0.44 workability shows lesser value than that of the mixture having 0.5 water cement ratio. And we can also conclude that at constant fine aggregate replacement and varying cement replacement with silica fume workability of mixture decreases. Lastly concluded wood after pretreatment with sodium silicate the workability of concrete increase than that of pretreatment with water. So based on all the research work we can conclude that the optimum content of replacement of wood chipping is 5% after pretreatment with sodium silicate & 5% wood as fine aggregate and 12% silica fume as cement.

5.2.2 Density of Fresh Concrete

Density of fresh concrete obtained by replacing wood saw dust as fine aggregate after pretreatment with water decrease as the as the level of replacement increases at the water cement ratio of 0.5. And if we decrease the water cement ratio from 0.5 to 0.44 the density of concrete further decreases. And we can also conclude that at constant fine aggregate replacement and

varying cement replacement with silica fume it shows the increasing trend. Lastly concluded wood after pretreatment with sodium silicate the density reduces very rapidly. So based on all the research work we can conclude that the optimum content of replacement of wood chipping is 5% after pretreatment with sodium silicate & 5% wood as fine aggregate and 12% silica fume as cement.

5.2.3 Compressive Strength

The compressive strength of concrete obtained by replacing wood saw dust as fine aggregate after pretreatment with water shows the decreased trend as the substitution percentage increases the strength decreases significantly at the water cement ratio of 0.5. And if we decrease the water cement ratio from 0.5 to 0.44 then the compressive strength increases but it can't match the compressive strength of control concrete. And we can also conclude that at constant fine aggregate replacement and varying cement replacement with silica fume it further shows the further increasing trend and Lastly concluded wood after pretreatment with sodium silicate the compressive strength increase as compared to that of after its treatment with water. So based on all the research work we can conclude that the optimum content of replacement of wood chipping is 5% after pretreatment with sodium silicate & 5% wood as fine aggregate and 12% silica fume as cement.

5.2.4 Split Tensile Strength

The split tensile strength shows the similar trend as that it was shown by compressive strength. The split tensile strength of concrete obtained by replacing wood saw dust as fine aggregate after pretreatment with water shows the decreased trend as the substitution percentage increases the strength decreases significantly at the water cement ratio of 0.5. And if we decrease the water cement ratio from 0.5 to 0.44 then the split tensile strength increases but it can't match the split tensile strength of control concrete. And we can also conclude that at constant fine aggregate replacement and varying cement replacement with silica fume it further shows the further increasing trend and Lastly concluded wood after pretreatment with sodium silicate the split tensile strength increase as compared to that of after its treatment with water. So based on all the research work we can conclude that the optimum content of replacement of wood chipping is 5% after pretreatment with sodium silicate & 5% wood as fine aggregate and 12% silica fume as cement.

5.2.5 Water Penetration Test

The penetration test of the concrete obtained by replacing wood saw dust as fine aggregate after pretreatment with water shows that the penetration resistant of the concrete decrease with increase of wood content and satisfactory results are obtained with 5% wood replacement and 12% cement replacement with silica fume.

5.2.6 RCPT

The rapid chloride permeability test of the concrete obtained by replacing wood saw dust as fine aggregate after pretreatment with water shows that the control concrete shows the moderate flow value and there was an overflow in 15 % and 20 % wood replacement and high flow values were shown by 5 and 10 % replacement level. However suitable results are obtained at 5% wood replacement and 12% cement replacement with silica fume and 5% wood chipping after pretreatment with sodium silicate. So the optimum value can be used where there is high concentration of rapid chloride ions.

5.2.7 Sorptivity

The sorptivity test of concrete obtained by replacing wood saw dust as fine aggregate after pretreatment with water shows that the rate of the soaking up of water of the concrete samples increases with increase in the replacement level of wood. However suitable results are obtained at 5% wood replacement and 12% cement replacement with silica fume and 5% wood chipping after pretreatment with sodium silicate.

5.3 APPLICATIONS OF STUDY

The concrete made by using wood chipping as partial replacement of fine aggregate can be used in various purposes in India like making concrete curbs used on the roads, making dividers on the roads in India and other uses can be in structures are different elements of the structures like Floor, Roof and Bridge Deck slabs.

It can also be used in structure like Masonry Blocks and Offshore Oil Structures as it make the concrete light in weight so by the use of this material we can save the money as well as we can make the environment friendly structures too.

5.4 SCOPE OF FUTURE STUDY

Since we have seen that at constant 5% wood replacement and after the inclusion of silica fume as 12 % substitution of cement the concrete shown the higher strength but it can't match the strength of control concrete. If further content of cement was replaced more than 12 % it may have achieved the higher strength than that of control concrete.

It was also observed that after pretreatment with sodium silicate strength was increased and to increase the strength further one can use cement replacement here also with silica fume.

As wood has lesser silica content and rice husk ash has more than the mixture of both can be used as a substitution of fine aggregate it may give the better results.

REFERENCES

- A. T. (2015) ‘Standard Method of Test for Surface Resistivity Indication of Concrete ’ s Ability to Resist Chloride Ion Penetration Surface Resistivity Indication of Concrete ’ s Ability to Resist Chloride Ion Penetration’, (C), pp. 1–8. doi: 10.1520/C1202-12.2.
- ã, T. Y. Lo, Tang, W. C. and Cui, H. Z. (2007) ‘The effects of aggregate properties on lightweight concrete’, 42, pp. 3025–3029. doi: 10.1016/j.buildenv.2005.06.031.
- Ahmed, W. *et al.* (2018) ‘Effective use of sawdust for the production of eco-friendly and thermal-energy efficient normal weight and lightweight concretes with tailored fracture properties’, *Journal of Cleaner Production*. Elsevier Ltd, 184, pp. 1016–1027. doi: 10.1016/j.jclepro.2018.03.009.
- Akkaoui, A., Caré, S. and Vandamme, M. (2017) ‘Experimental and micromechanical analysis of the elastic properties of wood-aggregate concrete’, *Construction and Building Materials*. Elsevier Ltd, 134, pp. 346–357. doi: 10.1016/j.conbuildmat.2016.12.084.
- Ameri, F. *et al.* (2019) ‘Optimum rice husk ash content and bacterial concentration in self-compacting concrete’, *Construction and Building Materials*. Elsevier Ltd, 222, pp. 796–813. doi: 10.1016/j.conbuildmat.2019.06.190.
- Bederina, M. *et al.* (2007) ‘Effect of the addition of wood shavings on thermal conductivity of sand concretes: Experimental study and modelling’, 21, pp. 662–668. doi: 10.1016/j.conbuildmat.2005.12.008.
- Bederina, M. *et al.* (2009) ‘Effect of the treatment of wood shavings on the physico-mechanical characteristics of wood sand concretes’, *Construction and Building Materials*. Elsevier Ltd, 23(3), pp. 1311–1315. doi: 10.1016/j.conbuildmat.2008.07.029.

- Bederina, M. *et al.* (2012) ‘Drying shrinkage studies of wood sand concrete – Effect of different wood treatments’, *Construction and Building Materials*. Elsevier Ltd, 36, pp. 1066–1075. doi: 10.1016/j.conbuildmat.2012.06.010.
- Coatanlem, P., Jauberthie, R. and Rendell, F. (2006) ‘Lightweight wood chipping concrete durability’, *Construction and Building Materials*, 20(9), pp. 776–781. doi: 10.1016/j.conbuildmat.2005.01.057.
- Corinaldesi, V., Mazzoli, A. and Siddique, R. (2016) ‘Characterization of lightweight mortars containing wood processing by-products waste’, *Construction and Building Materials*. Elsevier Ltd, 123, pp. 281–289. doi: 10.1016/j.conbuildmat.2016.07.011.
- IS:5816-1999, R. 2004 (2004) ‘Splitting tensile strength of concrete’, *Bureau of Indian Standards, New Delhi*.
- IS-4031 (Part V) (1988) ‘Methods of Physical Tests for Hydraulic Cement-Determination of Initial and Final Setting Times’, *Bureau of Indian Standards, New Delhi*.
- IS: 650 and IS 650 (1991) ‘Specification for Standard Sand for Testing Cement’, *Bureau of Indian Standards*, (May 1991).
- IS:2386 (Part III) (1963) ‘Method of Test for aggregate for concrete.’, *Bureau of Indian Standards, New Delhi*, p. (Reaffirmed 2002).
- IS:8112-2013 (2013) ‘IS 8112: 2013, Ordinary Portland Cement, 43 Grade — Specification, Bureau of Indian Standards, New Delhi’, *Bureau of Indian Standards, New Delhi*, (March).
- IS 10262 (2009) ‘Guidelines for concrete mix design proportioning’, *Bureau of Indian Standards, New Delhi*, pp. 1–21.
- IS 4031(Part 6), I. S. (2005) ‘Indian Standard Is: 4031 (Part 6) - 1988 (Reaffirmed 2005).

Methods Of Physical Tests For Hydraulic Cement Part 6 Determination Of Compressive Strength Of Hydraulic Cement Other Than Masonry Cement (First Revision)', *Bureau of Indian Standards, New Delhi*, pp. 1–3. Available at: <https://ia800400.us.archive.org/0/items/gov.in.is.4031.6.1988/is.4031.6.1988.pdf>.

- IS 456:2000 (2006) 'Plain and reinforced concrete-Code of Practice (Fourth Revision)', *Indian Standard*, p. 114.
- Kisan, M. *et al.* (1963) 'Indian Standard 2386 (Part I): Method of Test for aggregate for concrete- Particle size and shape', *Bureau of Indian Standards, New Delhi*, p. (Reaffirmed 2002).
- Kisan, M. *et al.* (1988) 'Indian Standard 4031 (Part IV): Methods of Physical Tests for Hydraulic Cement', *Bureau of Indian Standards, New Delhi*.
- Li, M., Khelifa, M. and Ganaoui, M. El (2017) 'Mechanical characterization of concrete containing wood shavings as aggregates', pp. 587–596. doi: 10.1016/j.ijsbe.2017.12.005.
- Mohammed, B. S., Abdullahi, M. and Hoong, C. K. (2014) 'Statistical models for concrete containing wood chipping as partial replacement to fine aggregate', *Construction and Building Materials*. Elsevier Ltd, 55, pp. 13–19. doi: 10.1016/j.conbuildmat.2014.01.021.
- Paramasivam, P. and Loke, Y. O. (1980) 'Study of sawdust concrete', *International Journal of Cement Composites and Lightweight Concrete*, 2(1), pp. 57–61. doi: 10.1016/0262-5075(80)90008-1.
- Prusty, J. K., Patro, S. K. and Basarkar, S. S. (2016) 'Concrete using agro-waste as fine aggregate for sustainable built environment – A review', *International Journal of Sustainable Built Environment*. The Gulf Organisation for Research and Development, 5(2), pp. 312–333. doi: 10.1016/j.ijsbe.2016.06.003.
- S, A. and K, G. (2018) 'Investigation on Mechanical properties of Partial replacement of Saw-

Dust to Fine-Aggregate in Coconut-Shell Concrete’, *International Journal of Engineering & Technology*, 7(2.12), p. 415. doi: 10.14419/ijet.v7i2.12.11508.

- Sukesh, C. *et al.* (2013) ‘Partial Replacement of Sand with Quarry Dust in Concrete’, *International Journal of Innovative Technology and Exploring Engineering*, 2(26), pp. 2278–3075.
- Taoukil, D. *et al.* (2013) ‘Moisture content influence on the thermal conductivity and diffusivity of wood – concrete composite’, *Construction and Building Materials*. Elsevier Ltd, 48, pp. 104–115. doi: 10.1016/j.conbuildmat.2013.06.067.
- Test, C. C. *et al.* (2004) ‘ASTM C 1585:2004 Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes’, *American Society for Testing and Materials.*, pp. 1–6. doi: 10.1520/C1585-13.2.
- Xu, R. *et al.* (2019) ‘Utilizing wood fiber produced with wood waste to reinforce autoclaved aerated concrete’, *Construction and Building Materials*. Elsevier Ltd, 208, pp. 242–249. doi: 10.1016/j.conbuildmat.2019.03.030.
- Zhu, H. *et al.* (2019) ‘Influence of rice husk ash on the waterproof properties of ultrafine fly ash based geopolymer’, *Construction and Building Materials*. Elsevier Ltd, 208, pp. 394–401. doi: 10.1016/j.conbuildmat.2019.03.035.