CAPITAL UNIVERSITY OF SCIENCE AND TECHNOLOGY, ISLAMABAD

Life Cycle Assessment of Concrete with Agricultural Waste for its Practical Utilization in Construction Industry

by

Syed Ali Shahbaz Shah

A thesis submitted in partial fulfillment for the degree of Master of Science

in the

Faculty of Engineering
Department of Civil Engineering

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This work is dedicated to all my valuable treasures in life, to my:

Respected Family

Which is my love and strength:

Thank you for always helping me through every difficult time of my life and for Encouraging me to move forward. You have been always a sign of love and happiness for me.

CERTIFICATE OF APPROVAL

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Syed Ali Shahbaz Shah

Abstract

In recent years, ecological concerns are on the top like carbon emissions due to many polluting activities. Construction sector is globally responsible for resource depletion, waste material production, and additional containments alongside Carbon Dioxide CO_2 mainly. It is one of the fundamental causes of waste production and ozone depletion named Greenhouse Gas emission (GHG). Concrete is a vital portion of today's infrastructure developments. Cement is a usually involved binding material for concrete. Construction industry is progressing rapidly to meet the increased demand of society. Concrete is the most widely used construction material and its consumption has increased tremendously over the years. Cement is a fundamental binder material in concrete. Subsequently, the annual cement production was reported almost 4.4 billion tons in 2021 world-widely which is responsible for 7% of annual global carbon emissions. These emissions have significant negative environmental impacts, ultimately causing ozone depletion and climate change. The consumption of cement can be reduced by using alternative waste materials such as agricultural waste fibers and respective ashes. Hence, researchers, overall are attempting to decrease the cement utilization in concrete to reduce CO_2 emissions consequently. In this research, commonly available natural fibers like Sugarcane Bagasse Ash (SCBA), Rice Husk Ash (RHA), and Wheat Straw Ash (WSA) have been utilized in a substitution portion for cement in concrete like 10% WSA, 15% RHA and 20% SCBA. This literature focused on life cycle assessment of natural fibers utilization in construction industry. On the life cycle assessment scale, natural fiber's adoption as a cement replacement is verified in this study. One cubic meter concrete sample of ratio 1:2:4 was adopted in input parameters of Open LCA software database. Hence climate change - GWP100 utilization for 20.5 Kg/cu.m wheat straw utilization, it was 1.65E+02 kg CO_2-Eq while for 30.75 KG/cu.m rice husk, it was 1.57E+02 kg CO_2-Eq and bagasse showed minimum quantity of all that is 1.52E+02 kg CO_2-Eq for 41 Kg/cu.m. Control mix of 1:2:4 showed highest quantity of carbon emissions that is 1.81E+02 kg CO_2-Eq. While ozone depletion also experienced same trend. Ozone depletion

is considered in terms of chlorflourocarbon-11 was found to be maximum for control mix of 1:24 with quantity of 6.21E-06 kg CFC-11-Eq, wheat straw utilization produced 4.78E-06, while rice husk released ozone harming gases in a quantity of 4.57E-06 CFC-11-Eq. Bagasse emitted 4.69E-06 kg CFC-11-Eq ozone harming gases. When fibers are burnt to ashes, similar pattern is observed. But on the structural point of view, it is recommended that in depth study is required to compare properties both concrete i.e., with natural fibers and with natural fiber's ash. Although, to utilize natural fiber's ash in concrete as a cement replacement, a proper burning technique along with specified furnace on specified temperature is essential so that fellow gases of CO_2 harming ozone stratosphere are restricted somehow.

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Abbreviations

Al_2O_3	Aluminium Oxide
ALOP	Agricultural Land Occupation Potentials
APOS	Allocation at the Point of Substitution
ASTM	American Society for Testing and Materials
BA	Bagasse Ash
BC	Before Christ
CaO	Calcium Oxide
CFC	Chlorofluorocarbon
CH	Chemical name of Methylene
CO_2	Carbon Dioxide
CSH	Calcium Silicate Hydrate
DCB	Dichlorobenzene- Formula for Freshwater, Human, Marine and Terrestrial Ecotoxicity
ECC	Engineered Cementitious Composite
EQ	Equivalent
EU	Europe
FA	Fly Ash
FAO	Food and Agriculture Organization
FDP	Fossil Depletion Potentials
Fe_2O_3	Ferric Oxide
FEP	Freshwater Eutrophication Potentials
FETP	Freshwater Eco-toxicity Potentials
FRC	Fiber-Reinforced Concrete
GDP	Gross Domestic Product

GGBS	Ground Granulated Blast Slag
GHG	Greenhouse Gases
GP	Glass Powder
GRHA	Ground rice husk ash
GWP	Global Warming Potentials
HFC	Hydrofluorocarbon
HTTP	Human Toxicity Potentials
IPCC	Intergovernmental Panel on Climate Change
IRP	Ionising Radiation Potentials
ISO	International Organization for Standardization
K_2O	Potassium Oxide
KG	Kilo-Gram
LCA	Life Cycle Assessment
LCIA	Life Cycle Inventory Analysis
MDP	Metal Depletion Potentials
MEP	Marine Eutrophication
METP	Marine Ecotoxicity Potentials
MgO	Magnesium Oxide
MK	Metakaolin
MPa	Mega Pascal, Unit of Pressure
Na_2O	Sodium Oxide
NLTP	Natural Land Transformation Potentials
NMVOC	Non-methane Volatile Organic Compounds
NO	Nitrogen Oxides
NP	Natural Pozzolana
O_3	Ozone
ODP	Ozone Depletion Potentials
OPC	Ordinary Portland Cement
PC	Portland Cement
PMFP	Particulate Matter Formation Potentials
POFP	Photochemical Oxidant Formation Potentials
PP	Polypropylene

RHA	Rice Husk Ash
RSA	Rice Straw Ash
SCB	Sugarcane Bagasse
SCBA	Sugarcane Bagasse Ash
SCC	Self-compacting Concrete
SCM	Secondary Cementitious Materials
SF	Silica Fumes
$\mathbf{SF_6}$	Sulphur Hexafluoride
$\mathbf{SiO_2}$	Silica
SO	Sulphur Oxide
$\mathbf{SO_2}$	Sulphur Dioxide
$\mathbf{SO_3}$	Sulphur Trioxide
TAP	Terrestrial Acidification Potentials
TETP	Terrestrial Ecotoxicity Potentials
ULOP	Urban Land Occupation Potentials
USA	United States of America
USD	United States Dollar
VA	Volcanic Ash
WDP	Water Depletion Potentials
WHO	World Health Organization
WSA	Wheat Straw Ash
WT	Unit of Electrical Power

Chapter 1

Introduction

1.1 Background

Now a days, developed countries are experiencing many drastic problems and ecological concerns are on the top like carbon emissions due to many polluting activities. Construction sector is major part of pollution in each realm. Construction sector is overwhelming factor globally responsible for resource depletion, unwanted material production, vigour utilization and additional containments alongside Carbon Dioxide CO_2 mainly [1, 2]. With increment in the population of world, need for construction increases automatically. Latest improvement in construction overwhelmingly depends on non-climate agreeable structure advancements. Besides, building development for the most part creates a lot of carbon, which is the main source of environmental change consequently. The worldwide development industry represents around 40% of essential energy use and 33% of worldwide fossil fuel by-products [1].

The Construction business consumes countless assets and energy. It is one of the fundamental causes of waste production and ozone depletion named as Greenhouse Gas emission (GHG). Being the biggest supporter of the age of GHG, the development division damages the environment step by step in expanding sequence consequently. According to the estimated idea of "Green Building Council of the United Kingdom", absorption of CO_2 in the air will be twice in the decade of 2100 [3]. Concrete is a vital portion of today's infrastructure in every realm of the world. In actual fact, concrete manufacturing is assessed at almost thirteen billion tons per year on a universal count [4]. It is by and large acknowledged that one of the frequently used man-made material on the Earth is concrete and that is due to the various benefits, toughness, reasonableness, and cost of this material. Binder material, involved in the manufacturing of concrete is the cement. Cement Production is causing up-to 7% of universally emissions and this figure is increasing day by day as need for concrete in building sector is rising [5]. In year 2021, the total quantity of cement production globally was according to an estimate was 4.4 billion tons [6]. Overall production of cement from year 1990 till estimated era of 2030 can be seen in the figure 1.1 [7].

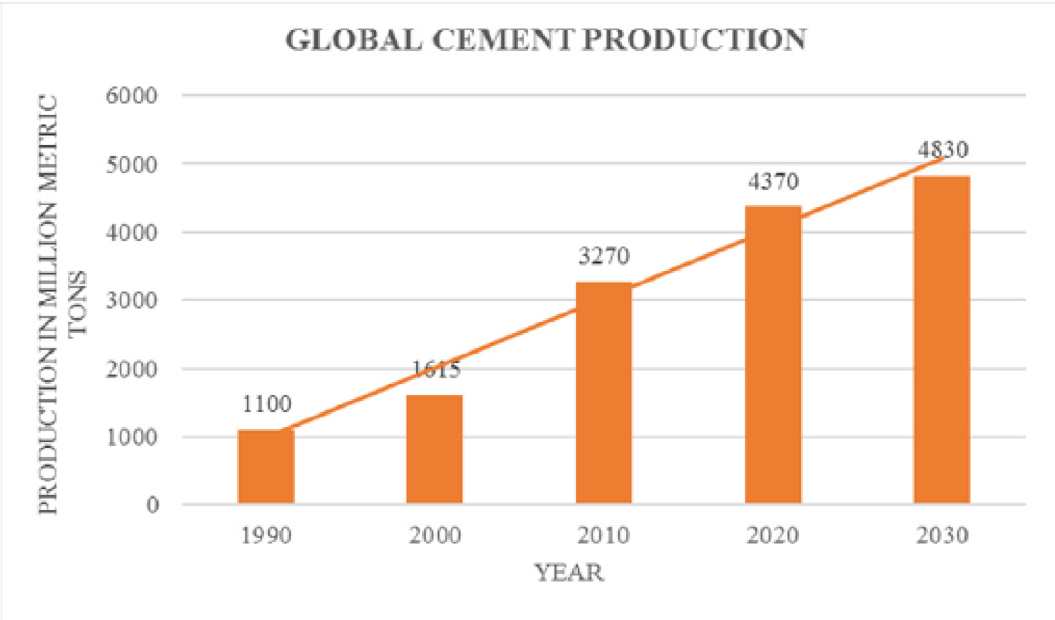

FIGURE 1.1: Estimated Cement Production from 1990-2030 [7]

The assembling of concrete polishes off enormous amounts of regular assets like shale, earth, gypsum, water and petroleum derivatives, to give some examples. The assembling of concrete causes a lot of GHG emissions causing a dangerous atmospheric deviation and environmental change. The foremost GHG discharge is the CO_2. Concrete constituents are the key origins of discharging plethora of CO_2 in the air. Studies demonstrate that one ton of concrete produces an equivalent measure of CO_2 to the climate and causes ecological degradation. As stated earlier, concrete and main constituent of concrete that is cement is mainly responsible of major part of carbon emissions. Concrete can't be taken as isolated due to its manufacturing and then transportation from place of manufacturing to the construction site [6]. Following figure 1.2 illustrates emissions of CO_2 from concrete.

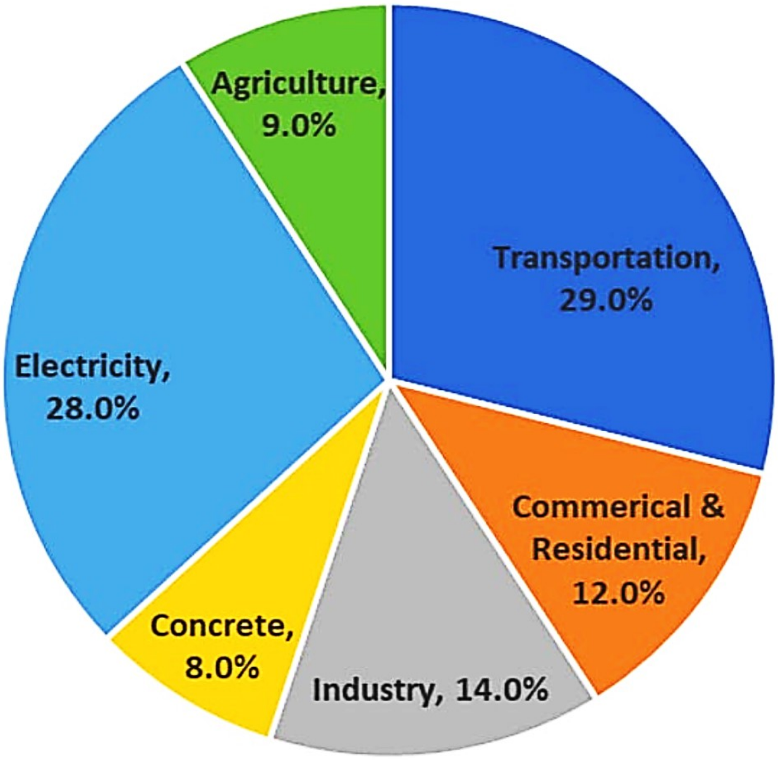

Figure 1.2: CO_2 Emissions Globally in 2020 [8]

Therefore, widespread extension in the development business has prompted a remarkable ascent in a dangerous atmospheric deviation and environmental change. Likewise, analysts overall are attempting to decrease the cement utilization in the concrete while enhancing the concrete characteristics. In this specific situation, analysts are attempting to utilize "SCBA, RHA, and WSA" etc., to give some examples [3, 7].

Adoption of above mentioned natural fibers is sustainable addition to the construction industry dealing with problem associated of dumping those fibers because of open burning hence prompting more CO_2 emissions. Addition of these fibers as a cement substitution for concrete address both issue like instead of open burn for more environmental problems, utilization to lessen CO_2 radiations from concrete due to cement industry. Hence fibers would be handy substitute instead of being waste material and causing more carbon emissions when burned in open fields. So, environmental impact of these materials including transportation process in concrete manufacturing must be examined by life LCA.

1.2 Research Motivation

During the recent decades, environmentally friendly construction has been emphasized because of some underlying factor including but not limited to diminution of natural resources, ecological deprivation and GHG pollution. Sustainable construction in necessity for today's era due to enhanced CO_2 emissions from up-rise in construction. Cement is the major contributor of emission resulting in global warming and causing acid rain, extreme weather and so on [8]. Furthermore various natural fibers materials like WSA, RHA and SCBA etc. which can be utilized in concrete to reduce carbon emission [9]. During the previous many years, worries on ecological crumbling, energy utilization and materials shortage have pushed the improvement of life cycle approaches pointing the natural reporting of items. Construction sector was 39% responsible for Greenhouse gases emissions in 2018 and 11% of those emissions was due to construction materials like cement. "The United Nation's Conference of Parties" signed a treaty of "Paris Agreement" in 2015 to take any essential step for reducing global warming 1.5^{o} C beyond preliminary development. The attention on sustainable development is presently applicable as far as structure's functional stage, energy requirement, funds, release, production of waste, rehabilitation and the finish of-life stages. LCA, a methodology that assesses the natural effects of items/administrations from fresh material securing to wastage removal [10, 11].

1.3 Problem Statement

Construction industry is progressing rapidly to meet the increased demand of society. Concrete is the most widely used construction material and its consumption has increased tremendously over the years. Cement is a fundamental binder material in concrete. Subsequently, the annual cement production was reported almost 4.4 billion tons in 2021 world-widely which is responsible for 7% of annual global carbon emissions. These emissions have significant negative environmental impacts, ultimately causing ozone depletion and climate change. The consumption of cement can be reduced by using alternative waste materials such as agricultural waste fibers and respective ashes. In literature, the comparable properties of concrete having natural fibers (i.e., wheat straw, rice husk, and sugarcane bagasse) and respective ashes are reported. However, the Life Cycle Assessment (LCA) of these natural fibers/ashes utilization in concrete is important to be explored before it's bulk production for practical implementation [3, 13, 14].

1.4 Objectives of the Study

The overall aim of this research program is to reduce CO_2 emissions caused by construction materials by using locally and abundantly available natural fiber wastes. However, the specific objectives of this study are:

- The assessment of commonly available natural fibers in Pakistan from the literature.
- Life cycle assessment of fiber-based concrete (i.e., wheat straw, rice husk, and sugarcane bagasse as dispersed reinforcement and respective ashes as cement substitution) in order to evaluate carbon emissions and ozone depletion.
- Comparative evaluation of conventional concrete with concrete having fibers and ashes for sustainable concrete mix.

1.5 Scope of Work

This research provides a comparative analysis of carbon emissions due to natural fiber concrete conventional concrete but it has some limitations as well. Firstly, only three fibers have been utilized of all the available natural fibers i.e. Rice Husk (RH), Wheat Straw (WS) and Sugarcane bagasse (SCB) along with respective ashes. Selection of these fibers is made upon there availability in Pakistan. Being an agricultural country, these fibers are commonly available in Pakistan. Carbon emissions from transportation have been derived from previous literature. Furthermore, this research utilizes Open LCA inventory rather than sampling data. From the 18 indicators of GHG obtained during Recipe Midpoint (H) method in

LCA, mainly indicators i.e. ozone depletion and climate change have been taken into considerations. Opted concrete mix ration of 1:2:4 is chosen from google medium as it suggests that Concrete grade M15 has concrete mix design of 1 part cement: 2 parts of fine aggregate: 4 parts of coarse aggregates. It is awesome and most ordinarily utilized grade. It is because of its compressive strength and benefits economically [15]. Structural properties of concrete have not been taken into consideration primarily.

1.6 Study Limitations

This research provides a comparative analysis of carbon emissions due to natural fiber concrete conventional concrete but it has some limitations as well. Firstly, only three fibers have been utilized of all the available natural fibers i.e. Rice Husk (RH), Wheat Straw (WS) and Sugarcane bagasse (SCB) along with respective ashes. Selection of these fibers is made upon there availability in Pakistan. Being an agricultural country, these fibers are commonly available in Pakistan. Carbon emissions from transportation have been derived from previous literature. Furthermore, this research utilizes Open LCA inventory rather than sampling data. From the 18 indicators of GHG obtained during Recipe Midpoint (H) method in LCA, mainly indicators i.e. ozone depletion and climate change have been taken into considerations. Opted concrete mix ration of 1:2:4 is chosen from google medium as it suggests that Concrete grade M15 has concrete mix design of 1 part cement: 2 parts of fine aggregate: 4 parts of coarse aggregates. It is awesome and most ordinarily utilized grade. It is because of its compressive strength and benefits economically [15]. Structural properties of concrete have not been taken into consideration primarily.

1.7 Brief Methodology

The stepwise methodology to conduct this research is given below in figure 1.4. To conduct literature review, research articles from Google Scholar were considered including widely cultivated crops in Pakistan and their easy availability. After that, practical implementations of the selected fibers i.e., RHA, WSA and SCB were observed alongside suitable proportions to be considered as replacement of cement. Carbon emissions from conventional concrete have been observed via literature to provide a comparison. After summarizing the data, conclusions were drawn i.e. use of fibers in concrete is practically suitable or not. Finally, a few recommendations for future research work are also provided.

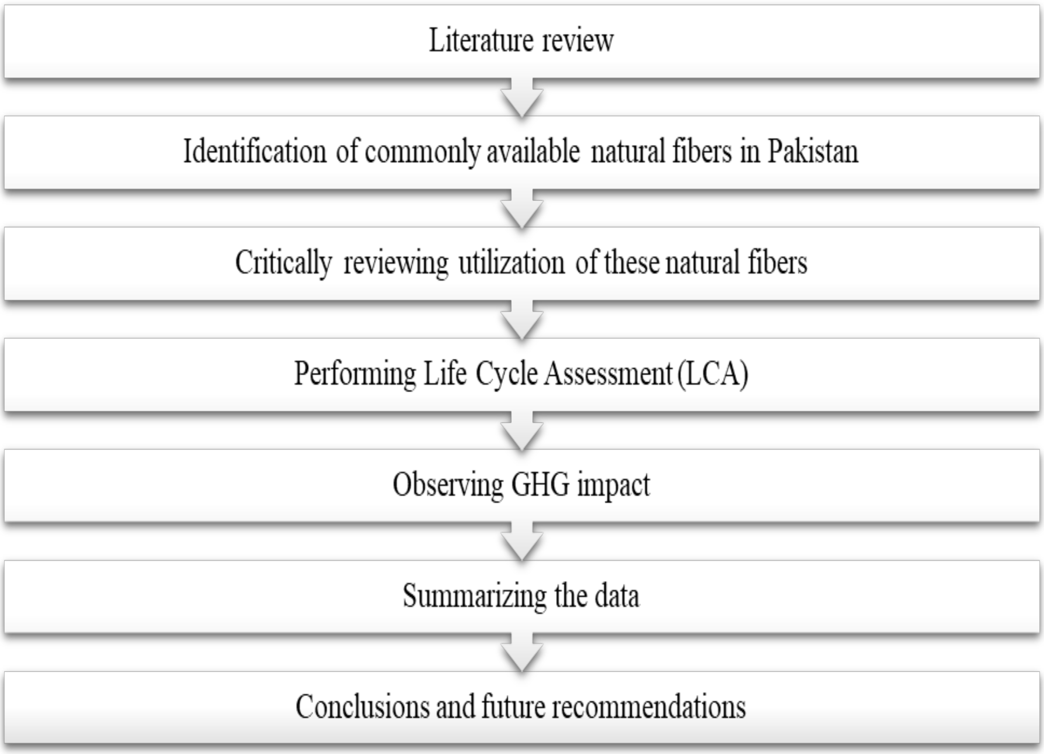

FIGURE 1.3: Brief Methodology for Research Work

1.8 Thesis Outline

This study consists of five chapters which are arranged in such a manner that readers can easily understand the idea behind research and how it is progressed step by step to achieve final goals. These five chapters and their essential details are given below:

Chapter 1 – Introduction, background details of this study, research motivation, overall aim and objectives as well as some limitations. A stepwise methodology is also provided in the end of this chapter to get a clear idea about conducted research.

Chapter 2 – Literature review, epigram introduction, progresses in construction industry, Greenhouse Gases mainly CO_2 emissions due to construction industry, identification of research gap and adoption of fibers in concrete as a cement replacement.

Chapter 3 – Methodology, provides description about selected software, Open LCA to perform proposed research work.

Chapter 4 – Results and discussions, gives carbon emissions calculated from the inventory of Open LCA software including emissions due to fuel while transportation of material.

Chapter 5 – Conclusion and recommendations, provides conclusions based upon results achieved in software and indicating future research work also.

Chapter 2

Literature Review

An overview of enhanced carbon emissions resulting in global warming due to construction industry is provided in this chapter. Furthermore, various natural fibers and their fractional substitution of cement material in concrete has been examined thoroughly. This chapter provides an effective description of already available knowledge in the primarily focussed area.

2.1 Background

Construction sector has a vital impact on human lives due to better standards of living and improvements in those standards. Population is increasing globally day by day; therefore well-established constructions and civil groundwork must be provided to accommodate more and more people. Building sector is providing its share in Gross Domestic Product (GDP) up to 13% universally and this figure is rising more quickly. According to a rough estimate, this figure may rise up-to 14.7% by year 2030. Along with positive impacts upon life style, construction sector is accountable for 35% CO_2 emissions globally and almost 45-65% discarded material is generated which occupies landfills. Additionally, there are some other Greenhouse Gases too which range up-to 30% generated due to activities being performed during construction. Conferring to the "IPCC guidelines for National Green-House Gas "inventories" GHG emanations omit carbon dioxide (CO_2), Methane (CH_4), Ozone (O_3), Nitrous oxide (N_2O), chlorofluorocarbon

(CFC_s), hydrofluorocarbon (HFCs), and sulphur hexafluoride (SF_6). Transportation and handling of construction resources is also considerable phenomenon which ranges likely 18% to the overall 30% Greenhouse gases emissions [16-18].

Preparation of construction materials results in almost every stage like factory preparation, transportation and up to disposal stage. This phenomenon is expressed in a fig. 2.1 [15].

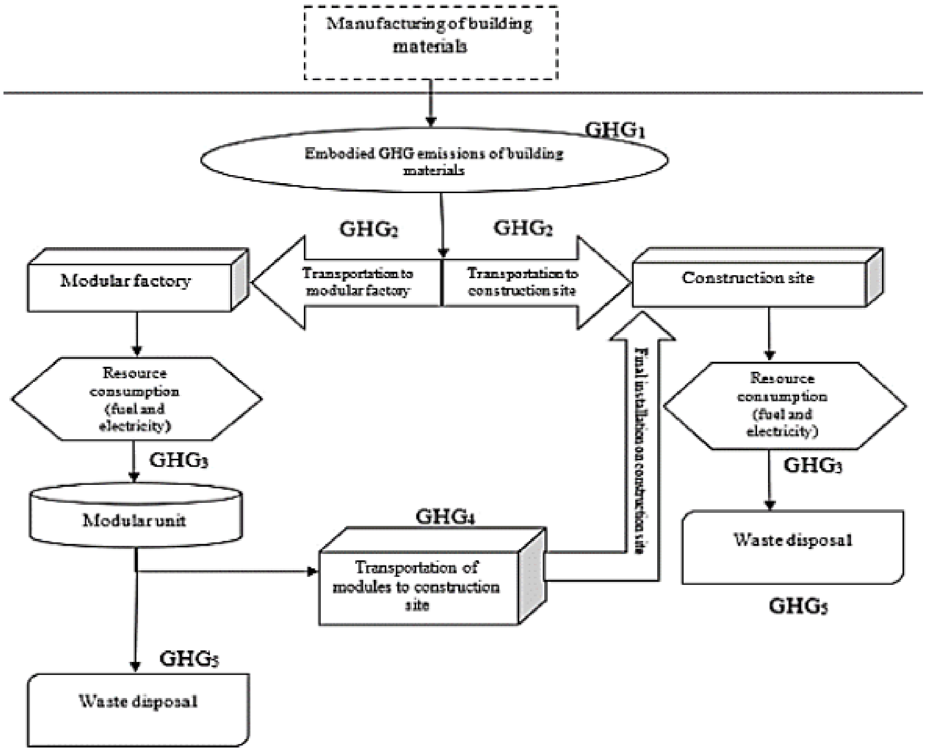

FIGURE 2.1: Greenhouse Gases Emission During Material Preparation [15]

Ecological issues like increasing temperature globally and excessively waste generation are being considered as the topics of global concerns. Correspondingly, environmental systems and performances of firms are being updated with time by starting to use life cycle management in their organization. To deal with this disturbing issue, corporations are now considering more sustainable and environmental-friendly techniques by implementing the life cycle assessment techniques in their association. Sustainable structures which can be named as ecological/eco-friendly construction, is getting popular because there is scarcity of resources and other issues form decision-making, planned and effective perspective [16]. In obtaining sustainability objectives, activities and procedures associated with construction sector are key factors. According to an estimation, a significant reduction in resources depletion i.e., 35% reduction in GHG, 40% reduction in total energy usage and 50% due to construction can be achieved in European (EU) republics if building management and activities of construction sector go to sustainability. Construction practices, if performed according to defined parameters, can be tricky to achieve sustainability more precisely. To preserve natural resources from a swift declination as well as less carbon society, there are some substitute materials which may be considered waste but these materials are being utilized in construction industry. European republics are bright example in this regard where according to a calculation, energy utilization can be minimized up-to 40%, overall CO_2 can be reduced by 35% and materials deprivation may be reduced by 50% if sustainable construction practices are applied [14].

2.2 Construction Industry

Construction industry is considered as old as human civilization and there are no proper proofs available justifying the initiate of this industry. There are some gestures according to archaeologists pointing out proper construction almost 4000 B.C. [19]. The architecture, engineering and construction sector in considered as one of the significant beneficial sector on the Earth due to it's contributions to economic growth. This sector makes a considerable contribution to the world economy. It is for sure that construction is necessary for any nation to be more prosper [15]. Construction is major source of strength for the frugality of any nation as a lot of professional or even nonprofessional jobs are attached to it. Construction does not work as a solo industry and it is always linked with other businesses hence contributing to the prosperity as a whole [10, 20, 21].

Universally, this sector provided approximately 13.6 trillion USD in 2021 and there are strong chances to increase this value up to 15.2 trillion. If this trend continues, this calculation is assumed to a figure 23 trillion USD in 2026. Pakistan is standing at number 5 in population overall in the world and construction is also playing vital impact in this country. Construction provided nearly 14.9 billion rupees to the GDP of Pakistan in year 2021 which was higher than previous year of 12.3 billion [22]. Figure 2.2 below is showing role of construction in GDP of Pakistan containing inputs from both i.e. provisional and federal government and revenue generated in billion from year 2017 till 2022's second quarter [17].

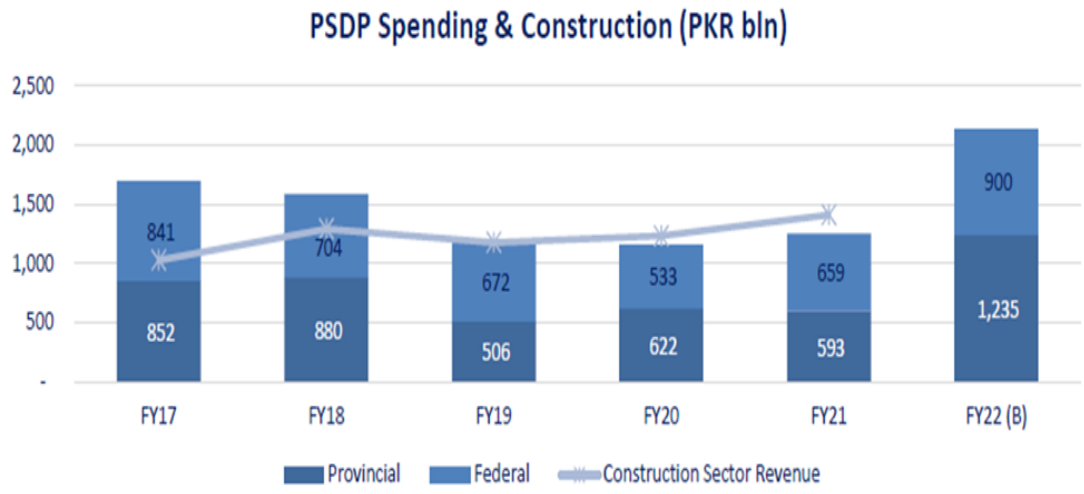

FIGURE 2.2: Construction Industry's share in GDP of Pakistan [17]

2.3 GHG Due to Construction

Usually construction industry lies in between building and operational phase which is bifurcated into housing and non-housing structures. Abandoned piece of land is utilized for construction of buildings, facilities and preservation of constructed structures correspondingly. Specifically, the development business is liable for using an enormous piece of resources that is up to 32% [16]. With the advances of civilization, explicitly due to worldwide environmental change, the retro gradation of framework has become continuously challenging and of the great considerations for present-day structural designing. Beneficial material for the structures around the world is concrete till date. Alongside usefulness and strength, which are as yet the central focal point of substantial quality administration what's more, substantial blend designs, the toughness property of cement concrete ought to be impressively viewed as a medicinal rule for the ascending interest for infrastructures degradation over span of time. In addition, monstrous creation what's more, utilization of concrete, which is the super binding piece of the substantial, presents a few huge ecological dangers. As per assessment, emissions are in between 0.8 to 1.3 tons per one ton manufacturing of the concrete with dry method, whereas figures due Sulphur dioxide SO_2 discharge seems exceptionally elevated likely depending upon fuel utilized class. Since one of the essential constituent is concrete utilized in the structure what's more, represents 8-10% of the complete CO_2, hence, critical need exist to swap for the concrete to lessen the ozone harming substances like CO_2 [21].

As the construction industry is presenting boom in its size, devastating environmental effects have also been experienced consequently which have both primary and secondary impacts. Pakistan is proving a lot of construction activities day by day and concrete utilization is increasing consequently. Figure 2.3 given below shows uprising cement production in Pakistan during span of yeas.

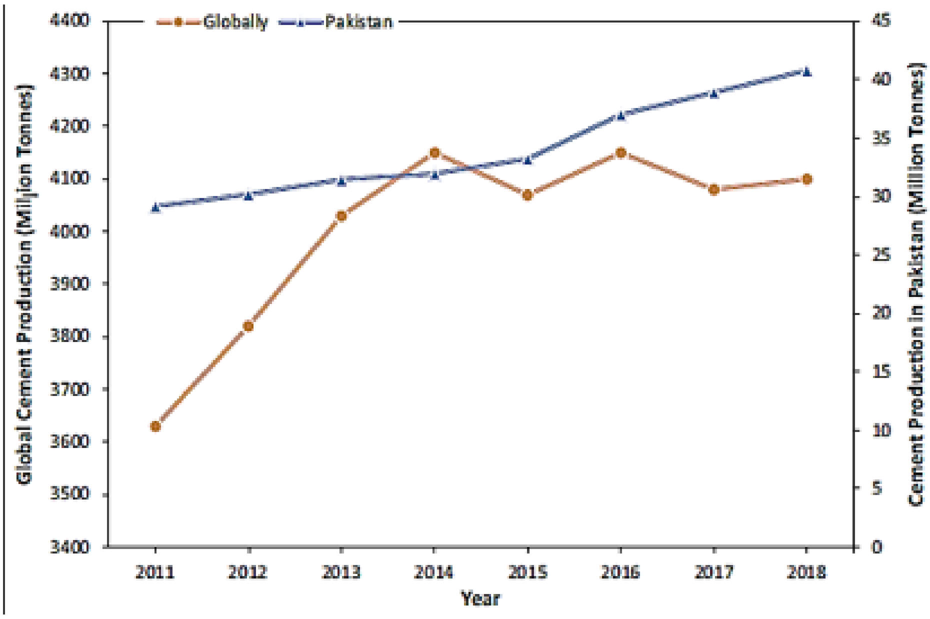

FIGURE 2.3: Cement Production Globally Vs Pakistan [22]

Universe is facing climbing temperature in atmosphere which is indication of global warming and this global warming has negative impacts upon our universal system for example abnormal changes in climates and weather durations. Pakistan offers under 1% of the world's ozone harming substance emanations, yet is encountering a portion of its most extreme effects [23]. Dangers due to global warming, which Pakistan is facing are:

- Pakistan encountered a dangerous intensity wave in March and April that sent temperatures taking off above 120∘F

- The intensity wave compromised the country's wheat crop, and the floods will upset cotton crops when food tacks are more earnestly to stop by because of the Ukraine war. Pakistan might be going to Russia for trade in wheat to enhance its low supplies.
- Human-caused environmental change made the intensity wave no less than multiple times more probable and as many as 1○C (1.8○F) more sultry on normal than it would have been without human discharges of GHG.
- Monsoon is happening more swiftly then previous years which resulted in devastating floods in the major parts of country.

Major reason behind this aggravating phenomenon is Greenhouse gases (GHG) which are releasing heat radiations to the universe and these gases are rising due to rise in human's own activities. Carbon Dioxide (CO_2) is the most dangerous gas among greenhouse gases because of it's profusion in the air and it can stay in the air over a long period of time. Carbon Dioxide (CO_2) can originate from nature as well as human's activities and it is directly linked with development which can be named as urbanization. The concrete business alone adds to around 7% of worldwide CO_2 discharges because of the method of the concrete creation procedure. Most of CO_2 emanation in concrete creation is because of calcination with thermal process of limestone in a concrete oven where quick lime and a huge amount of carbon dioxide are delivered. Chemical formula presented in equation below represents CO_2 formation due to chemical action in cement formation [16].

$$CaCo_3 + Heat \rightarrow CaO + CO_2$$

Urbanization is defined as transforming abandoned areas into well developed by construction hence causing carbon emission in the result [25]. Some of the harmful effects of carbon are illustrated in the **Figure 2.4** [17].

So this is the task to opt sustainable improvements in construction practices to minimize huge amount of CO_2 due to applying non-ecological resources in construction. As indicated by the Global researchers, the utilization of nature's resources has dramatically multiplied beginning around 1970 and proceeds to develop

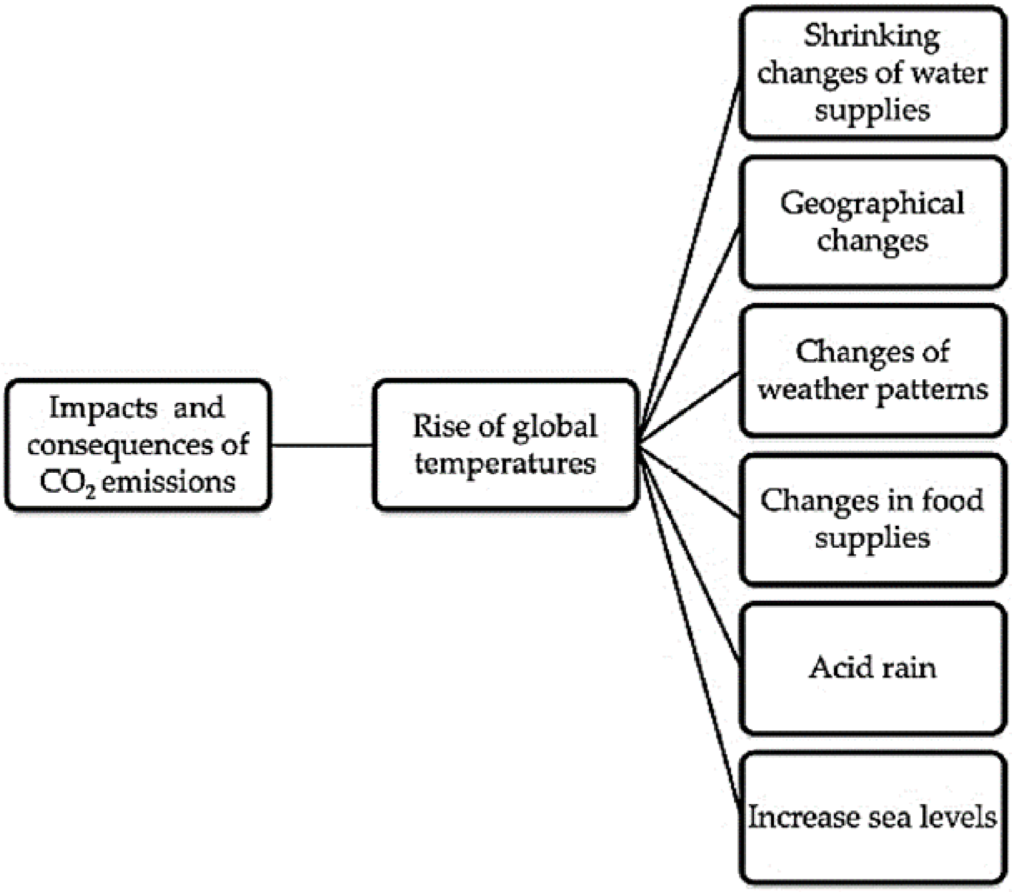

FIGURE 2.4: Harmful Effects of Carbon on Environment [17]

Building materials required for construction are haul out from natural sources and sustainable use of these materials is vital for persistent utilization [25, 26].

To minimize carbon emissions, there are four techniques through which the carbon impression could be diminished [22]

a) The progress to biofuels or eco-accommodating fills with diminished carbon content.

b) Further developing the CO_2 detention tool.

c) The progress from wet clinker assembling to dry clinker producing.

d) Addition of supplementary cementitious materials (SCMs) in concrete.

Between available options given above, concrete mixed with SCMs is the utmost suitable as well as practical other option so it might actually be opted in prepared blended concrete even during on site. Since a greater part of the accessible SCMs are by-products, their utilization in the development of cement gives ecological advantages like normal asset preservation and reutilizing of side-effects. Specialists have searched for elective restricting materials, which might actually be utilized instead of cement or possibly to be substitution up-to some degree. The utilization of agrarian-modern waste materials as SCMs, to some extent supplanting concrete substance, is a possible arrangement. Endeavours have been made to settle two central questions, one being the decrease of concrete substance in the assembling of cement, consequently diminishing the concrete creation and accordingly lessen the CO_2 gas discharges and the second is to reuse agrarian-modern by-products which would be unloaded in landfills and thusly causing extra natural concerns [22].

2.4 Carbon Emissions Due to Construction Industry

As previously discussed, there are numerous research's indicating an up-rise of CO_2 emissions due to enhanced construction activities/developments. Adnan, et al. [27] studied that development business is one of the main impetuses of financial areas. Nonetheless, the development business had moved toward a basic breaking point by which, in quite a long while, huge development building and foundations improvement will prompt an expansion in concrete creation. The development business had contributed altogether towards different contamination issues. This is on the grounds that the assembling of concrete has answered to be a significant wellspring of residue, harmful and carbon dioxide discharges, which is a critical donor of ozone depleting substances. Other than that, the development business had different natural effects on the grounds that it is at last making the dirt thick and impermeable to water. Although the development business itself adds to the turn of events, it's anything but a harmless to the ecosystem action on the grounds that numerous issues might exist in the event that this industry's advancement and improvement are not very much arranged. The development business would put a more prominent weight on the climate, especially because of discharge of residue elements along with CO_2 to the environment. Concrete, aluminium and steel are a few to be named construction materials regarded with huge CO_2 outflow. The development business is one of the greatest generators of contamination and has then turned into a basic issue. According to Bheel, et al. [28], From the absolute initial beginning of humankind advancements, concrete has accomplished broad barrenness. Concrete is fundamental material, utilized in construction projects all through the world. It has been considered as second most generally utilized material by the humankind. By and by, uplifted utilization of concrete will expand necessity of assets of its fundamental resources. The, tremendous usage of concrete is quickly improving, that prompts prerequisite for less valued and promptly present materials that stimulate equivalent or else significantly larger while being in concrete utilization. Cement is the vital element of concrete, whose creation adds enormous CO_2 discharges in the climate. One ton concrete preparation deliveries equal CO_2 in the climate consuming 1.6 tons of resources on other hand.

Razak, et al. [29] mentioned that Concrete is one of the principal constituent utilized in building because of its high toughness and strength, regardless of that it has a couple of weaknesses. The development of "self-compacting concrete (SCC)" is constantly associated to the utilization of "ordinary Portland cement (OPC)" as cover. In any case, concrete creation is lastingly connected to CO_2 emanation, which is damaging to the climate. In continuation, Bheel, et al. [30] mentioned that Concrete is the most flexible and most broadly utilized development material around the world.

Concrete is the best structure material when contrasted with blocks, bricks or steel, and so forth. Cement, sand, coarse aggregates, admixtures and water mix create concrete. More than ten billion tons of concrete are delivered yearly. Because of critical utilization of concrete, the interest for concrete is likewise expanding as time passes. The current utilization of concrete is assessed to associate with twelve million tons per year and this is extending step by step till date. Creation of Portland cement is extremely risky for climate as the heat and an unnecessary measure of CO_2 is generated. It's undeniably true about creation cement around one 1 ton depletes almost same, 1 ton of CO_2 straightforwardly in the air.

What's more, it is accounted that production of cement is accounted in between 5% to the 7% CO_2 emanations as of industries. Siddika, et al. [31] stated that

Sustainable/maintainable development is continuously becoming demanding because of natural and financial contemplations. Since the principal user of natural resources is the building area that delivers a huge mass of waste. Cement is a material that is widely utilized in development while requiring a huge supply of constituent hence it is expensive. World-wide CO_2 emanations due to cement are about 5-8% during production of cement and this cement is a significant part of concrete's mix design.

According to Tayeh, et al. [21], With the advances of development, explicitly in view of worldwide environmental change, the retro gradation of foundation has become dynamically challenging and one of the superb contemplations for contemporary structural designing. Concrete is as yet the fundamental, positive material around the world for structures. Alongside functionality and strength, which are as yet the major focal point of substantial quality administration and substantial mix designs, the toughness property of concrete ought to be significantly viewed as a soothing resolution for the rising interest for infra-structure decadence over the time span. Along with the cement's monstrous creation and usage, which is the best material for concrete binding, it represents a few critical ecological dangers.

As per assessment, emissions are in between 0.8 to 1.3 tons per one ton manufacturing of the concrete with dry method, whereas figures due Sulphur dioxide SO_2 discharge seems exceptionally elevated likely depending upon fuel utilized class. Utilization of the energy for the cement production also regarded as very immense like 100-150 kWT per ton in manufacturing of cement. Memon, et al. [22] studied that after water, 2nd mostly consumed material on Earth is the concrete has become an indispensable material for humans. Popularity of concrete upon other available engineering and developing resources is due to its accessibility, elasticity, along with toughness properties.

Regardless of its worldwide popularity, it has some drawbacks. One of them is not to be an environmentally appealing building material, mainly related to the carbon footprint of cement. Globally, it is recognized that the heavy use of concrete has adversary concussion on the atmosphere and human healthiness, and this is because the yield of concrete components emits an expressive number of

GHG. As per a Geological survey conducted by United States of America (USA), approximately 4.1°F109 tons of OPC was made in USA while it one of the major sources of GHG along as well as being an energy consuming material for buildings.

Being as the main construction material in the world, the boost in the construction and renovation of infrastructure utilization concrete, the requisition for cement is expected to accelerate significantly, thus 18 billion tons of concrete will be utilized by 2050. With such a requisition for concrete, it is expected that cement's utilization will also accelerate and hence the need to produce more cement. According to an estimation, 900 kg of CO_2 is emitted during 1000 Kg cement production. This CO_2 gas outflow is critical as it is confined to the discharges brought about by the cement production and different origins, for example, emanations created while excavating for natural aggregate, cement shipment from the production site, and the plant outflows. Notwithstanding CO_2, additional gases harmful for ozone are absorbed to the ozone layer and trigger acid raining for instance Sulphur Dioxide SO_2 and Nitrous Oxides (NO_x).

Aside from the ozone depleting gases outflows, creation of one ton of cement is responsible for almost 1.5 times raw materials. However the cement creation has been dramatically expanding throughout the long term, the cement production business is confronted with different difficulties, for example, deprivation in natural aggregates, expansion in energy costs, and critical decrease in CO_2 outflow necessities as per supportable objectives. Pakistan, likewise a non-industrial nation, cement creation was $4.08\times10_7$ tons in 2018 that is 1% of world-wide production.

Ahmad, et al. [32] stated that the ongoing utilization of concrete is inadmissible on the grounds that it consumes enormous amounts of both i.e. coarse and fine aggregates, prompting the exhaustion of natural assets/resources. Not exclusively is this, yet a billion tons of concrete are delivered consistently, prompting natural contamination because of the emanation of a massive amount of CO_2 during assembling system. Connection among development and sustainable environment has become pivotal in the designing area, and various convictions have as of late showed up in the development business connecting with limiting the impact of development on the climate. The overall creation of cement as the utilization of concrete is expanding, is projected to increase continually from 1990 to 2050. This trend seems to be normal since cement is the most utilized item on Earth after water. The business is quickly rising, particularly in emerging nations like China and India that have a significant requirement for concrete for lodging and framework. Last year, Pakistan delivered 41.14 million tons of concrete as per the "Worldwide Concrete Review" hence prompting more CO_2 emissions and resources depletion. Solanke and Pawade [33] also studied CO_2 emissions due to construction sector and stated that Concrete resembles the compound material used all through building development. Concrete is made as a conclusive product from water, cement, sand and aggregate. PCC is the widely utilized type of cement. PCC, that is harming the climate at an extremely high speed, can be considered as one of the primary parts in manufacturing of concrete. Concrete is building material that is an enormously preferred, and unavoidable piece of the development area is the cement that is the essential part in concrete manufacturing. Higher utilization of energy and ozone depleting substance emanations are nonetheless connected with the creation of cement. There are a few systems engaged with the development of cement, like the processing, pulverizing, and blending extents of some materials for example "alumina, iron, lime, gypsum, and silica". Binder and a layer that assists with restricting together different materials in concrete is the cement. Cement handling produces high amounts of CO_2. After the vehicle business and the power creation area, cement is the 3rd biggest producer of CO_2 worldwide due to human activities. Creation of single ton of cement is responsible around 0.97 ton of CO_2 is supposed to be delivered into the climate. CO_2 is considered by and large for an unnatural weather changes.

2.5 Utilization of Natural Fibers in Construction

In the light of environmental impacts associated due to construction sector, feasible improvement includes the utilization of optional but useful materials to support the unnecessary exhaustion of natural resources. Subsequently, the streamlining of the purposes of cement and sands in concrete is fundamentally important. By and by, various strengthening cementitious and Pozzolana materials, for example, SCBA)

, RHA) , Natural Pozzolana (NP), WSA and Metakaolin (MK) are consistently implanted within concrete-based materials to be fractional exchange of PC for both mechanical and hardiness demonstrations, while minimizing threat to the natural reserves of clinker due to concrete productiveness. The utilization of these results in concrete as a waste material diminishes the material expense as well as the waste administration cost consequently reducing CO_2 emissions also [31, 35].

There is something to be noticed that utilization of these fibers have occurred in both ways i.e. by burning and converting into ashes for instance Ahmad, et al. [32] utilized wheat straw ash to prepare self-compacting concrete while other approach is to prepare fiber by some means and the utilizing the fiber instead of ash of the fiber. In this scenario, Jiang, et al. [40] modified wheat straw fiber and then utilized it in the concrete to check mechanical properties of cement-based compounds. Same is the case with other two selected fibers i.e. rice husk and sugarcane bagasse and both of these approaches have been addressed in the results chapter later in this study.

Plant filaments, called as a green material also, are logically concern of different specialists in the development field to exhibit true capacity for usage in composites for venturing about practical turn of event. The philosophy of decrease in the natural effect of any item is basically the revaluation of expressed influence all through the entire life cycle, taking into account factors. Those factors are given below:

(1) Creation technique

(2) Improvement strategy

(3) Bundling

(4) Conservation

(5) Utilization

(6) Removal and additionally reusing

(7) As needs be, strands are extensively characterized into three classes: a. Normal plant filaments

b. Artificial filaments

c. Engineered fibers

Notwithstanding, regular fiber enjoy a few extraordinary benefits when contrasted with synthetic and engineered strands, like minimal expense, natural benefits, and abundant resources in quantity [37, 38]. Plant filaments are acquiring the consideration of analysts in the development material sciences field for the investigation of their capability to be utilized in composites, with the point of feasible turn of events. In the previous 10 years, the ubiquity of eco-accommodating plant fiber has been impressively upgraded due to their good properties, including modest and plentiful accessibility, adaptability in dealing with and utilization, low thickness, practically identical mechanical attributes, high solidarity to-weight proportions, and so forth [38-40]. Some commonly adopted natural fibers are shown in **Figure 2.5** [24]. Filaments of inexhaustible beginning enjoy many benefits. They

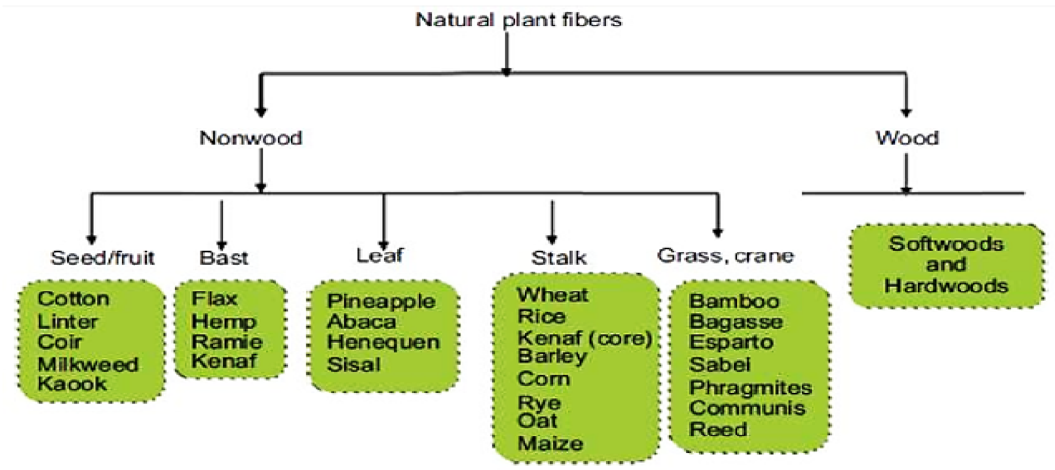

Figure 2.5: Natural Fibers being Adopted in Construction [24]

are bountiful and modest, they reducibly affect the climate, and they are likewise autonomous from fossil assets [45]. Changes are made for plant components as planned for alteration of the synthetic, physical, or other allowable characteristics of the filaments, or to protect the regular hydrophobic filaments in contradiction of legitimate holding with the encompassing framework. Primary motivation behind substance medicines for plant strands is basically to work on the filaments' attributions by adjusting micro-structure in lined up with improvement of surface morphology, compound gatherings, rigidity, and wettability [42]. On a note, Asian nations have bountiful assets of regular filaments, however tragically, they have not been ideally used. Researchers, specialists, and experts all over the planet have as of late been attempting to amplify the capability of regular filaments to make the most feasible, biodegradable, and top notch normal fiber items. From the physical and mechanical properties perspective, regular fiber has somewhat high elasticity and Young's modulus, great warm, great aural protection attributes, also, high electrical safe. Besides, substance properties of regular strands, for example, high cellulose content, have serious areas of strength for a ductile properties, crystallinity, and thickness. Regular filaments can be utilized as support with progress. Regular filaments have been effectively applied to many uses of construction sector [43, 46]. In any case, normal fiber are hydrophilic materials and because of the great explicit surface energy are profoundly inclined to the agglomeration; consequently, any treatment that works on the scattering, grip, and similarity of which with the composite's lattice [47]. Preferred natural fibers to conduct this study are given below as:

1. Rice Husk Ash (RHA)
2. Wheat Straw Ash (WSA)
3. Sugarcane bagasse Ash (SCBA)

2.5.1 Rice Husk Ash (RHA)

Rice husk ash (RHA) is an agrarian by-product that can be utilized in place of cement. RHA has not any commercial uses, consequently it frequently unloaded in the landfills by making wide scale natural contamination [48]. Rice is Pakistan's second most significant agrarian harvest, furthermore, the nation has an upper hand in the development of rice production. Pakistan reaped a higher rice harvest of 8.9∘106 tons in the year 2021 and 2022 ongoing, ahead of 8.4∘106 tons the past year, as per a Global Agricultural Information Network report from the Foreign Agricultural Service of the US Department of Agriculture (USDA) [27, 49, 50].

Numerous analysts attempted to some degree substitute the concrete with modern and farming waste which are promptly accessible like silica fumes, rice husk dash (RHA), fly ash which diminishes concrete expenses and discharge of CO_2 [7, 29]. Global CO_2 emissions are tallying increasing day by day. **Figure 2.6** below shows carbon emissions during previous years [5].

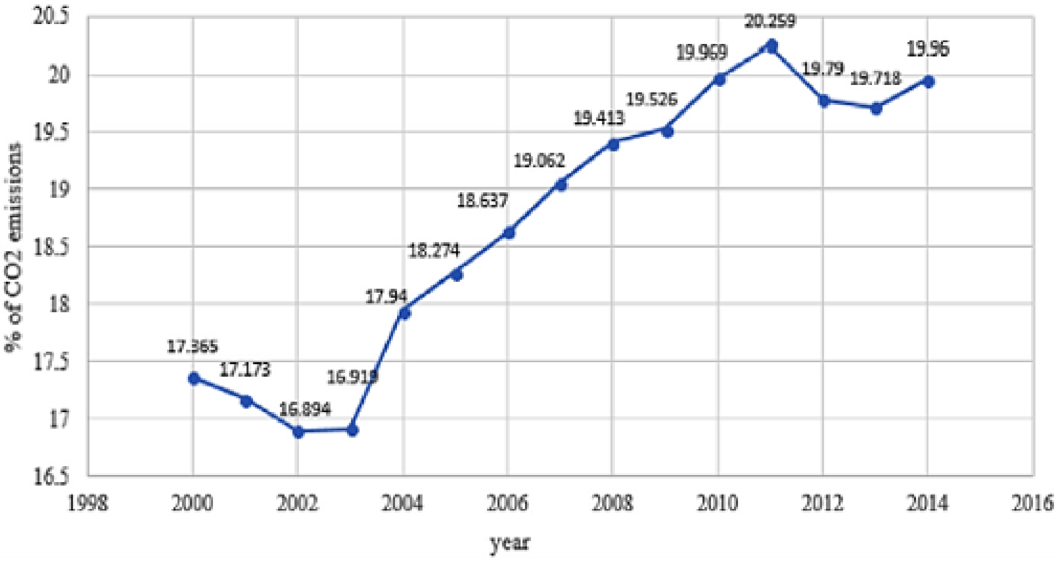

FIGURE 2.6: CO_2 Emissions due to Construction Industry [5]

To minimize carbon emissions due to cement in concrete, rice husk ash is best choice because has non-crystalline silica properties. One of the most generally utilized materials to somewhat supplant OPC in concrete without compromising the quality and hardiness attributes of concrete is the Pozzolanic material. Moreover, RHA, a build-up got from the burning of rice, containing high fineness, has been utilized in concrete as a folio. Rice husk is considered as a waste material and a number of scientists have already completed research for concrete creation, on squander materials as a cement substitution. Other than some of the benefits, squander materials moreover had been demonstrated can be utilized as a concrete substitution because of its synthetic and actual properties in substantial execution for example compressive strength, flexural strength, elasticity, and hardiness as of experimental outcomes. Notwithstanding, squander materials likewise have been demonstrated like a decent pozzolanic material which is advantageous for cement substitution. Decent pozzolanic aspect can be characterized with its respond synthetically with CH at normal heat during the cement hydration [27, 51]. Some beneficial Uses of RHA are given below [52].

- Aggregate and fillers for cement and sheet creation.
- as residue for shield in steel industries
- as a defence substance for houses and ice-boxes

Per ton paddy creates roughly 200 Kg husk hence each significant amount of RH may yield around 180-200 Kg of wastes relying upon the circumstances of climate, rice classifications and paddy fields geographic properties. In certain territories, RH is as often provided as a source of fuel in the steam generators for production of power. Rice husk ash contains necessary properties which are compulsory according to the standard ASTM C150 to be considered as an alternate of cement for concrete. Less utilization of cement leads towards less carbon emissions accordingly [30]. Properties associated with this fiber alter under unique situations thus RHA compositions also differ with both i.e., uncontrolled (Open burning) and controlled burning. After burning, the chemical properties of RHA show a considerable quantity of silica oxides representing pozzolanic activity. Pozzolanic attributes empower silica content inside ashes by responding with the C-H in the pores of cement to create hydration excessively. The incorporation of these ashes as partial replacement of cement in concrete has been proven for both improved mechanical properties as well as solidness of respective concrete [49]. Chemical composition of RHA is shown below in the **Table 2.1** [49].

Table 2.1: Relative Percentages of Chemicals Present in RHA [49]

Chemical Present in RHA	**Relative Percentages**
SiO_2	93.4408
Al_20_3	0.1031
Fe_2O_5	1.0129
CaO	0.7193
S	0.2227
K_2O	3.4808
TiO_2	0.0946
MnO_2	0.2285
Fe_2O_3	0.68

2.5.1.1 Rice Husk-(RH)

It may be noted that rice waste is utilized in both manners i.e., Rice husk and rice husk ash. Various researches have been carried in this regard. For instance, Goodman [50] conducted a research to study effects and environmentally sustainable function of rice husk and ash of rice husk in different applications of construction industry. Core constituents of rice husk are presented below table 2.3 below [50].

Table 2.2: Relative Percentages of Chemicals Present in RH [50]

Components of Rice Husk	Relative Percentages
Cellulosic Compounds	28.6-43.3
Hemi-cellulosic Compounds	22.0-29.7
Lignin Compounds	19.2-24.4

2.5.1.2 Ecological Benefits of Utilizing RH-RHA in Construction

Utilization of RHA and rice husk RH as a productive means has been studied by many authors. It's utilization is multipurpose i.e. issue related with open burning of rice husk causing hazard to human health, reduction in cement for concrete hence minimizing CO_2 emissions as well as cost. According to the Adnan, et al. [27], Subsequently, the issue connected with the development business and concrete creation may be moderated by supplanting cement with wastage materials in regard with halfway substitution for concrete creation. Other than of its few benefits, waste materials likewise had been demonstrated can be utilized as a cement substitution because of its compound and actual properties in concrete which are compressive strength, flexural strength, and rigidity, along with toughness from experimental outcomes. In addition, waste materials likewise have demonstrated themselves as to be a proper pozzolanic material which give a benefit as a cement substitution. Visible as well as genuine characteristics of RHA in light of the past examination shows roughly 85% to the 90% of amorphous silica in it being harmless to the ecosystem and as beneficial establishing material in concrete.

Rattanachu, et al. [51] suggested that one of the most generally utilized materials to some extent supplant of OPC in concrete is pozzolanic material and can work on the attributes of concrete. Similarly, RHA is an agrarian waste got as of the burning of RH for energy stations, contains high fineness, hence being utilized as a concrete binder. The presence of ground rice husk ash (GRHA) in concrete expands the toughness strength as equivalent with ordinary concrete. The mortar prepared with good quality RHA with decreased penetrability, expanded sulphate obstruction, with further developed opposition to the penetration of chlorides. In another study, Lim and Pham [55], noticed a growing interest towards improvement with sustainable/manageable construction materials in the direction of diminishing ecological concerns related with concrete. Creation of OPC is answerable for around five percent to seven percent of worldwide CO_2 emanations. As of late, scientists have paid attention in on investigating elective materials for binding in OPC, for example RHA. This ash be able to be utilized to deliver Geo-polymer Concrete (GPC) that is a type of harmless for the ecosystem. Concentration on these waste materials detailed that the most elevated compressive strength was achieved with 15% RHA.

Memon, et al. [22] provided resembling statement by saying that 2nd most involved material on the Earth after drinking water is concrete and has become an indispensable material for humans. Popularity of concrete as compared with other engineering and building resources is due to its accessibility, elasticity, and toughness. Regardless of its worldwide popularity, it has some drawbacks. One of them is not being an environmental-friendly construction part, mainly related to the carbon footprint of cement.

Globally, it is recognized that the heavy use of concrete has adversary concussion on the atmosphere and human healthiness, and this is because the yield of concrete components emits an expressive number of GHGAs per a Geological survey conducted by United States of America (USA), approximately 4.1◦F109 tons of OPC was made in USA while it one of the major sources of GHG along as well as being an energy consuming material for buildings. With the boost in the construction and renovation of infrastructure utilization concrete as the main construction constituent world-wide, the requisition is expected to accelerate significantly for concrete, thus 18 billion tons of concrete will be utilized by 2050. With such a requisition for concrete, it is expected that cement's utilization will also accelerate and hence the need to produce more cement. It is estimated that 0.9 ton of (CO_2 is emitted during the production of 1 ton of cement. This CO_2 gas outflow is critical as it is confined to the discharges brought about by the cement production and different origins, for example, emanations created for excavation of natural aggregate, cement shipment from the production site, along with plant outflows.

Concrete utilizing cement mixed with SCMs is the most reasonable and conservative other option and might actually be related with onsite concrete production.

Tayeh, et al. [21] suggested that eco-accommodating concrete use in the structure is presently a rising practice and a basic objective of specialists and manufacturers to lessen exhaustion of resources and comfort to the nature by integrating reused materials into concrete. In such manner, a few agro-modern results have been effectively proposed as suitable materials for construction industry. Be that as it may, the results of rice are carefully utilized for research articles. The capability of RHA in concrete and as a cement substitution might be not equivalent attributable RHA as far as reactivity of pozzolana, physicochemical characteristics of RHA, and carbon substance. Nonetheless, RHA pozzolanic properties may be controlled with the intensity and flaming level of RHA. Gursel, et al. [51], [52, 53] studied that rice husk ash is a by-product of rice and it is usually burnt in open fields hence causing more ecological issues but due to pozzolana characteristics, it can be a satisfactory substitute of cement without compromising cement strength.

2.5.1.3 Effect of RHA-RH as a Material in Construction Sector

Utilization of RHA-RH as a material for somehow cement substitution provided a few empowering consequences. Many researchers studied effects of RHA-RH in concrete. According to Adnan, et al. [27] concluded that the utilization of RHA as a somewhat cement substitution exhibited a few encouraging effects related to the strength. Notwithstanding, a constraint occurs in supplanting cement with RHA that is the greatest substitution varies in between 5%- 15% as part of this rate. Bheel, et al. [28] determined that the ideal workability was acquired by 13.64%, 23.64% and 40% increment while using of 5%, 10% and 15% of RHA is more modest when contrasted with concrete without remembering RHA as substitution of PC for concrete. Razak, et al. [29] found that The SCC concrete with 15% of RHA as a cement substitute has the most noteworthy strength in compression. Lim and Pham [55] also obtained similar results and mentioned that a noticeable enhancement in compression strength up to 22.44% with 15% OPC replacement with RHA happened. Memon, et al. [22] found sustainable use of RHA as cement replacement and stated that concrete having RHA as the cement replacement may possibly be used being valuable cementitious material. Ahmed, et al. [56] concluded that All RHA concrete blends conformed to the designed strength order of C32/40, outperforming C50/60 mix design strength. Unlike most other “supplementary cementitious materials SCMs”, RHA concrete shows incredible early age strength with all blends outperforming the basic design strength in 7 days or less. Good potential to utilize RHA concrete for most sorts of structure’s utilization. RHA as a SCM likewise gives both natural and financial advantages. In the light of above-discussed literature, it can be summarized that significant enhancement in compressive strength (i.e., 22%), was achieved by partially replacing cement with 15% RHA, ultimately indicating this substitution as an optimized percentage content [28, 29, 30, 51].

2.5.1.4 Burning of Rice Husk

In different areas across the world, RH is burnt under different circumstances. Properties associated with this fiber alter under unique situations thus RHA compositions also differ with both. Open-air burning can also be adapted to obtain ash from rice husk but that is usually less reactive due to the high carbon content and structure of particles which is crystalline in nature [32]. Open burning causes obviously more carbon emissions as compared to burning under controlled temperatures. Uncontrolled RH contains a greater amount of carbon as compared with controlled burning and silica is also non-reactive. [56]. Usual temperature for controlled burning of RHA may vary in between 300° C t o 900° C, over a time duration of almost two hours [56].

2.5.2 Wheat Straw Ash

A significant farming side-effect got from wheat food creation is wheat straw waste, which energizes ecological contamination since farmers flame it in open environment. In any case, once wheat straw waste is appropriately burnt under well-ordered circumstances, residual which has establishing attributes and may be utilized as advantageous hardening material in concrete is delivered A few researchers have assessed the practicality of utilizing wheat straw ash (WSA) in ordinary cement. In the case of WS, on burning, it is converted into wheat straw ash. The WSA also shows silica composition as RHA, which is necessary to react with cement due to the pozzolanic characteristics and behave like Cementous material in concrete [30]. Chemical composition of wheat straw ash is provided in table 2.3 below [30]. Ongoing years have seen different creative ambitions occupied by

Table 2.3: Relative Percentages of Chemicals Present in WSA [30]

Chemicals Present in WSA	**Relative Percentages**
CaO	12.56
SiO_2	39.63
Al_2O_3	24.11
Fe_2O_3	6.2
MgO	3.5
SO_3	0.61
K_2O	2.09
Na_2O	0.049

means of the concrete business in reducing its carbon impression. Such objectives include utilization of incorporated wastes and reused materials as binding source and aggregate in concrete mix. A portion of above mentioned goals have concerned the associated use of these eco-accommodating materials with a fewer energy consuming building process. PC has the most elevated existed carbon and energy in concrete, tracking down ways of supplanting this will yield a huge decrease in the carbon impression of cement. As a few kinds of agrarian wastes are being created in enormous amounts particularly in agricultural nations, for example, Pakistan, they represent a few dangers to the sustainable environment. Farming cinders are reasonable as a substitution for PC because of their higher content of which is symbolized with pozzolanic capabilities. The abilities of these remains associated to pozzolanic attributes empower silica content inside ashes by responding with the CH in the pores of cement to create hydration excessively. The joining of these ashes into combination with cement has been proven to work on both i.e. mechanical as well as solidness of concrete [58]. Wheat is one of the main agricultural foods of Pakistan and Pakistan is supposed to import 2.5 million tons of wheat in promoting year 2022-23, up from a past estimate of 2 million tons. For each Kg of wheat grain delivered, roughly one and a half Kg of straw is created [57, 58]. Some of the advantages accomplished by utilizing wheat straw ash are given below [59].

- Wheat straw performs better in improving compressive strength
- When WSA is supplanted as cement, performance of the subsequent concrete expresses enhanced results when exposed to Sodium and Magnesium sulphate solution with regards to compressive strength along with decreasing CO_2 emissions consequently.
- WSA as the substitution of cement in the concrete results in greater protection from frost-defrost also the antacid/alkali-silica response.
- Specialists presumed that in concrete, the use of WSA as filler material is because of the particles fineness.

2.5.2.1 Wheat Straw

Wheat straw also can be utilized in construction in both manners that are in the form of either straw or ash. Petrella, et al. [60] studied WS to make sustainable cement mortars and achieved beneficial results. Chemical composition of constituents present in WS are hence presented below in table 2.4 [36].

Table 2.4: Relative Percentages of Components in WS [36]

Chemicals Present in WS	**Relative Percentages by Weight**
Holocellulose	66.68
Cellulose	42.1
Pentosan	22.41
Lignin	17.53
Pectin	0.31
Moisture content	4.69
Ash content	11.19

2.5.2.2 Ecological Benefits of Utilizing WS-WSA in Construction

Just like rice husk, burning of wheat straw in open field is a common practice adopted by many farmers. Instead of burning it in the open fields and causing smog with other environmental issues, it can be utilized in the concrete to play a vital role in economy as well as lessened carbon emissions because it is a great substitute for the cement. Some of the key factors behind utilization of wheat straw ash in concrete have been studied by a lot of authors. According to the Katman, et al. [62], Keeping in mind about the climate, expenses of materials to be used in building construction, decrement of natural resources and interest for energy production, utilization of alternate waste material has turned into an essential part to lessen these impacts. Latest explorations have analysed the utilization of agrarian by-products which contain properties of counterfeit pozzolana and can substitute cement up-to some extent. The specialists trust that utilizing "supplementary cementitious material" (SCM) as somewhat replacement of cement for concrete manufacturing can assist with diminishing the antagonistic ecological effects related with the concrete. By involving such wastage as SCM in concrete, many sustainable goals like saving the energy, minimizing the cement utilization consequently reducing carbon dioxide radiations to the environment can be achieved.

World's important oat grain and an essential food contributor for two and a half billion individuals is the wheat. Around the world, wheat creation is assessed at around $7.5\times10_8$ tons. At the point whenever wheat is handled, a lot of wastes in form of wheat straw are created which are ordinarily scorched in open climate triggering ecological contamination, street car crashes whenever burnt close to open streets, and respiratory illnesses. WSA is the waste produced because of flaming straws of wheat. Logical examinations have analysed the capability of WSA in concrete as a potential SCMs. WSA holds a greater level of silica and higher degree of fineness than the PC subsequently, WSA might viewed as valuable cementitious material in concrete.

A few characteristics of cement may also be developed by the existence of WSA. To prepare WSA, the wheat straw is put to fire at 570^o C to 670^o C under controlled flaming for five hours almost. Ahmad, et al. [32] presented about SCC and stated that SCC is an extraordinary concrete mix which is exceptionally flowable, non-isolating/segregating and spreads into position due to the own weight itself, behaving as the totally fill up in the shuttering even within thick support. Concrete is the most broadly involved development material in development industry all around the world in light of its high cohesion and compressive strength.

With the usage of this by-product as a material for strengthening and substitution of cement, there is extensive energy decrease as well as decrease in the utilization of cement, which supports the decrease of the arrival of CO_2 to climate. Furthermore, there might be significant development in the potency and solidness characteristics in concrete with the utilization of advantageous materials. Thusly, boundless examination has been done on various advantageous materials, for example, RHA and WSA to be named a few. The substance response between bentonite clay and sand produces fundamental oxides of magnesium (MgO) and potassium (K_2O), which are known to further develop strength. A significant agrarian outgrowth got from grain creation is wheat straw, which energizes natural contamination since ranchers flame it in open climate.

Notwithstanding, when WS waste is appropriately singed under organized circumstances, a material that has solidifying properties and that be able to be utilized as strengthening establishing material created for concrete. A few specialists have assessed the practicality of utilizing WSA in ordinary cement. Research on WSA for halfway substation of concrete in substantial creation was done, and a positive impact on concrete execution was accounted for. Nonetheless, further examination suggested the utilization of various synthetics or a mineral admixture with WSA in concrete. From the trial results, it very well may be reasoned that the presentation of concrete was improved extensively with the joining of bentonite clay in WSA.

Memon, et al. [63] studied partial replacement of wheat straw ash as sand and stated that Human actions have spread disorder in the light of sustainable environment of Earth. Concrete is a broadly used material on the planet that requires a colossal measure of resources. Aggregates are being consumed by uprooting the materials from earth. As per measurements of the "United Nation's Food and Agriculture Association", wheat delivered all around the world was $7.43 \times 10_8$ tons in the year of 2017. As per assessment, 1.3Kg to 1.4 Kg of WS is created during the handling stage accommodating one Kg wheat. Wheat yields wheat straw as a result during extraction of grains are from the chaff. Flaming of wheat straw creates a lot of waste ash that is unloaded into lakes causing limitation of the helpful land alongside environmental deterioration through the age of waste material, and it represents a few wellbeing dangers. Utilization of concrete has expanded dramatically over the most recent thirty years around the world. Being a superb constituent of concrete, usage of natural resources has likewise expanded at a comparable speed, which has brought about the exhaustion of the sand. Thusly, steady endeavours are utilized to supplant aggregates with counterfeit and reused aggregates in cement to satisfy the total interest for accomplishing practical cement. Scientists tracked down the joining of agrarian and modern waste appropriate as the accomplishment in sustainable concrete. It is assets focusing on that WSA is being recently utilized in concrete mix as a combination.

Bheel, et al. [58] discussed about carbon emissions and WS by means of a substitution of cement by introducing WSA by discussing that late years have seen different imaginative drives chosen by the activity of concrete for reduction in its carbon impression. Such drives include accumulation of decays and reused materials as binding materials and natural resources in different mixes of concrete. As PC is the material regarded as most noteworthy demonstrated carbon and power in concrete, tracking down means of supplanting this will bring in a significant decrease in the cement's carbon impressions. Rural cinders are reasonable to the same extent swap on behalf of PC because of their prominent silica content.

Qudoos, et al. [36] proposed some solutions for up grown CO_2 emissions due to construction by stating that outflows due to using large quantity of cement, be able to be limited by integrating waste or unrefined components as incomplete or full substitute of cement. These materials are most usually known as SCMs. Aimed at this reason, use of SCMs for example RHA, WSA, and so on is acquiring a lot of consideration in the development business. The usage of such materials as a cement replacement can be a visible answer for the lessening of CO_2 discharges. The cinders got by flaming farming deposits has been generally used to supplant cement. Most regularly utilized agrarian are RHA, RSA, and SCBA. Previous studies have reasoned that utilization of WSA worked on the mechanical properties of cementitious compounds. Notwithstanding, WSA also has been accounted to have filling attribute. Solidified properties of cement mortars are upgraded due the filling skill of WSA too, the expansion of WSA has been accounted for improvement in the toughness associated properties of materials containing cementitious properties. For instance, supplanting a part of gravel or PC with WSA brings about decreased incorporation and further developed protection from corrosive and sulphate assault. Essentially, in another review, it has been presumed that freeze-defrost opposition of substantial examples containing WSA upgraded. In view of the discoveries showed in the current writing, the situation obvious that WSA behaves like both i.e. the filler as well as properties of pozzolana. In continuation, Qudoos, et al. [64] stated about "fiber-reinforced concrete (FRC)" by providing in literature that Farming build-up cinders/ashes are representing a serious danger to the climate as a large portion of these terminates as a landfill substance. Agricultural residue ashes (ARAs), for example, RHA, SCBA in addition to so on, include a tremendous measure of silica content which composes such wastes as a compelling pozzolana. Content of silica in the residue responds towards Calcium Hydroxide (CH), a resulting effect due to cement comes about in the arrangement of hydration excessively. From the literature findings it was proved that that consolidation of RHA brought about an expanded compressive strength, less penetrability, and upgraded protection from chloride infiltration and corrosive degradation. Likewise, the productivity of wheat straw ash (WSA) as a filling and pozzolana in the composites based on cement has been examined in a number of literatures. It is for sure that utilization of WSA improved both i.e. compressive and flexural strength of the mortars comprising cement. Impact of WSA as a filler came about in gotten to the next level of properties related to the mechanical behaviour. Support of composites based on cement with fibers is a demonstrated method to upgrade strength, malleability and elasticity. Introduction of fibers confines the cracks also.

2.5.2.3 Effects of WS-WSA as a material in construction sector

Utilization of WSA-WS by means of a material for somehow substitution for cement in the concrete and a worthy construction material showed a few empowering results. Many researchers studied effects of wheat straw-ash in concrete. According to Katman, et al. [60], Strength of concrete like flexural, tensile and compressive strength showed better results after replacement of cement by 10% WSA. WSA can also perform as a cost minimizing tool for the construction industry hence providing economical solution. Khan, et al. [64] studied same pattern and described that by using 10% WSA, sustainable concrete is achieved without compromising strength of concrete while reducing cement content hence minimizing carbon emissions. Utilization of WSA in concrete can take care of problem related to deposition of Wheat straw ash causing environmental issue converting into useful by-product. In an exploration, Ahmad, et al. [32] found that when bentonite earth clay (BC) and WSA were supplanted to the extents of 0%, 5.0%, 10%, 15%, and 20% corresponding to the cement. In light of the exploratory works, the accompanying end can be made: Strength i.e. both compressive and tensile expanded as the replacement level of bentonite clay expanded by up to 15%, and afterward it diminished when contrasted with the control blend. On account of wheat straw ash, the strength expanded with up to 10% replacement. The most elevated strength was gotten at the proportion of 14% WSA and 12%, separately, and it had a greatest compression strength of 52 MPa, that is practically 93% higher than that of reference concrete. Memon, et al. [63] found that Expanding slumps were achieved with expanded WSA substitution levels. This pattern was unsurprising due to lubrication impact of unnecessary accessibility of water consumed by WSA, thus expanded the ease of WSA mix. Expanding compression strength consequences were achieved by the expansions in the time of examining and the WSA substitution rate in concrete. Such increment is ascribed because of the presence of pozzolana. Density of concrete composed of WSA expanded alongside the substitution rate because of pozzolanic response and filler impact. Bheel, et al. [58] explored that notwithstanding the sustainability prospective of WSA, it's joining up-to 10% substitution of PC was discovered to improve the compression strength, splitting rigidity in addition to flexural strength by 12%, 10% and 11% individually. Thus, utilization around 10% WSA by means of substitution for PC was considered ideal because of a diminishing in the strength at elevated substance. Qudoos, et al. [64] concluded that degree of fineness for WSA conferred pozzolana effect and filling characteristics which brought about denser structure of composites. Moreover, the usage of WSA as a substitution material for cement adds to a neat and sustainable climate. El-Sayed, et al. [65] studied combined WSA and RHA and resulted that Keeping in mind the consequences of the trial study, it is reasoned that wheat straw ash (WSA) is a characteristic rural waste that can be utilized as an excellent cement substitution material because of silica delivered by the synthetic enactment technique. The creation of silica from horticultural wastes furnishes an earth amiable outcome with the precisely appropriate and practical items. Utilizing the RSA and WSA upgraded the compressive strength and elasticity of concrete mixes. When WSA is used as a supplement material instead of cement, there was a decrement in concrete's porousness of water. Thusly, it is suggested that presence of WSA in concrete composed of higher grades is beneficial so that the durableness of concrete is gotten to the next level. Moreover, existence of some sort of superplasticizers in WSA and RHA concrete enhanced the some other properties like slump values and workability also. Amin, et al. [39] found that X-ray powder diffraction analysis showed that necessary pozzolana in WSA enhanced as the temperature enhanced. Although WSA changed into a crystal-like structure instead of formless when burning temperature was increased from 550°C to 750°C. Wheat straw flamed at 550°C proved to have high formless in character. Memon, et al. [66] found similar results and concluded that X-ray powder diffraction design showed that silica was for the most part in nebulous stage in WSA burnt at 500° C and WSA burnt at 600° C, yet in the instance of WSA500 a high natural substance was found. According to the "Blaine fineness test", it was seen that up to 30 min of crushing, there was an immaterial expansion in Blaine surface area of only 11% as for WSA prior to crushing.

Hence, considering the improved mechanical properties of WSA, it's addition up to 10% replacement of cement was reported as the most optimized content to improve the compressive strength of respective concrete up to 12%, splitting tensile strength up to 10% and flexural strength up to 11% [33, 57, 61, 65].

2.5.2.4 Burning of Wheat Straw

The flaming of wheat straw creates a lot of ash in form of waste unloaded into lakes containing ash causing confinement of the valuable land alongside environmental corruption through the age of disposed material, and it represents a few wellbeing risks. Moreover, it was revealed by world health Organization (WHO) that in year

2012, atmospheric contamination was reason behind 3.7 million deaths from one side of the planet to the other. Hence pointing out towards more sustainable use of the burned wheat straws and this ash can be utilized as cement replacement [62]. "Wheat straw ash can be collected by open burning of wheat straw to be utilized in concrete instead of causing threats to human safety. WSA is gathered in the wake of either flaming WS in the open climate or bringing WS into ashes in a kiln present in invariable air meant for 2 hours at 600°C. Change in the temperature of wheat burning to get wheat straw ash can affect the chemical properties of wheat straw ash i.e., the amount of silica content. Thus, the organized flaming procedure of WS prompts the creation of silica with a high amount [59]."

2.5.3 Sugarcane Bagasse-Ash

The bagasse is a fundamental result from sugar manufacturing plant which is used as a source of energy for sugar creation inside a similar production line. Creation of extra C-S-H because of aftereffect content of silica in the pozzolana act in response with free lime produced during the hydration of cement, which improves the solidified characteristics of concrete, hence making bagasse a solid component of concrete. Silica oxides are also present in the chemical composition of sugarcane bagasse ash as the other two fibers ashes i.e., RHA and WSA. Thus, sugarcane bagasse ash also exhibits pozzolanic characteristics making SCBA a cementitious material in concrete [31]. Chemical components of sugarcane bagasse along with some structural characteristics are given in table 2.5 below [28].

Table 2.5: Relative Percentages of Chemicals Present in SCBA [28]

Chemicals Present in SCBA	**Relative Percentages**
CaO	2.15
SiO_2	76.34
Al_2O_3	8.35
Fe_2O_3	3.8
SO_3	0.48
Na_2O	1.98

Populace development is constantly joined via land procurement for the development of new framework and residences. Populace development grows horticultural terrains, expanding the level of waste discarded. A lot of regular waste, like strands, grains, and mash, are created incidentally all through the creation and fabricating processes and are discarded in landfills or then again consumed. The amassing of inappropriately overseen and untreated squander has triggered acute ecological and extended disposal issues. In numerous nations, natural wastes are discarded by unloading them in landfills, prompting more contamination and adverse consequences on the climate resulting [67, 68] in global warming as discussed previously. The execution of agrarian by-products in the development business is currently on the ascent. Around the world, sugarcane bagasse is as yet utilized for energy age in modern stoves, however the bagasse's worth has expanded strikingly because of its significance as a reused material. The utilization of sugarcane bagasse might address monetary and natural significance for the sugarcane-delivering nations [68].

2.5.3.1 Sugarcane Bagasse (SCB)

Sugarcane bagasse is also being adopted in construction also like other two mentioned fibers i.e. RH and WS and SCB also helps in achieving sustainable construction goals [34]. Chemical composition present in SCB is given in table 2.6 below, [68].

Table 2.6: Relative Percentages of Components in SCB [68]

Chemicals Present in SCB	**Relative Percentages by Weight**
Dextrose	19.5
Xylulose	10.5
Pectinose	1.5
Lactose	0.55
Lignin	9.91
Organic soluble	2.7
Reducing-sugars	1.85
Uronic-acids	1.91
Ash	1.6
Cellulose	50
Overall hexoses	20.04
Overall pentose	12

2.5.3.2 Ecological Benefits of Utilizing Sugarcane Bagasse-Ash in Construction

To minimize CO_2 emissions due to high demand of construction activities and materials associated with construction, sugarcane bagasse also plays a role in a sustainable construction by replacing construction materials hence providing solution to the issue concerned with safe disposal of SCBA acquired as a waste as of sugar manufacturing plants and energy plants. Many studies have been carried in this regard. According to the Bheel, et al. [30], Concrete is the most flexible and most broadly utilized development material around the world. Concrete is the best structure material when contrasted with blocks, bricks or steel, and so forth. Concrete is composed of cement, aggregates, water, and some admixtures if required. In excess of $1*10^{10}$ tons of concrete are delivered yearly. Because of critical utilization of concrete, the interest for concrete is likewise expanding as time passes. The creation of PC is extremely risky to the climate as it produces heat and an unnecessary measure of CO_2.

It's undeniably true that the creation of per ton cement depletes around same amount of CO_2 straightforwardly in the air. What's more, it is accounted that production of cement is because for 5-7% of CO_2 from industries. Beforehand, various specialists have previously worked a great deal to diminish the utilization of cement and supplant concrete by some supportable materials, which contribute the characteristics just like cement. The notice is happening on the using modern and farming squanders, as they are an ecological beneficial. It is hard to discard horticultural waste since it actually makes a natural weight. In any case, it is gainful when utilized in concrete. There are numerous agrarian by-products are accessible on the lookout for substantial creation. Probably the most well-known materials are SCBA, RHA, WSA, and so on. Attributable towards the ecological concerns related with PC, not just the fractional supplanting cement with a waste material will diminish the prerequisite of concrete in development, yet additionally comparing unloading of the wastes in landfills will be decreased.

Solanke and Pawade [33] studied similar pattern and stated that Concrete resembles the compound material used all through building development. Concrete is made as a conclusive product from water, cement, sand and aggregate. PCC is the most usually utilized concrete. PC, that harms the climate by an extremely high speed, is prime part of concrete. An enormously preferred building material is concrete while cement is an unavoidable piece of the development area being as the essential part of concrete. Cement creation is, nonetheless, connected with higher utilization of energy and ozone depleting substance emanations. Cement is the binder that assists with restricting together different materials in the concrete.

Cement handling produces high amounts of CO_2. After the vehicle business and the power creation area, cement is the 3rd biggest producer of CO_2 worldwide due to human activities. CO_2 is criticized by and large for an unnatural weather change. This urges one to explore the different options for making a particular environment cordial by replacing cement. Usage agrarian waste materials could be the substitute for cement without decrease in a necessary strength of concrete. SCBA is an extra outcome of the sugar production, created during sugarcane juice extraction. SCBA can also happen to be replacement of cement due to it's beneficial properties.

Another study was done by Quedou, et al. [69] and they suggested that Nowadays, concrete is the most generally involved human invented development material on the Earth. Vital constituent in concrete is the cement and it is the 2nd most utilized substance after water on Earth. Production of the cement has devastating affects the people and the climate. Its creation cycle has a vital impact in the GHG impact and is liable for just about ten percent of the overall CO_2. In this manner, to limit CO_2 emanations, numerous scientists have concentrated on elective materials which may supplant cement just like the super restricting part of concrete. Many examinations have shown the way that rural squanders can for sure be utilized in concrete. The attention on this waste has been proposed because of its accessibility and qualities of pozzolana. Agrarian by-products, for example, SCBA and RHA are viewed like inactive combination with great qualities of pozzolana. The impact of pozzolana improves the properties of concrete concerning materials geology, and strength advancement and adds to the end results drawn out solidness. These qualities of pozzolanic materials rely for the most part upon the kind of remains, the supply, the handling stages, and the temperatures at which these squanders are singed. SCBA can be utilized as a reasonable material containing cementitious properties in the development business.

Talavera-Pech, et al. [34] studied resistance attributes of the mortars made with SCB and stated that Cement-concrete is the most broadly utilized development substance till date and the synthetic and mechanical properties make it more impervious to the climate and give incredible sturdiness. Be that as it may, it's anything but a latent material, as the pore arrangement shaped inside it can respond with the carbon dioxide (CO_2) of the environment, which creates calcium carbonate $CaCO_3$ and brings about a cycle known as "carbonation". As an outcome of carbonation, the potential of hydrogen "pH" of the pore arrangement diminishes, creating conditions for an erosion cycle to begin the implanted steel support. Consequently, a measure of strength is to configuration concrete with a base porosity to slow the development of carbonation. Supported concrete is presently the most generally utilized development material. Nonetheless, it is an extraordinary generator of CO_2 outflows to the air during the concrete assembling system. This adds to an unusual weather change, as an ozone depleting substance adds to the ongoing environment influence. Since farming produces around 20-30% waste, it has been shown to be a material that can be used again for eco-friendly intentions. As of late, rural waste materials have been utilized as alternative for supported compounds of the concrete. A few creators have endeavoured to consolidate sugarcane bagasse as fiber to work on the properties of built up concrete combinations. They have noticed a few benefits for the joining of these filaments, like an expansion in strength and effect obstruction. In a new state, it considers controlling the plastic shrinkage in the setting period.

Dhawan, et al. [70] raised a concern about climatic worries and stated that Concrete is a sort of compound substance utilized in developments of structures. This substance is shaped by restricting together cement, sand aggregates (gravel) and water. The binding quality of cement makes it a superb component of concrete. But as a negative side, creation of cement produces a high measure of CO_2. 3rd biggest factor of CO_2 emissions due to human inventions on the planet after transport and energy area is the Cement. According to an idea, creation of one ton cement caused 0.97 tons carbon emissions to the climate hence causing greenhouse gases and resulting for global warming consequently. One of the biggest crops of more than hundred countries is sugarcane and it is estimated that production of sugarcane crosses a figure of fifteen hundred tons over the world. In sugar manufacturing factories, all of useful sugar is extracted from sugarcane and almost 40% to 45% of residual is achieved in same factory that is used as a medium for production of heat to be utilized in boilers to generate heat. After this process, almost 8% to 10% cinder is achieved as a waste material that is called as SCBA. The bagasse ash contains plenty of substance which is not burned completely somehow, and contains silica, alumina and oxides of calcium. Although, ash which is collected from factory is not prone to the reaction because this ash is flamed at unmeasurable thermal conditions. So this cinder becomes nothing but a waste from factory and proper disposing off is additional concern. So this final product is processed at some parametric quantities to achieve a sustainable product. Sugarcane bagasse ash can be taken into considerations of somehow substitution as sand (fine aggregates), as climbing figures of concrete utilization are resulting in the declining figures of natural resources hence threatening the climatic balance.

Ribeiro, et al. [71] discussed about environmental assessment of concrete blocks made with sugarcane bagasse and suggested that As per the "Food and Agriculture Organization of the United Nations (FAO)", sugarcane is delivered around 100 nations in tropical and subtropical locales of the world. Of the sugar fabricated all over the planet, 70% is from sugarcane. During the production of the sugar and ethanol, a high amount of build-ups are created. Among the build-ups, there is the bagasse. The sugarcane build-ups are produced in huge amounts and make a serious removal issue for the sugar/ethanol industry, influencing the climate and general wellbeing. In a few nations, these deposits have been chiefly disposed of as soil manure. Nonetheless, considering the ecological effect, this strategy for removal is a long way from being the most reasonable one.

Then again, the complete emanations of carbon dioxide CO_2, of development area was 5.7 billion tons in 2009, adding to the 23% of absolute fossil fuel by-product delivered by worldwide financial exercises. The steel alongside cement businesses together represented 8% of worldwide energy use and 15% of worldwide anthropogenic CO_2 emanations in 2012. The reliance of development area on normal assets like sand and rock is other problem to be named. The utilization of sugarcane build-ups as development aggregate gives a more supportable option in contrast to the development business and the sugar/ethanol industry. The utilization of nearby sugarcane deposits as aggregate for concrete, particularly for islands with little land region, are attractive, since it can diminish natural burden and abatement transportation CO_2 discharges.

2.5.3.3 Effects of SCB-SCBA as a Material in Construction

The utilization of SCBA as a material intended for somehow substitution of cement in concrete manufacturing and by means of a worthy material for construction sector showed a few empowering results. Many researchers studied effects of SCBA in concrete. As per findings of Jamshaid, et al. [75], elasticity of regular fiber-based concrete slowly increments through expansion in level of natural fibers inside the concrete. While twisting strength of the regular fiber built-up concrete examples expanded by expanding the fiber stacking. Bheel, et al. [29] concluded that characterized carbon due to utilization of the concrete is diminished with expanding the supplanting level of PC with SCBA. From trial examinations, it is presumed that the utilization of SCBA up to 10-15% in concrete gives ideal outcomes to primary applications. According to the Souza, et al. [76], Utilization of agrarian by-products as support for concrete blocks has worked on physical, mechanical and thermo properties. Both of properties i.e., physical and compound of lignocellulistic have straightforwardly affected the properties of blocks made of concrete. SCB has shown more prominent aptitude as support in the blocks. In a study conducted by Solanke and Pawade [77] it was found that the outcome on the prospect of fractional replacement of cement with SCBA as an alternative was inspected. SCBA utilized concrete creates higher strength in compression than that of typical cement concrete however the utilization of SCBA is an ideal addition. Ribeiro, et al. [74] concluded that the natural burden related with the development of blocks with concrete interlock involving sugarcane build-ups as aggregate was viewed as more modest than that of utilizing natural aggregates, generally because of the more prominent effortlessness of securing of the deposits. What's more, in the comparison of the flexural strength for blocks ready with no sugarcane deposits, blocks ready with bagasse fiber volume proportions of 2% in contrast with the absolute amount of aggregates have further developed strength. Ribeiro, et al. [78] in continuation concluded in study that Sugarcane deposits in their unique structure were utilized to get ready blocks made by interlocking of the concrete, and the flexural strength will in general somewhat increment because of the impact of the organization of the strands. Furthermore, since sugarcane bagasse fiber has a decent water maintenance trademark, the warmth of the outer layer of the blocks was decreased, with more modest water dissipation. Berenguer, et al. [79] studied that sugarcane bagasse contains silica hence it can be replacement of cement reducing CO_2 emissions. Neto, et al. [80] also stated the same that SCBA is a by-product and it is usually deposited in landfills. Instead of depositing it in fills, it can be a good replacement of cement due to high silica hence reducing carbon emissions.

Therefore, it can be summarized from the literature that the optimized replacement content in case of SCBA is 20% by mass of cement which resulted in almost 40% enhancement in compressive strength of the respective concrete [34,74,76,77].

2.5.3.4 Burning of Sugarcane Bagasse (SCB)

Ordinary Portland cement (OPC) with fractional l bagasse ash quantity further develops the compressive strength contrasted with normal concrete at 28 days age after curing. Some concrete samples mixed with bagasse ash can likewise upgrade the strength of cement and decline the intensity of hydration. However, bagasse residue from the factories has a high carbon content and unburned organic substance which adversely influences properties of concrete and furthermore brings down the cement workability. That's why a controlled and calculated burning of bagasse is required to achieve desired chemical properties [75]. Many researchers have paid attention towards this scenario, hence according to the Quedou, et al. [69], the arrangement of huge amounts of indistinct silica is for the most part connected with the calcination of SCBA at temperatures running somewhere in the range of 600° C and 700° C is the justification for its higher pozzolanic progress. Thus, SCBA act in response with the portlandite delivered through the concrete hydration cycle and causes C-S-H arrangement that builds the properties of concrete.

2.6 Life Cycle Assessment (LCA)

From the mankind outset, our age has been on the edge of tracking down appropriate answers for increment the item's life-cycle and decrease the natural effect of the item. Bio-strands based items are materials which are gotten from natural beginning, for example, yields, plants or other inexhaustible rural, or ranger service materials. These items, give elective material choices to traditional petrol-based materials by involving inexhaustible carbon like feedstock. Regular filaments and their composites are the new patterns in the worldwide setting. Regular filaments are an expected substitute for various engineered materials due to their eco-accommodating way of behaving, impressive mechanical and actual properties Regular filaments and their composites are the new patterns in the worldwide setting. Regular filaments are an expected substitute for various engineered materials due to their eco-accommodating way of behaving, impressive mechanical and actual properties. Momentum specialists centre their examination towards novel materials which negligibly affects the climate which could supplant the traditional composites as they cause environmental issues. Estimation of ecological effect appraisal and LCA is the flow process for the analysts because of the expanded interest for asset protection. LCA is a cycle to assess the impacts of items or administrations though natural effect evaluation in between related course of assessing the ecological effect of an item or administration [76].

During the previous many years, worries on natural resources depletion, energy utilization and materials shortage have pushed the improvement of life cycle approaches going for the gold of items. In the European countries, around half of handled unrefined components are applied in development likewise, the development business is on the first spot on the list of ozone harming substance patrons. The emphasis on manageable development is presently applicable in wording of structures functional stage, energy interest, assets, emissions, squander age, upkeep and the finish of-life stages. Accordingly, research on the appraisal of the ecological effects of building items over their whole life cycle have been escalated. Besides, it is progressively essential for experts, as designers, engineers, developers, chiefs and financial backers, to examine the effects connected with the whole life pattern of a structure. The substitution of customary (with high natural influences) by elective folios, which require less energy for creation furthermore, transportation would be favourable in a specialized what's more, social way [11].

From the carbon emission prospective of natural fibers opted in construction, some of the adopted tactics are being utilized and life cycle assessment of resource which are used in construction are very significant [24, 77, 78]. "Life cycle assessment" or simply known as LCA is most useful technique to assess effects on resources during production and utilization in construction. LCA is defined as medium to trace impressions of resources during whole life span from the stage of presence in raw form, preparation, supply, carriage and discarding stage. It is officially approved by universal standards according to ISO 14040 serial. LCA can be further divided into sub-categories that are given below as:

- Purpose and scope
- Inventory interpretation
- Assessing the Influence of GHG
- Analysis of further progress.

Above mentioned procedure can be seen in figure 2.7 presented below [7].

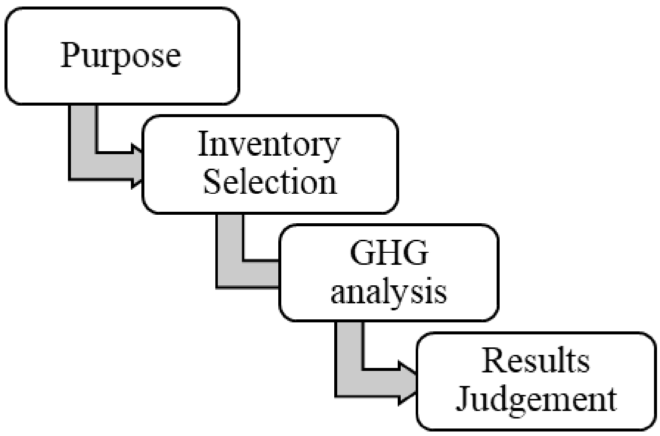

FIGURE 2.7: Typical Flow Chart of LCA [7]

First of all purpose for conducting life cycle assessment is defined. After that inventory is analysed by providing all necessary input parameters and then outputs are assessed pointing towards future planning to either use the replacements of natural resources or not. This is a systematic flow process through which LCA is performed.

LCA philosophy has acquired and more unmistakable quality and acknowledgment lately. LCA ordinarily requires controlling countless information and presumptions, furthermore, the utilization of explicit programming apparatuses can work with this cycle. The utilization of programming devices can be more thorough in one programming than others because of usefulness issues, accessibility of information base and datasets, UI, information quality and information the board, as well as the demonstrating standards to assemble item frameworks and unit processes [79]. There are many software available to conduct LCA but Open LCA is very popular and handy. Open LCA is a freeware bundle (open source) and a commonly realized programming software which is not difficult to deal with and it permits it's client in the direction of work out every one of the stages related to LCA. One more benefit of this device is that it offers clients the chance of working with various information bases, for example, those utilized by Gabi, and others [86].

2.7 Identified Research Gap

In the light of above discussed literature, it can be summarized that construction industry is growing rapidly. Concrete is main element for construction sector and cement is the binder material involved in concrete but also a major source of CO_2 emissions on other hand [30]. These emissions are responsible for climate changes and ozone depletion resulting in hazardous environment. As the waste agricultural fibers are reported to be utilized in concrete as dispersed reinforcement or respective ashes as cement replacement due to chemical composition and presence of silica content [7, 30-33, 57, 63, 64, 68, 72, 79]. However, information on LCA regarding utilization of ashes in concrete is still lacking. So, there is a need to explore this aspect prior to the practical utilization of fibers and respective ashes ash in concrete. Accordingly, the flowchart for the identified research gap is shown in figure below.

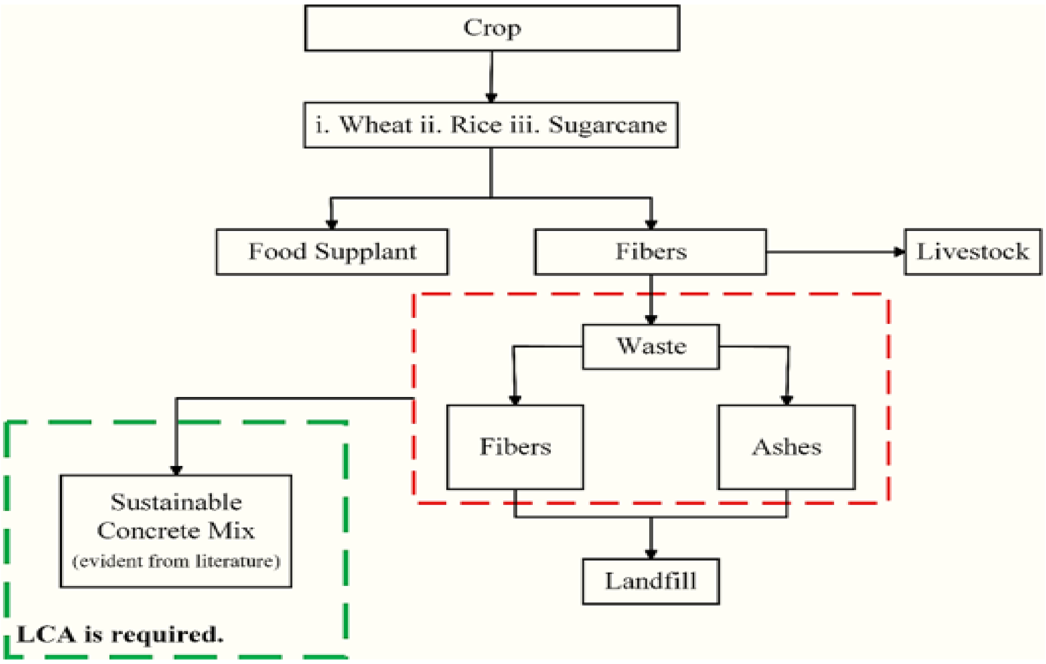

FIGURE 2.8: Identified Research Gap

Chapter 3

Research Methodology

3.1 Introduction

This literature depicts strategies for an effective expression of LCA of natural fibers when those fibers are utilized as a limited replacement of the cement in concrete. LCA primarily focusses upon carbon emissions from both i.e. conventional concrete and concrete composed of natural fibers along with emissions during transportation of the material. During life cycle assessment, conversion of fibers into ash has also been taken into consideration while life cycle assessment has been carried by a software that is “Open LCA”.

3.2 Research Design

This research depends on reviewing the literature in depth which depicts the carbon emissions due to increment in construction and then utilization and benefits of natural fibers in construction as a replacement of the cement to lessen CO_2 emissions. On other hand, the construction business is on the first spot on the list of ozone harming gases depletion and is answerable for up to 40% of the worldwide essential energy demand. A detailed research methodology has been presented in the figure 3.1 below which will provide ultimate results to assess CO_2 emissions from fibers adoption in construction.

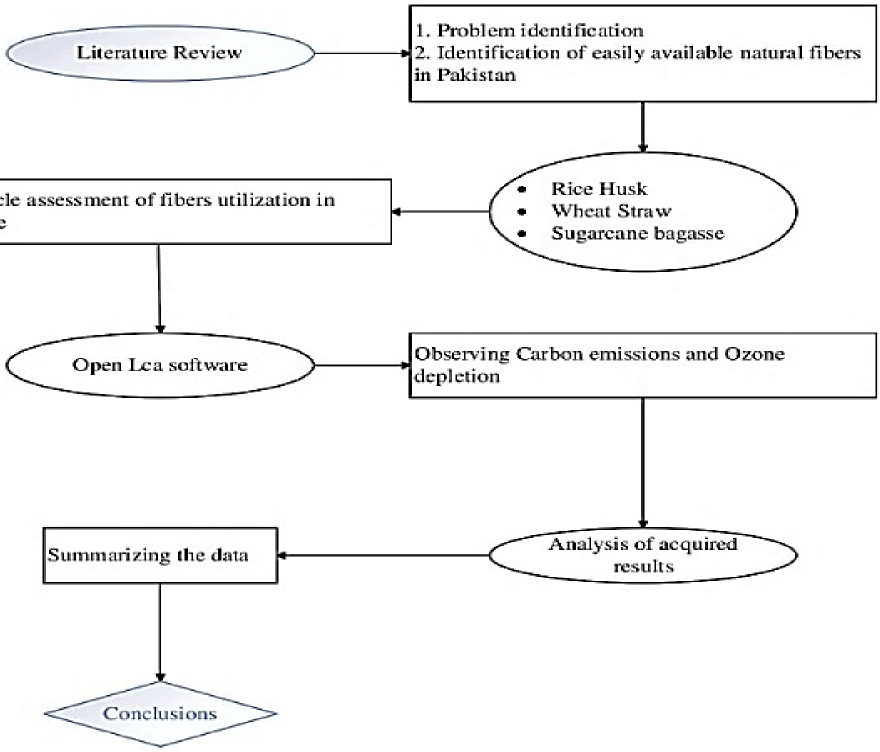

FIGURE 3.1: Adopted Methodology

3.3 Literature Review

The Construction business utilizes an enormous number of natural assets and energy. It is one of the fundamental causes of waste production and ozone depleting gases release usually known as GHG. According to Green Building Council of the United Kingdom, it is anticipated that CO_2 concentration in the environment may be twofold by the year 2100. On other hand, the construction business is on the first spot on the list of ozone harming gases depletion and is answerable for up to 40% of the worldwide essential energy demand. Concrete is a fundamental piece of the present foundation from one side of the planet to the other. Truth be told, concrete creation is assessed at 13 billion tons each year on an overall scale.

The creation of concrete has been recognized as a significant driver of ozone harming substance discharges on the planet. The “United Nation’s Conference of Parties” took on in 2015 the Paris Agreement to go to altogether fundamental lengths to restrict an unnatural weather change to 1.5° C above pre-manufacturing planes. Lessening carbon impression and energy utilization requires materials and advancements targeting working on the practices for development and support and at limiting ecological weights. The utilization of harmless green materials to the ecosystem, which are biodegradable, decomposable, and sustainable, has been as of late considered to diminish the natural effect of petrol-based materials in construction. One concern from eco-accommodating material plan is to increment plant beginning fiber content in construction materials, which may diminish thermo conductivity, increment noise absorption along with lessening ecological effect. Lately, more sustainable plant assets have been found and utilized in construction because non-inexhaustible assets are turning out to be scant. These in costly normal fiber can turn into a suitable option for costly and non-inexhaustible materials.

3.3.1 Problem Identification

From the exploration of the literature, problem has been identified that is CO_2 emissions related to the construction sector. During the previous many years, worries on ecological crumbling, energy utilization and materials shortage have pushed the improvement of life cycle approaches pointing the natural reporting of items. The attention on sustainable development is presently applicable as far as structure's functional stage, energy requirement, funds, release, production of waste, rehabilitation and the finish of-life stages. LCA, a methodology that assesses the natural effects of items/administrations from fresh material securing to wastage removal.

Thus, the problem statement of research work becomes as: "The practical advantageous fibers are utilized to somewhat supplant the concrete, diminish the expense of development, and make concrete eco-accommodating material. It is obligatory to focus on the absolute manufacturing progressions, of the life cycle of the material, as well as the limitations beyond the project".

3.3.2 Commonly Available Fibers in Pakistan

Commonly available natural fibers and their details are presented below.

3.3.2.1 Wheat Straw

Wheat is the predominant product and it guarantees fulfilling the food requirements in the country. Wheat is harvested on more than twenty two million sections of land and records for 7.8% of the worth included horticulture and 1.8 percent of Gross domestic product (GDP). Wheat production over the span of years is shown in **Figure 3.2** below [81]. Wheat straw is obtained from this cultivated wheat in bulk.

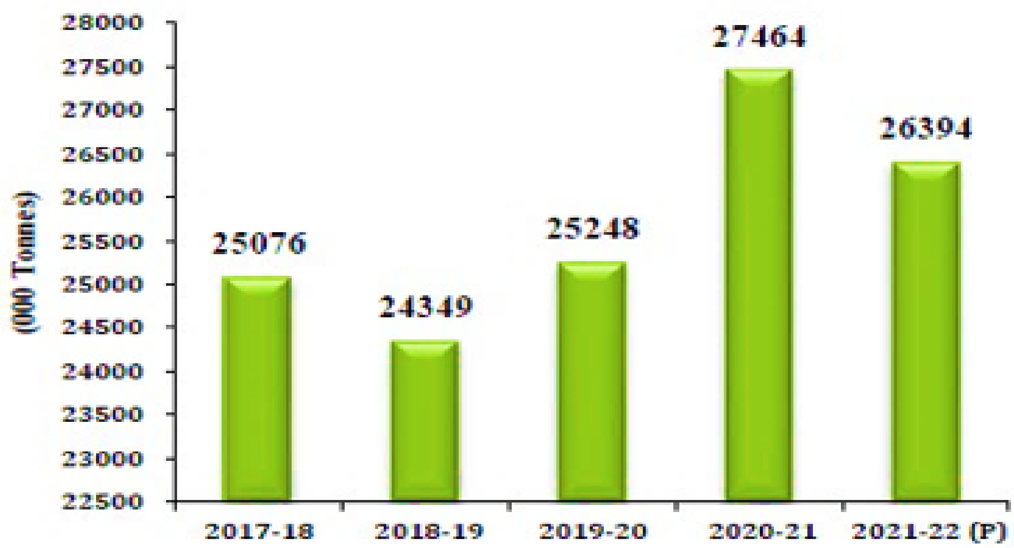

Figure 3.2: Wheat Production Over the Years in Pakistan [87]

According to the literature, for each Kg of wheat grains delivered, roughly one and a half Kg straw is produced [59]. In such manner, it can be observed from above chart that huge amount of wheat straw is achieved each year in Pakistan. These straws are flamed to the ashes to be utilized as cement replacement as well [60].

3.3.2.2 Rice Husk

Rice is a significant money crop and after wheat and it is second significant essential crop, utilized in the country. It contributes 2.4% of significant worth including agricultural industry and 0.5% in Gross domestic product. Rice production in Pakistan over the span of years in shown in figure 3.3 [87].

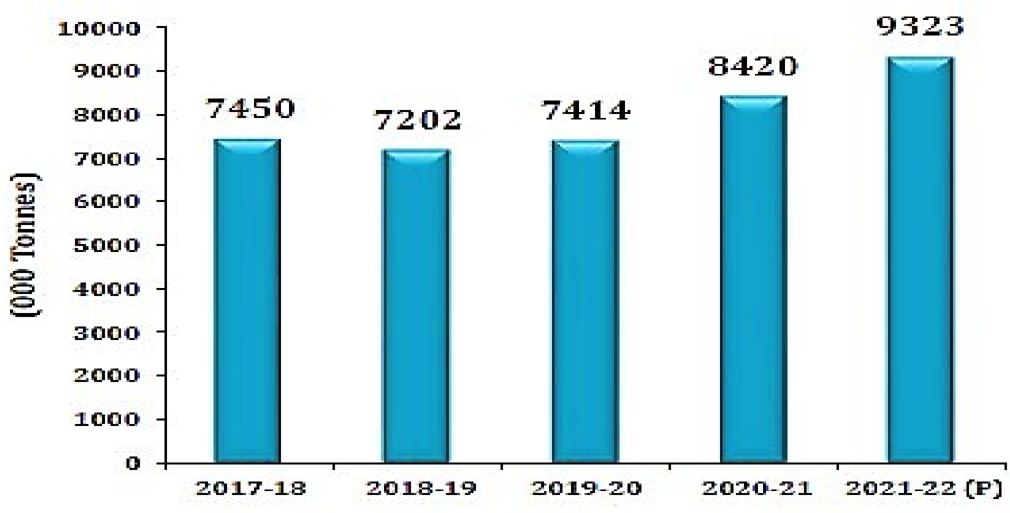

FIGURE 3.3: Rice Production in Pakistan [87]

Per ton paddy creates almost 200Kg husk [29], hence bulk quantity of rice husk is available to be utilized in concrete due to common availability of rice crop in Pakistan. This husk is burnt to ashes to e utilized in concrete as cement replacement [57].

3.3.2.3 Sugarcane

Sugarcane is of extraordinary importance for sugar related factories and second the biggest agro-based industry after clothing industry. Its creation represents 3.7% in farming's worth expansion and 0.8% in Gross domestic product. **Figure 3.4** represents production of sugarcane in Pakistan [87].

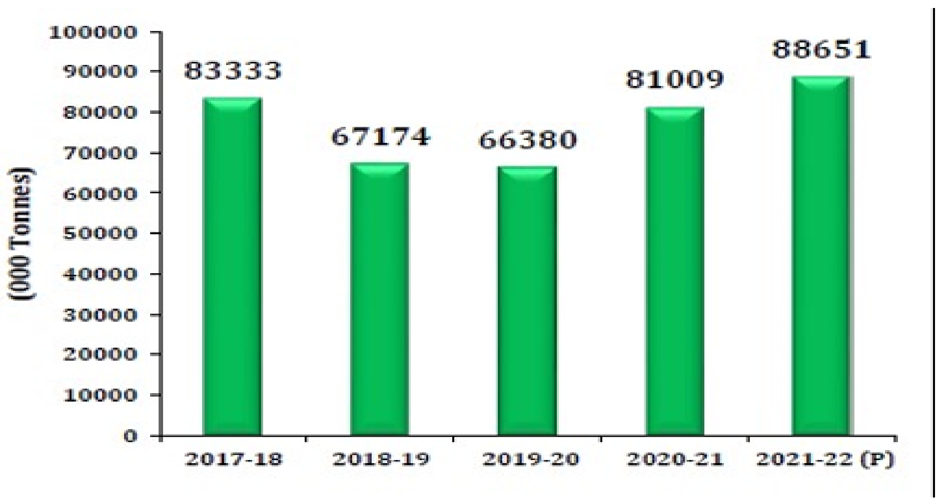

FIGURE 3.4: Sugarcane Production in Pakistan [87]

3.4 LCA of Utilization of Fibers within Concrete

LCA is a technique to acquire general climatic impressions of a product. The objective of a LCA is to decide all ecological effects of an item or administration over its lifetime. LCA system is characterized through a progression of guidelines from the "International Organization for Standardization (ISO)", ISO 14040, and ISO 14044 [82]. Life cycle assessment of utilization of natural fibers i.e. RH-RHA, WS-WSA and SCB-SCBA can be calculated via available software like Open LCA. Properties associated with this fiber alter under unique situations thus RHA compositions also differ with both i.e., uncontrolled (Open burning) and controlled burning. After burning, the chemical properties of RHA show a considerable quantity of silica oxides representing pozzolanic activity. Pozzolanic attributes empower silica content inside ashes by responding with the C-H in the pores of cement to create hydration excessively. The joining of these ashes into combination with cement has been proven to work on both i.e., mechanical as well as solidness of concrete [49]. A few researchers have assessed the practicality of utilizing wheat straw ash (WSA) in ordinary cement. In case of WS, on burning, it is converted into wheat straw ash. The WSA also shows silica composition as RHA, which is necessary to react with cement due to the pozzolanic characteristics and behave like Cementous material in concrete [30]. Creation of extra C-S-H because of the aftereffect content of silica in the pozzolana act in response to free lime produced during the hydration of cement, which improves the solidified characteristics of concrete, hence making bagasse as a solid component of concrete. Silica oxides are also present in chemical composition of sugarcane bagasse ash as the other two fibers ashes i.e., RHA and WSA. Thus, sugarcane bagasse ash also exhibits pozzolanic characteristics making SCBA as a cementitious material in concrete [31].

3.4.1 Open LCA

Open LCA is a free software available for life cycle assessment. This software has many utilities like modelling of process alongside environmental impact assessment. In Open LCA, there is component level "item frameworks" which are explicitly demonstrated life cycles, for example a particular series of cycles. These item frameworks can be determined and dissected in Open LCA [82].

3.4.1.1 Brief Methodology of Software Open LCA

Open LCA software is very handy free software which works with inputs data already present in databases. A detailed methodology on the working of software is presented in **Figure 3.5**.

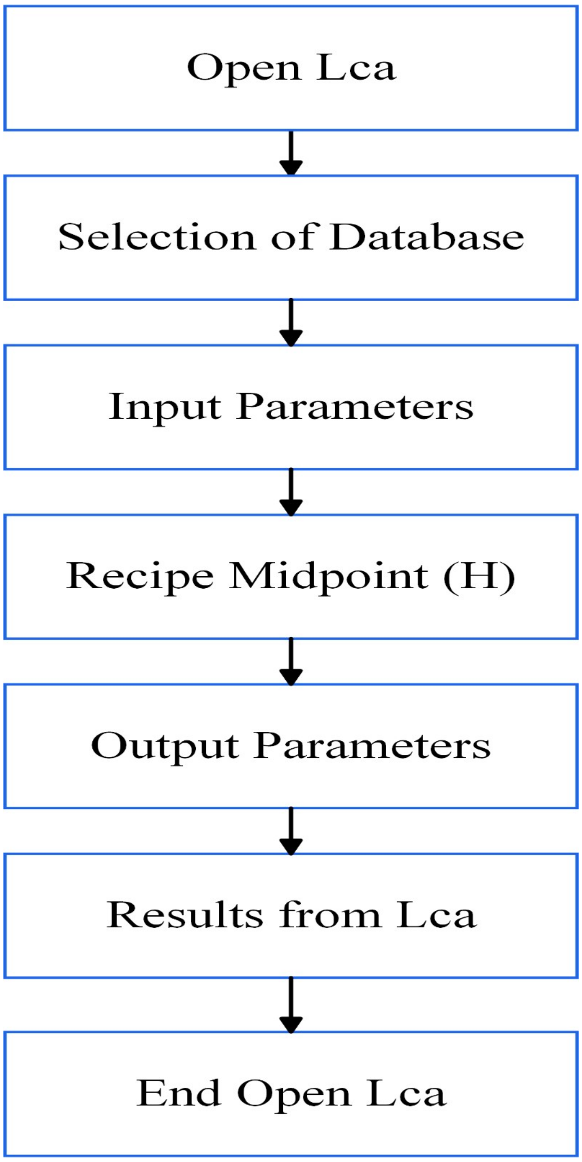

FIGURE 3.5: Detailed Methodology of Software

Selection of database is made from official website of open LCA. A number of databases like "Open LCA LCIA methods v2.1.3", "Agribalyse" and "ecoinvent" are to be named a few widely used databases. After picking up database ecoinvent, input parameters are added to the software in as the substitution proportion for cement is obtained from the literature i.e. 15% Rice husk, 10% for wheat straw and 20% for Sugarcane. Recipe Midpoint (H) is a methodology of software which provides CO_2 discharges in Kilograms of CO_2 equivalent, over a time horizon of 100 years. Output results are achieved and further observed.

3.5 Observing CO_2 Emissions and Ozone Depletion

After putting input data and acquiring results from Open LCA, results have been examined in detail showing CO_2 emissions and Ozone depletion from all mixes i.e. rice husk concrete, wheat straw concrete, sugarcane bagasse concrete and control mix of 1:2:4. On burning, chemical composition of the fiber's ash shows silica content and these fibers possess pozzolanic properties too, which reacts with cement and acts as a material just like cement to be utilized in concrete [29, 57, 77]. Results are discussed and summarized in Chapter 4 of this study to provide results and observations. At the end of this study, brief conclusions are future indication to minimize carbon emissions are present in logical manner.

Chapter 4

Results, Analysis and Discussion

4.1 Background

Life cycle assessment approach via Open LCA software was performed on a test sample of 1 cubic meter concrete with and without utilizing natural fibers i.e. rice husk, wheat straw-ash sugarcane bagasse to assess the carbon emissions and Ozone depletion with up-rise in construction by concrete and cement. This chapter provides results in a systematic way as described in the previous chapter of methodology and chosen concrete sample along with substituting proportions of cement to the relevant fibers are adopted from the detailed study of already available literature. For instance, opted concrete mix ration of 1:2:4 is chosen from google medium as it suggests that Concrete grade M15 has concrete mix design of 1 portion cement, 2 portions of fine aggregate and 4 portions of coarse aggregates and it is awesome and most ordinarily utilize grade. It is because of its compressive strength and benefits economically [13]. Following the similar pattern, cement substitution proportions are also gathered around from the latest available literature on Google Scholar.

4.2 Data Analysis

Inventory analysis and descriptive analysis were performed on conventional concrete and the fiber based concrete. Concrete is key factor behind up-rising in construction and cement must be reduced as the cement is key component behind CO_2 emissions [9]. The details are presented below in the pie chart section.

4.2.1 Inventory Analysis

Inventory analysis will help to understand the quantities of mix design alongside substitution of cement with natural fibers to provide a better idea about the input parameters of the Open LCA for further analysis. **Table 4.1** shows quantities for 1 cubic meter control mix of cement comprised of ratio 1:2:4.

TABLE 4.1: Substituted Quantified Table for Concrete Ingredients

Concrete Quantities with Substitute Fiber								
Cement	174.25	Kg/cu.m	Cement	164	Kg/cu.m	Cement	185	Kg/cu.m
Sand	410	Kg/cu.m	Sand	410	Kg/cu.m	Sand	410	Kg/cu.m
Gravel	820	Kg/cu.m	Gravel	820	Kg/cu.m	Gravel	820	Kg/cu.m
RHA	**30.75**	Kg/cu.m	**SCBA**	**41**	Kg/cu.m	**WSA**	**20.5**	Kg/cu.m

These substitutions are made from previous literature i.e., 10% for wheat straw, it's joining up-to 10% substitution of PC was discovered to improve the compression strength, splitting rigidity in addition to flexural strength [57, 61, 65], 15% for rice husk because using most noteworthy and improved strength was achieved when cement was replaced with 15% RHA in concrete [29, 30, 51] and 20% for sugarcane bagasse because SCBA utilized concrete creates higher strength in compression than that of typical cement concrete however the utilization of SCBA is regarded as optimum if added as 20% replacement [34,77]. Quantity of cement which was taken as 205 KG/cu.m is reduced in similar manner as shown in table 4.1 above. To convert fibers into ash, there is a heat process in input parameter of software named as start-up heat.

4.3 Impact Assessment

After putting input data in the software, output results are achieved from Open LCA software. These output results are presented below.

Table 4.2: Wheat Straw Process-Wise CO_2 Emissions

Name	**Category**	**Impact Results**	**Units**
Climate change - GWP100		164.73167	kg CO_2-Eq
cement production, Portland — cement, Portland — APOS, S - RoW	239:Manufacture of non-metallic mineral products n.e.c. / 2394:Manufacture of cement, lime and plaster		kg CO_2-Eq
gravel production, crushed — gravel, crushed — APOS, S - RoW	081:Quarrying of stone, sand and clay / 0810:Quarrying of stone, sand and clay	6.6288	kg CO_2-Eq
gravel and sand quarry operation — sand — APOS, S - RoW	081:Quarrying of stone, sand and clay / 0810:Quarrying of stone, sand and clay	1.65926	kg CO_2-Eq
wheat production — straw — APOS, S - RoW	011:Growing of non-perennial crops / 0111:Growing of cereals (except rice), leguminous crops and oil seeds	0.79988	kg CO_2-Eq

4.3.1 Carbon Emissions from WSA Concrete

Wheat straw ash concrete showed 164.73 KG CO_2-EQ emissions and detailed emissions are presented below in the table 4.2. Pie chart presented below in fig. 4.1 shows relative percentages of CO_2 emissions during each process to get final product to one cubic meter concrete.

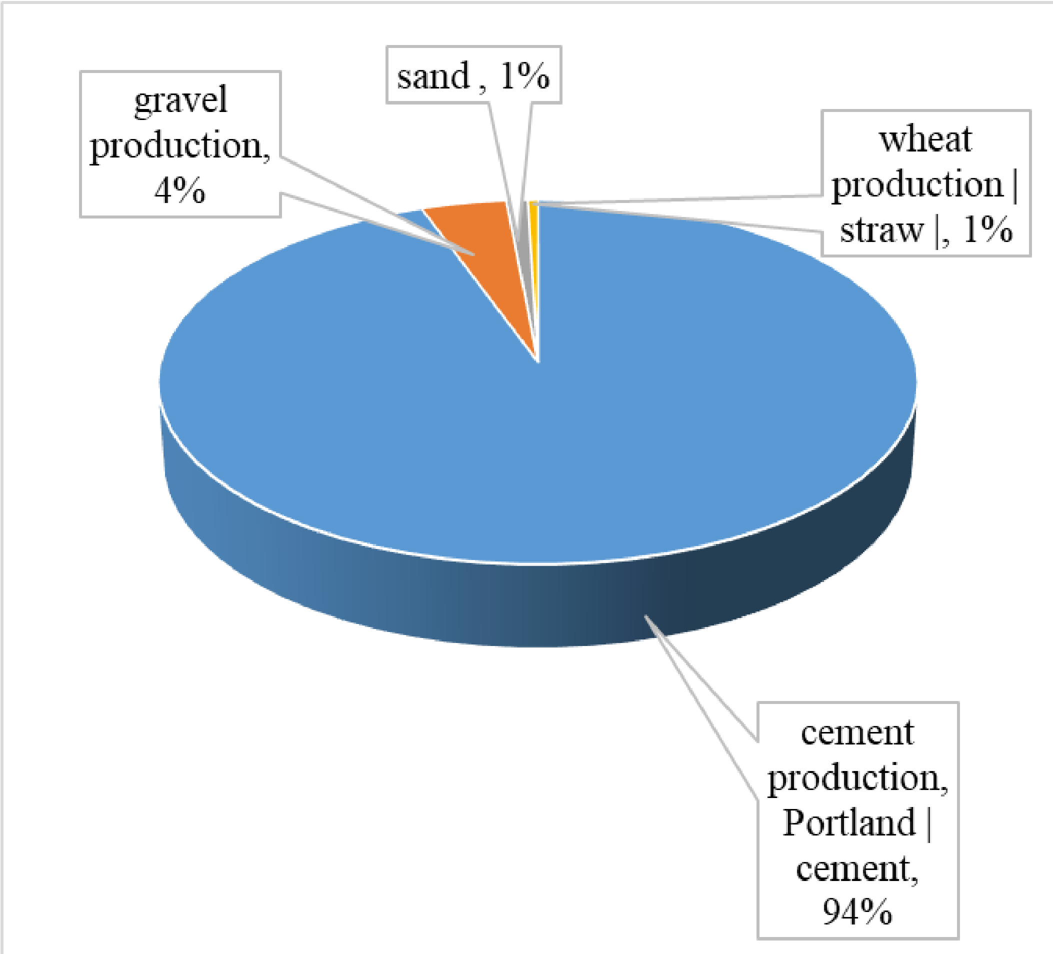

FIGURE 4.1: CO_2 Emission Relative Percentages from WSA Concrete

It is for sure that cement is the major factor with 94% CO_2 emissions while wheat production to provide 30 Kg/cu.m straw is only 1% responsible for CO_2 emissions.

4.3.2 Carbon Emissions from RHA Concrete

Rice husk ash concrete showed 157.099 KG CO_2-EQ emissions and detailed emissions including CO_2 emissions during 30 KG of rice husk are presented below in table 4.3.

Table 4.3: Process-wise CO_2 Emissions During RHA Concrete

Name	**Category**	**Impact Assessment**	**Units**
climate change - GWP100		157.09919	kg CO_2-Eq
cement production, Portland — cement, Portland — APOS, S - RoW	239:Manufacture of non-metallic mineral products n.e.c. / 2394:Manufacture of cement, lime and plaster	146.99685	kg CO_2-Eq
gravel production, crushed — gravel, crushed — APOS, S - RoW	081:Quarrying of stone, sand and clay / 0810:Quarrying of stone, sand and clay	6.6288	kg CO_2-Eq
sand quarry operation, extraction from river bed — sand — APOS, S - RoW	081:Quarrying of stone, sand and clay / 0810:Quarrying of stone, sand and clay	1.9232	kg CO_2-Eq
rice production, non-basmati — straw — APOS, S - RoW	011:Growing of non-perennial crops / 0112:Growing of rice	1.55034	kg CO_2-Eq

Pie-chart is presented in figure 4.5 below to illustrate percentages of CO_2 emissions during each process to achieve one cubic meter RHA concrete.

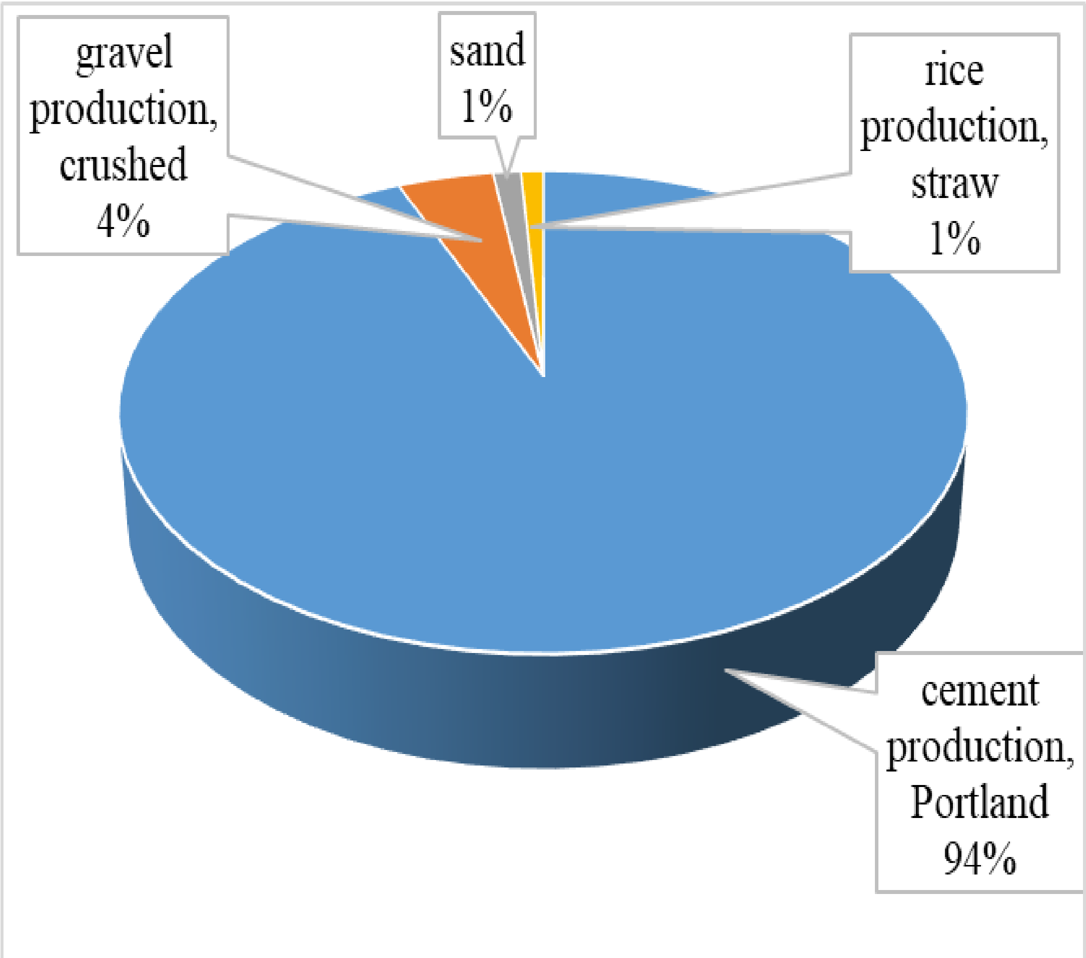

FIGURE 4.2: CO_2 Emission Relative Percentages from RHA Concrete

Following the similar trend as WSA, RHA concrete also emits 94% CO_2 from cement manufacturing while production of 30.75 Kg/cu.m is responsible for least emissions that is only 1%.

4.3.3 Carbon Emissions from SCBA Concrete

CO_2 emissions from bagasse ash concrete are presented in table 4.4.

It is obvious that from 152.20988 kg CO_2-Eq emissions, 41 Kg/cu.m sugarcane production is responsible for 5.3079 kg CO_2-Eq while cement generates plenty of CO_2 that is 138.34998 kg CO_2-Eq.

Table 4.4: Process-Wise CO_2 Emissions During SCBA Concrete

Sugarcane Bagasse Ash Process Wise Results

Name	**Category**	**Impact Result**	**Unit**
climate change - GWP100		152.20988	kg CO_2-Eq
cement production, Portland — cement, Portland — APOS, S - RoW	239:Manufacture of non-metallic mineral products n.e.c. /2394:Manufacture of cement, lime and plaster	138.34998	kg CO_2-Eq
gravel production, crushed — gravel, crushed — APOS, S - RoW	081:Quarrying of stone, sand and clay / 0810:Quarrying of stone, sand and clay	6.6288	kg CO_2-Eq
sugarcane production — sugarcane — APOS, S - RoW	011:Growing of non-perennial crops / 0114:Growing of sugar cane	5.3079	kg CO_2-Eq
sand quarry operation, extraction from river bed — sand — APOS, S - RoW	081:Quarrying of stone, sand and clay / 0810:Quarrying of stone, sand and clay	1.9232	kg CO_2-Eq

Pie chart containing percentages of SCBA concrete is presented below in **Figure 4.3**.

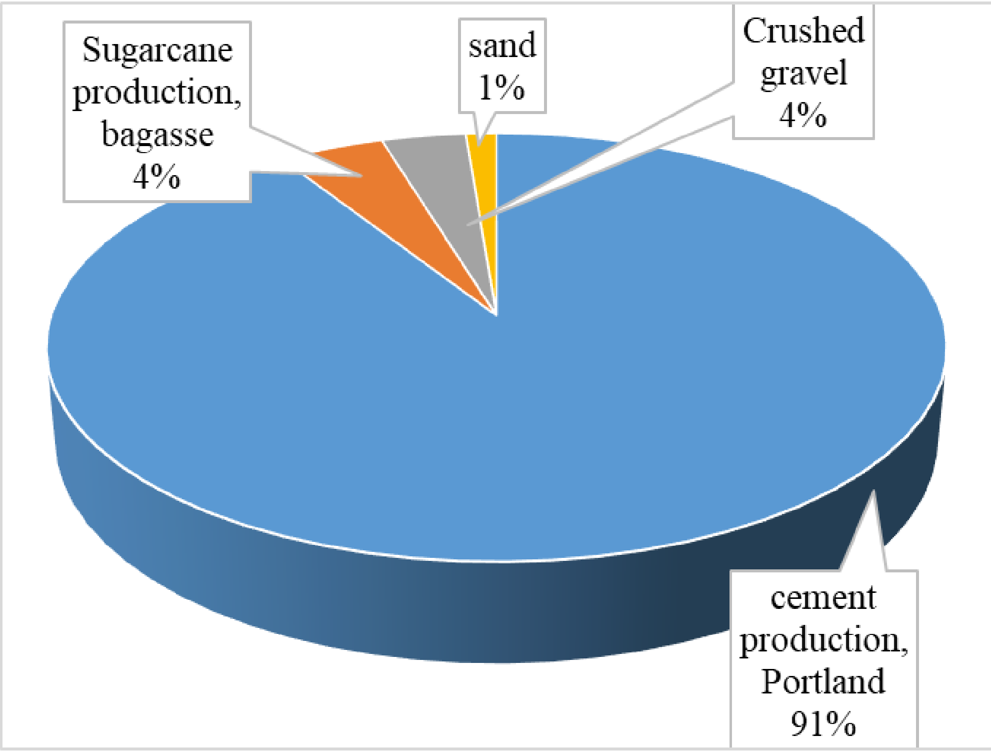

FIGURE 4.3: Carbon Emissions Relative Percentages from SCBA Concrete

There is something to be noticed that relatively, sugarcane production contributes to 4% CO_2 emissions as compared to the rice and wheat. This elevated carbon emissions indicate towards usage of some fertilizers in excessive quantity as the similar behaviour was observed in a study conducted by Sinoh, et al. [83]

4.4 Impact Categories

In the GWP 100 technique of software, which indicates towards global warming potentials over a period of 100 years, there are a number of indicators which are observed during life cycle assessment of proposed fibers. Those factors along with units are presented below in table 4.5 and there are two key factors i.e. climate change and Ozone depletion which are main concern of this literature.

On the basis of above mentioned indicators, two separate procedures have been carried out in Open LCA software. Some researchers for instance Farooqi and Ali [84] have suggested utilization of natural fibers with some treatments instead of

Table 4.5: Indicators During GWP 100 Method of LCA

Impact Categories **Indicator**	**Unit**
agricultural land occupation - ALOP	m2a
fossil depletion - FDP	kg oil-Eq
freshwater ecotoxicity - FETPinf	kg 1,4-DCB-Eq
freshwater eutrophication - FEP	kg P-Eq
human toxicity - HTPinf	kg 1,4-DCB-Eq
ionising radiation - IRP_HE	kg U235-Eq
marine ecotoxicity - METPinf	kg 1,4-DCB-Eq
marine eutrophication - MEP	kg N-Eq
metal depletion - MDP	kg Fe-Eq
natural land transformation - NLTP	m2
particulate matter formation - PMFP	kg PM10-Eq
photochemical oxidant formation - POFP	kg NMVOC
terrestrial acidification - TAP100	kg SO_2-Eq
terrestrial ecotoxicity - TETPinf	kg 1,4-DCB-Eq
urban land occupation - ULOP	m2a
water depletion - WDP	m3

burning it and converting into ashes. While other researchers like Bheel, et al. [58] have converted fiber into ash and then concluded performance as replacement of cement. Keeping in mind about sustainability, both practices i.e. with converting into ashes and without converting into ashes have been practiced in Open LCA inventory. Results for both practice are presented below in this chapter.

4.5 Impact Assessment while Fibers are Un-Burnt

Fibers are utilized in concrete as strengthening ingredients or any other beneficial purposes without being converted into ashes. In such case, some treatment methods and varying lengths of fibers as suggested by Farooqi and Ali [84] can be taken into consideration. Impact assessment of natural fibers utilization in concrete without converting into ash is presented below in table 4.6.

Table 4.6: Impact Assessment of Un-Burnt Natural Fibers with Control Mix

Results Indicator	**Rice**	**Wheat**	**Bagasse**	**Control Mix**	**Unit**
agricultural land occupation - ALOP	3.26E±00	5.24E±00	9.54E±00	2.36E±00	m2a
fossil depletion - FDP	1.79E±01	1.86E±01	1.72E±01	1.94E±01	kg oil-Eq
freshwater ecotoxicity - FETPinf	9.58E-01	1.05E±00	9.91E-01	2.23E±00	kg 1,4-DCB-Eq
freshwater eutrophication - FEP	1.94E-02	2.10E-02	1.88E-02	2.82E-02	kg P-Eq
human toxicity - HTPinf	2.01E±01	2.15E±01	2.05E±01	4.68E±01	kg 1,4-DCB-Eq
ionising radiation - IRP_HE	4.51E±00	4.70E±00	4.39E±00	9.24E±00	kg U235-Eq
marine ecotoxicity - METPinf	8.55E-01	9.16E-01	8.49E-01	2.09E±00	kg 1,4-DCB-Eq
marine eutrophication - MEP	1.46E-01	1.43E-01	1.56E-01	2.48E-02	kg N-Eq
metal depletion - MDP	3.27E±00	3.50E±00	3.22E±00	9.52E±00	kg Fe-Eq
natural land transformation - NLTP	5.58E-02	2.71E-02	5.56E-02	4.63E-02	m2
particulate matter formation - PMFP	1.63E-01	1.68E-01	1.67E-01	1.79E-01	kg PM10-Eq
photochemical oxidant formation - POFP	3.81E-01	3.85E-01	4.36E-01	4.41E-01	kg NMVOC
terrestrial acidification - TAP100	3.49E-01	3.63E-01	3.73E-01	3.83E-01	kg SO_2-Eq
terrestrial ecotoxicity - TETPinf	5.70E-03	1.12E-02	3.40E-02	2.36E-02	kg 1,4-DCB-Eq
urban land occupation - ULOP	8.98E±00	2.87E±00	8.80E±00	2.36E±00	m2a
water depletion - WDP	4.59E±00	6.83E-01	5.71E±00	5.91E-01	m3

It is for sure that control mix without any fiber has greatest impact assessment and ozone depletion. Graphical presentation of above mentioned results is presented below in the figure 4.4.

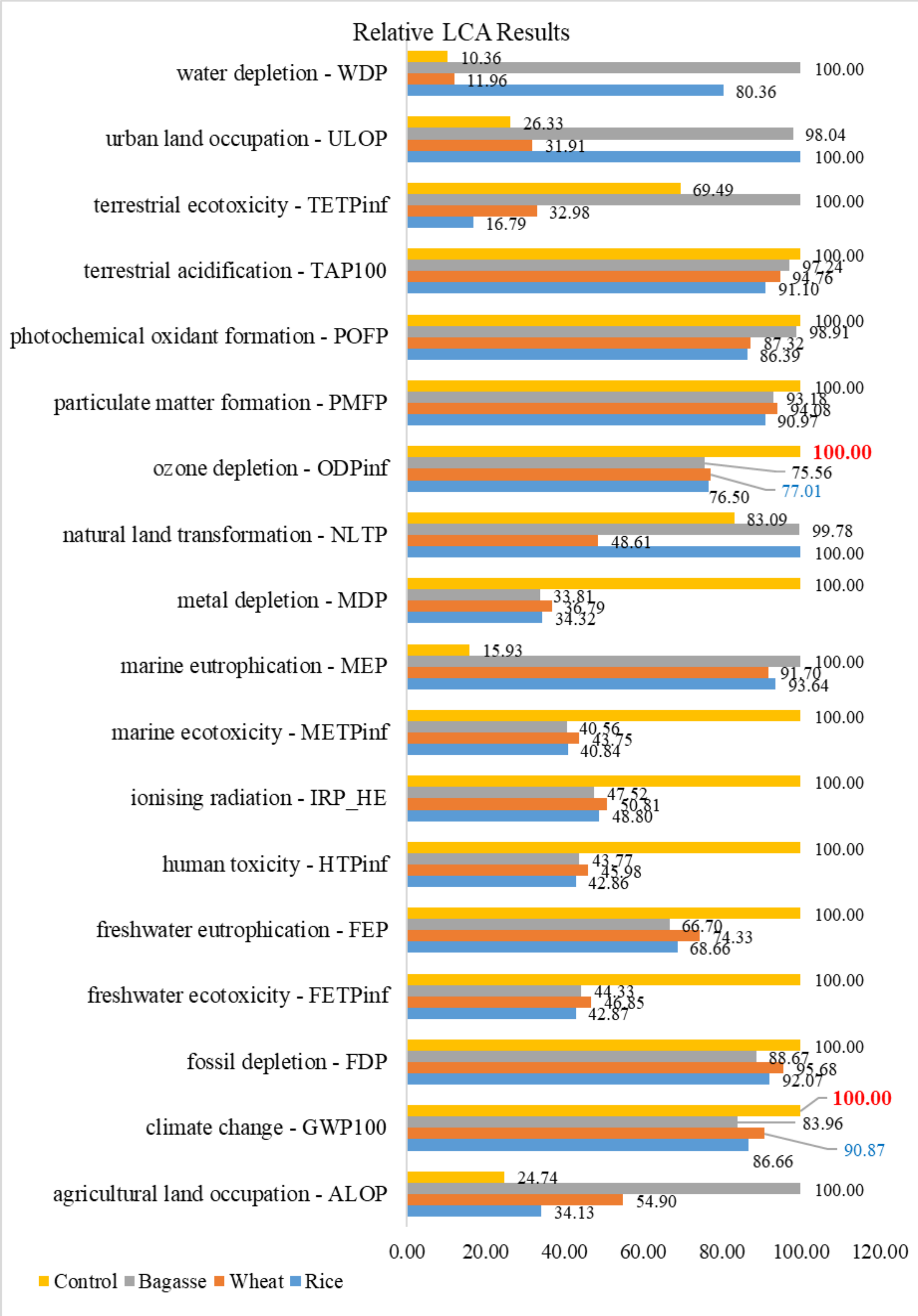

Figure 4.4: Relative LCA Results for Natural Fibers Impact Assessment

It is for sure that both i.e., ozone depletion and climate change relative values are greatest for control mix 1:2:4 and it is proven from pie charts that cement is main factor behind elevated CO_2 emissions. Moreover, Ozone depletion is mainly linked with Chlorine and bromine gases. According to the Barnes et, al. [91], ozone depletion is linked with climate changes directly as it is one of the reasons behind climate changes. Ozone depletion is mainly linked with chlorine and bromine gases while climatic changes happen due to CO_2 and methane gases mostly [93].

However, ozone depleting substance emissions were suggested to be restricted under some fixed values i.e., 1-2 giga tonnes of CO_2-equivalent on average per year between 2008 and 2012 according to the Montreal protocol by developed countries but these emissions were 5 to 6 times larger in actual period of year from 2008 to 2012 [92]. Bagasse ash concrete has shown minimum carbon emissions due to the fact that bagasse is already a waste product after being utilized in sugar and energy factories.

While climatic changes happen due to CO_2 and Methane gases mostly [91]. This is the reason that climatic change factor shows higher values rather than ozone depletion due to type of gases being trapped in the atmosphere.

4.6 Impact Assessment while Fibers are Burnt and Used as Ash

According to some researchers, natural fibers converted into ash have better impacts upon the characteristics of concrete. Impact analysis by applying heat to change fibers into ashes in presented below in table 4.7.

It is interesting to see that ozone depletion of wheat straw ash concrete is the relatively highest followed by rice husk ash. It is due to two key factors and one is utilization of different type of agro-fertilizers and second one is the burning. Bagasse ash concrete has shown minimum carbon emissions due to the fact that bagasse is already a waste product after being utilized in sugar and energy factories.

Table 4.7: Fibers-Ash Concrete Impact Assessment

Results **Indicator**	**Rice Ash**	**Wheat Ash**	**Bagasse Ash**	**Control**	**Unit**
agricultural land occupation - ALOP	1.38E±01	1.59E±01	1.82E±01	2.36E±00	m2a
fossil depletion - FDP	5.11E±01	5.20E±01	1.72E±01	1.94E±01	kg oil-Eq
freshwater ecotoxicity - FETPinf	7.63E±00	7.66E±00	9.74E-01	2.23E±00	kg 1,4-DCB-Eq
freshwater eutrophication - FEP	3.34E-02	3.45E-02	1.88E-02	2.82E-02	kg P-Eq
human toxicity - HTPinf	4.57E±01	4.67E±01	2.01E±01	4.68E±01	kg 1,4-DCB-Eq
ionising radiation - IRP_HE	1.15E±01	1.17E±01	4.39E±00	9.24E±00	kg U235-Eq
marine ecotoxicity - METPinf	6.69E±00	6.72E±00	8.46E-01	2.09E±00	kg 1,4-DCB-Eq
marine eutrophication - MEP	4.68E-02	4.28E-02	4.42E-02	2.48E-02	kg N-Eq
metal depletion - MDP	1.01E±01	1.01E±01	2.27E±00	9.52E±00	kg Fe-Eq
natural land transformation - NLTP	2.94E-02	2.96E-02	2.28E-02	4.63E-02	m2
particulate matter formation - PMFP	3.19E-01	3.28E-01	1.69E-01	1.79E-01	kg PM10-Eq
photochemical oxidant formation - POFP	7.35E-01	7.54E-01	4.36E-01	4.41E-01	kg NMVOC
terrestrial acidification - TAP100	6.79E-01	6.99E-01	3.84E-01	3.83E-01	kg SO_2-Eq
terrestrial ecotoxicity - TETPinf	2.32E-02	2.86E-02	2.70E-01	2.36E-02	kg 1,4-DCB-Eq
urban land occupation - ULOP	3.18E±00	3.12E±00	5.48E-01	2.36E±00	m2a
water depletion - WDP	1.58E±00	1.20E±00	1.83E±00	5.91E-01	m3

Figure 4.5 below shows relative results of impact assessment when fibers are burnt, turned into ashes and utilized in concrete.

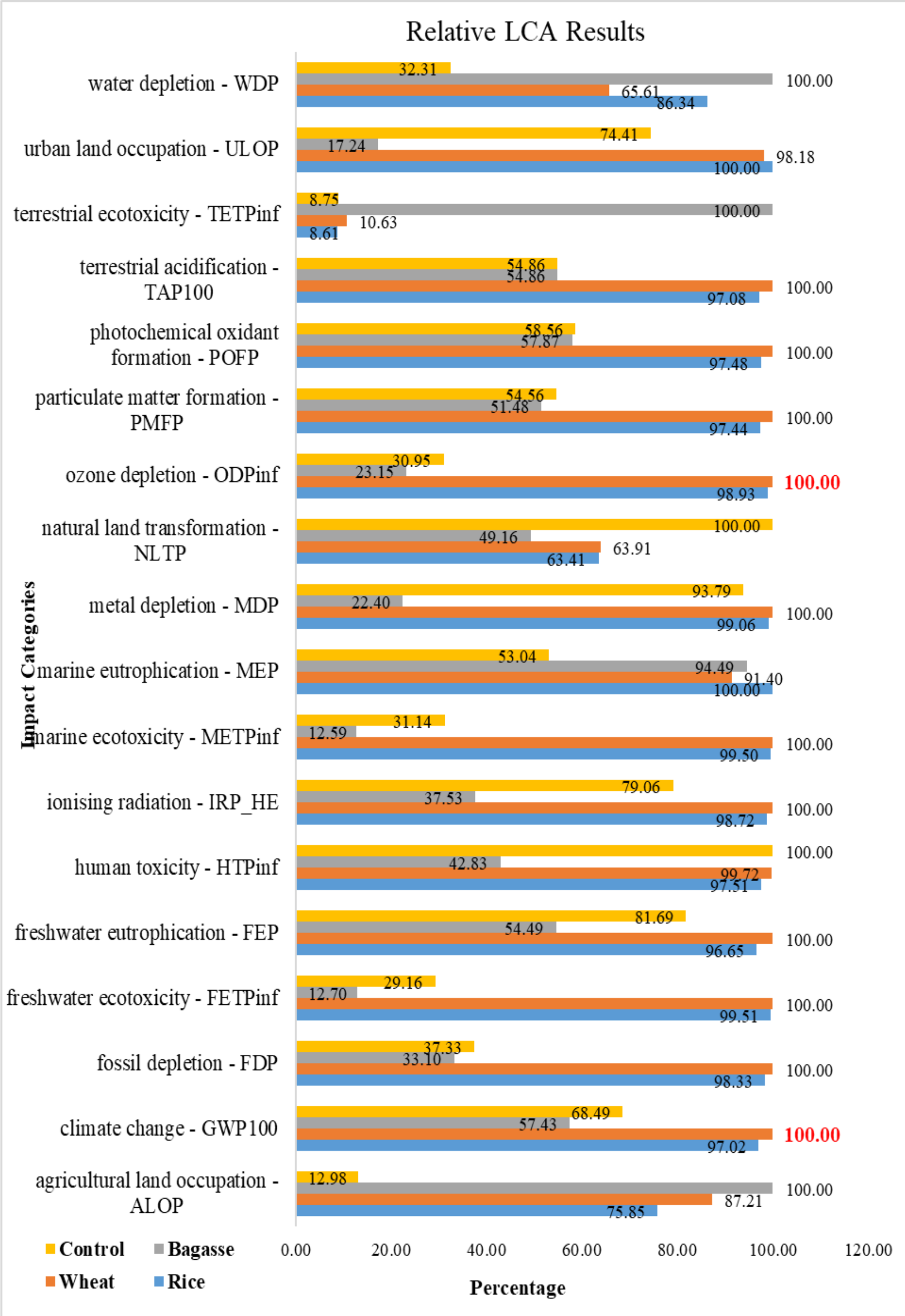

FIGURE 4.5: Relative LCA Results of Natural Fibers Ash

A similar trend was observed when Sinoh, et al. [89] performed LCA of sugarcane bagasse and concluded that utilization of nitrogen fertilizers in agriculture sector is destroying stratosphere hence causing ozone depletion at increasing pace. In this regard, a report submitted by Tynan [92] suggests that utilization of fertilizers and chemicals to agricultural sector are main source of the carbon emissions from agrarian territory. Table 4.8 shows difference in carbon emissions when wheat was grown conventionally and with fertilizers.

TABLE 4.8: Difference in CO_2 Emissions with different Techniques of Crop Growing [92]

Treatment	**Removable Straw Yield (kg Straw/ha)**	**Total CO_2/Ton Straw**
Conventional	983	154
Organic	961	52

Another consideration in this regard can be taken from the study of Jaiswal and Agrawal [93], they suggested that carbon emissions for same crop in different region may not be the same due to agricultural methods and climatic variations. Hence these are some of the reasons behind elevated ozone depletion when natural fibers are burnt to ashes and then utilized in concrete. Graph presented below in figure 4.6 shows an idea about changes in ozone depletion and climates changes with respect to control concrete for variations.

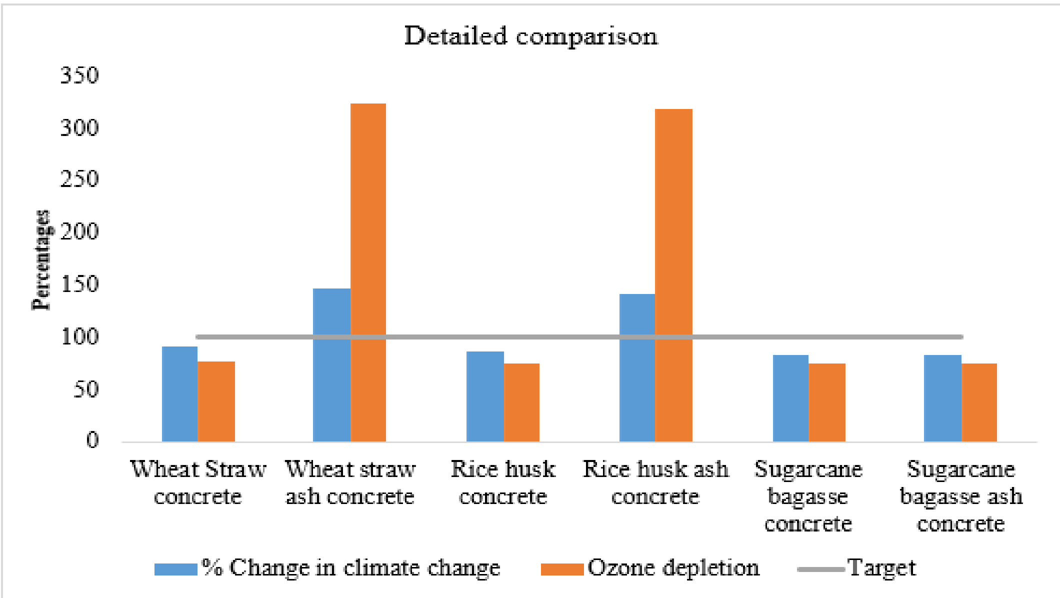

FIGURE 4.6: Detailed Comparison of Ozone Depletion and Climate Change

4.7 CO_2 Emissions During Transportation

Transportation is another factor related with life cycle assessment of natural fibers utilization in concrete and it includes both phases i.e. transportation to the treatment plant and later transportation of concrete to the site. According to the Maag [88], consumption of one gallon oil emits almost 8.71 KG CO_2 into the climate. Different fuel type along-with CO_2 emissions are presented below in **Table 4.9**[84].

Table 4.9: CO_2 Emission Due to Different Fuels [94]

Fuel Type	**CO_2 Emissions Tailpipe (Kg/L)**
Gasoline	2.29
Diesel	2.65

This reference article and it's findings may be utilized to calculate amount of diesel consumed while transportation of the material.

4.8 Discussion

This literature focused on life cycle assessment of natural fibers utilization in construction industry. Natural fibers are somehow substitution of normal concrete to minimize greenhouse gases impact and these fibers are used to lessen cement quantity resulting in less CO_2 emissions without compromising the strength. This chapter provides detailed parameters of defined methodology and relative results are presented in tabular form to have a better understanding and deciding the best suitable fiber on the basis of CO_2 emissions. Carbon emissions during the transportation of materials cannot be neglected hence the emissions during transportation can also be taken into consideration to choose best available fiber close to the working site.

In the light of above obtained results, it is for sure that global impact assessment and ozone depletion is elevated for wheat straw, followed by rice husk and then sugarcane bagasse. Nitrogen is key factor behind carbon emissions as the nitrogen fertilizers utilization is major source of CO_2 emissions. Hence agricultural methods of cropping can play an important role in GHG resulting climatic impacts [94]. As far as Pakistan is concerned, every major crop is supported with nitrogen fertilizers to improve fertility of land and better yield of crops. Major crop which utilizes nitrogen fertilizer is wheat followed by rice and 3rd one is sugarcane [95], hence indicating towards most elevated climatic change impact and ozone depletion by wheat straw followed by rice husk and sugarcane bagasse in the last position. Rice containing lands are also key source of GHG like CH4 and N20 [96], hence making it a significant contributor towards climatic changes after wheat straw.

On other hand, using natural fibers while burnt to the ashes showed higher impacts of climatic changes and ozone depletion. For instance, after cultivation and obtaining grains from wheat crop, almost 85% of waste is burnt for disposal purposes after harvesting [97, 98]. When wheat straw is burnt to ash, it showed much higher climatic impact and ozone depletion values. In a study conducted by Sun, et al. [96], it was obvious that burning wheat straw has devastating climatic impacts. But as mentioned earlier in this study, ashes of natural fibers have pozzolana and instead of open burning creating more ecological problems, their utilization in concrete is more sustainable as the mentioned fibers have potential to be a sustainable replacement of cement hence lessening the CO_2 emissions [51-53].

It may be noticed well that on a comparative scale, ozone depletion is rather less than climate change impact values. This is due to a connection between ozone depletion and climate change impact. According to the Barnes, et al. [89], ozone depletion is linked with climate changes directly. It means GHG for instance nitrogen and methane are depleting ozone level hence this depletion is causing severe changes in climates directly. These consequences are happening in form of extreme and unexpected weather conditions like extreme rains or no rain at all resulting in droughts. In addition to the climatic changes, health of human beings is also a major result of the ozone depletion for example increment in numbers of cancer patients eyes related diseases [90]. From the achieved results of this study, it is proven that burning fibers to ashes in resulting in elevated ozone depletion hence elevated climatic changes which is affecting humans as well as animals and plants badly.

Transport is also contributing towards GHG. According to the Peng, et al. [91], transport is responsible for 1/4 CO_2 emissions world-wide and from this portion, three parts are directly linked with transportation by road. As the transportation to manufacture concrete then to the construction site, this portion is having quiet an impact towards enhanced global warming potentials. With rapid increase in construction activities, transportation of material is also enhancing contributing towards more damage to the climate and ozone depletion.

To summarize the above discussion, it is obvious that due to cement utilization, CO_2 emissions are increasing rapidly worldwide. Natural fibers are being used as cementitious materials in concrete and if the optimized substitution properties of concrete related to the strength i.e., compressive, splitting and flexural strengths aren't compromised i.e., 10% for wheat straw improved the compression strength by 12%, splitting strength 10% along with flexural strength by 11% [57, 61, 65]. For 15% rice husk, the most noteworthy and improved compression strength by 22% was achieved [29,30,51]. When the 20% substitution for sugarcane bagasse has opted, 39.02% improved compressive strength was achieved as compared to the control concrete mix [34].

On the other hand, CO_2 emissions are also responsible for damaging the ozone layer-wise and making the ozone colder hence the carbon should be restricted to a fixed value somehow [100]. Agricultural wastes are usually burnt in the open environments causing excessive ozone depletion and smog hence damaging the environment in a devastating way [61]. To deal with this issue of open burning of fibers, burning in a controlled environment on some specified temperature and utilization as cement replacement up to some extent tends to minimize uplifted CO_2 and chlorofluorocarbons content hence dealing with rapid ozone depletion phenomenon providing improved strength in concrete also the problem dealing with the disposal of these waste agricultural materials into landfills consequently reducing cement utilization in concrete and hence reduction in CO_2 emissions per anum [29,57,77].

Chapter 5

Conclusion and Recommendations

This chapter deals with the conclusions and recommendations based on the data analysis as well as suggests the directions for future research.

5.1 Conclusion

Purpose of this study was to assess carbon emissions via life cycle assessment from locally available natural fibers in Pakistan which are considered as somehow replacement of cement in traditional concrete control mix to minimize CO_2 emissions leading towards Ozone depletion and causing abnormal climatic changes around the globe. Open LCA software was used to perform life cycle assessment of natural fibers in concrete in both manners i.e. with burnt to ashes and without converting into ashes as the literature suggested both of the techniques to utilize natural fibers in construction. This study and findings extracted from results and discussion chapter will help for sure the authorities to adopt techniques to lessen cement quantity without compromising the strength and other essential properties ultimately. Results, which are concluded from output of software are presented below as conclusions: To prepare one cubic meter concrete sample as input in software, 1:2:4 of control mix was adopted as it is widely used control mix according to the studied researches. Wheat straw-ash, Rice husk-ash, and Sugarcane bagasse-ash were used in proportion on 10%, 15%, and 20% respectively. Thus the quantities were 20.5 Kg/cu.m, 30.70 Kg/cu.m and 41 Kg/cu.m respectively as a substitution material from total quantity of cement which was 205 Kg/cu. As mentioned previously in this chapter, output analysis was performed in Open LCA with natural fibers as well as by burning into ashes. Hence conclusions are presented below in same order i.e. results of natural fibers and natural fibers turned into ashes:

- From the 18 indicators like ALOP, MDP, NLTP and so on, included in library of "Global Warming Potentials" GWP 100 method which is calculated for a time span of 100 years, main focus of this research was upon carbon emissions in the climate and ozone depletion gases. Hence climate change - GWP100 utilization for 20.5 Kg/cu.m WS utilization, it was 1.65E+02 kg CO_2-Eq while for 30.75 KG/cu.m. For RH, it was 1.57E+02 kg CO_2-Eq and SCB showed minimum quantity of all that is 1.52E+02 kg CO_2-Eq for 41 Kg/cu.m. Control mix of 1:2:4 showed highest quantity of carbon emissions that is 1.81E+02 kg CO_2-Eq. Ozone depletion which is considered in terms of chlorflourocarbon-11 was found to be maximum for control mix of 1:24 with quantity of 6.21E-06 kg CFC-11-Eq, WS utilization produced 4.78E-06, and while RH released ozone harming gases in a quantity of 4.57E-06 CFC-11-Eq. SCB emitted 4.69E-06 kg CFC-11-Eq ozone harming gases.
- On a relative measurement, control mix is responsible for 100% climate change impact followed by WS 90.87%, RH 86.66% and SCB 83%.
- On a relative measurement, control mix is also responsible for ozone depletion by 100% followed by WS 77%, RH 76% and SCB 75.56%.

To convert natural fibers into ashes for utilization in concrete, a specified temperature/heat is provided for a period of time. Hence while applying input parameter for start-up heat to convert natural fibers into ashes respectively, output results were changed. Results obtained from substituting fibers ashes into concrete as cement are presented below:

- Climate change impact of GWP 100 comprising oh GHG showed highest emissions from WSA at a quantity of 2.65E+02 kg C02-Eq followed by RHA

2.57E+02 kg CO_2-Eq. Control mix presented 1.81E+02 kg CO_2-Eq and SCBA showed minimum quantity of 1.81E+02 kg CO_2-Eq. Reason behind uplifted Global Warming Potential of both wheat straw ash and rice husk ash is the indication of fertilizers usage and open burnt technique, while bagasse is obtained already as a burnt product from boilers while comparatively less fertilizers usage during cultivation. Ozone depletion opted similar pattern as climatic impact with highest values from WSA with 2.01E-06 kg CFC-11-Eq followed by RHA with 1.98E-06 then control mix showed 6.21E-06 while SCBA showed quantity of 4.648E-06 kg CFC-11-Eq of ozone depleting gases.

- On a relative measurement, wheat straw ash is responsible for 100% climatic impacts followed by rice husk ash 97%, control mix 68.49% and sugarcane bagasse ash 57.43% on a relative scale. Elevated impacts results are already utilized fertilizers and agricultural techniques while burning of wheat straw and rice husk to convert fiber into ash. Bagasse is already a burnt product from factories in the database of software hence it represents less climatic impacts.

- Ozone depletion follows same trend as above mentioned with 100% WSA, 98.93% RHA, 30.95% control mix and 23.15% from SCBA. It may be well noted that ozone depletion is considered on the basis of hydroflourocarbons-11 scale with other relevant gases like chlorine or else bromine to harm ozone and it is obvious case for elevated figures for rice husk ash and wheat straw ash due to uplifted fertilizers usage and release of other fellow gases during cultivation, harvesting and burning.

5.2 Recommendations

This study offers a fair assessment of carbon emissions from ordinary concrete and fiber utilized concrete. Recommendations from gathered results are given below as:

- Use of natural fibers is more efficient in climatic changes achieving sustainable goals as compared to the fibers burnt into ashes.

- Sugarcane bagasse showed more promising results other than two comparatives i.e. rice husk and wheat straw.
- Highest ozone depletion was experienced from WSA followed by RHA, hence showing excessive fertilizers during cultivation consequently.
- WSA and RHA may also be practical if burnt under optimized conditions in some furnace ensuring controlled emissions.
- In most regions of Pakistan, nitrogen fertilizers are widely used in the agricultural sector [103] which has adverse effects on the environment. So, it may also be shifted towards lesser utilization to minimize the negative environmental impacts.

5.3 Future Indications

There are some key considerations in this study for further exploration which are presented below as:

- On the life cycle assessment scale, natural fiber's adoption as a cement replacement is verified in this study.
- To utilize natural fiber's ash in concrete as a cement replacement, in depth study is required to compare properties both concrete i.e. with natural fibers and with natural fiber's ash along with a proper burning technique along with specified furnace on specified temperature is essential so that fellow gases of CO_2 harming ozone stratosphere are restricted somehow.

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