ENHANCING THE STRENGTH OF RECYCLED AGGREGATE CONCRETE USING WHEAT STRAW ASH

A PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the guidance & supervision

of

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by

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May 2025

STUDENT’S DECLARATION

I hereby declare that work presented in this report entitled **“Enhancing the strength of recycled aggregate concrete using wheat straw ash”**in partial fulfillment of the requirement for the requirements for the award of degree in bachelor of Technology in the Department of Civil Engineering from **Jaypee University of Information Technology Waknaghat, Solan, H.P** is original record of my own work carried out under the supervision of **Dr. Kaushal Kumar (Assistant Professor)**. This work has not been submitted elsewhere for the award of any other degree/diploma. I am fully responsible for the contents of my project report.

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Date: 14/05/2025

SUPERVISOR’S CERTIFICATE

This is to certify that the work which is being presented in the project report titled"**Enhancing the strength of recycled aggregate concrete using wheat straw ash**" in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Anirudh (211613) during a period from August, 2024 to May, 2025** under the management of **Assistant Professor Dr. Kaushal Kumar** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.
Date: 14/05/2025

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ACKNOWLEDGEMENT

The fulfillment along with the effective culmination of any undertaking would be deficient without the mention of individuals whose perpetual contribution made it conceivable, whose steady direction and consolation crowned all endeavors with progress. I thank God for providing me with everything that is required for the completion of this project. I am especially thankful to Prof. Kaushal Kumar for the steady push and kind-heartedness which ultimately lead to the report. His suggestions and his instructions have served as the major contributor towards this project. I would also like to thank my family and friends especially my father who have helped me in any way possible and whose guidance has been very helpful in various phases of completion of the project.

Thank you.

Anirudh

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LIST OF ABBREVIATIONS

S NO.	ABBREVIATION	FULL FORM
I.	OPC	Ordinary Portland Cement
II.	FA	Fine Aggregate
III.	CA	Coarse Aggregate
IV.	WSA	Wheat Straw Ash
V.	RCA	Recycled Coarse Aggregate
VI.	RAC	Recycled Aggregate Concrete
VII.	SCM	Supplementary Cementitious Material
VIII.	MPA	Megapascal
IX.	BIS	Bureau of Indian Standards
X.	PPC	Portland Pozzolana Cement
XI.	ASTM	American Society for Testing and Materials
XII.	IS	Indian Standard
XIII.	W/C	Water to Cement Ratio
XIV.	SEM	Scanning Electron Microscope
XV.	XRD	X-ray Diffraction
XVI.	TGA	Thermogravimetric Analysis
XVII.	DTA	Interfacial Transition Zone
XVIII.	ITZ	Calcium Silicate Hydrate

XIX.	C–S–H	Calcium Aluminate Hydrate
XX.	C–A–H	Calcium Alumino Silicate Hydrate
XXI.	C–A–S–H	Stochastic Gradient Boosting
XXII.	SP	Superplasticizer
XXIII.	OMC	Optimum Moisture Content
XXIV.	MDD	Maximum Dry Density
XXV.	GWP	Global Warming Potential
XXVI.	CO_2	Carbon Dioxide
XXVII.	Kg/m^3	Kilogram per Cubic Meter
XXVIII.	cm	Centimeter
XXIX.	Kg	Kilogram
XXX.	Mm	Millimeter

ABSTRACT

As the pressures of environmental sustainability heighten and natural supply issues arise, our ability to reduce construction waste and develop environmentally sustainable solutions is becoming increasingly important. Conventional concrete relies heavily on natural aggregates and cement as a construction material, and is both increasing environmental degradation and contributing tremendously to the depletion of natural resources. The purpose of this project is to provide a new system to increase the mechanical properties and longevity of Recycled Aggregate Concrete (RAC) using a sustainable agricultural waste by-product (wheat straw ash) as a replacement for cement at different levels.

Wheat straw ash (WSA) has pozzolanic properties as a sustainable and beneficial alternative, and it is a product that houses clay and silica content that offers better vertically aligning bonding and microstructure in the concrete matrix, both of which lead to improvements in the mechanical and durability properties of the final material. This system will include an evaluation of the physical and chemical characteristics of the WSA, preparation and curing of the specimens of the RAC with replacement over a predetermined proportionating of the WSA, and an of the mechanical properties, including compressive strength, splitting tensile strength, workability and others. The main features of this system will include the original mix design, strength gain properties and the comparisons against the baseline control concrete. This method addresses the major limitations of conventional RAC, which often suffers from reduced strength and increased porosity due to weaker interfacial zones. The proposed blend improves the structural integrity while contributing to waste reduction and carbon footprint minimization. Performance metrics such as strength enhancement percentage, setting time, and durability index are used to evaluate the effectiveness of WSA incorporation.

The results of this study offer valuable insights into sustainable construction practices, promoting circular economy principles by turning agricultural and construction waste into valuable resources. Moreover, the research highlights underexplored potential in the use of biomass ash in structural applications, paving the way for further investigations in green concrete technology.

CHAPTER 01: INTRODUCTION

1.1 Recycled Aggregate Concrete

Recycled Aggregate Concrete (RAC) is a sustainable building material containing recycled aggregates from construction and demolition (C&D) waste, usually crushed discarded concrete, instead of the virgin natural aggregates such as gravel, crushed stone, or sand. RAC provides an environmentally friendly substitution to traditional concrete, allowing for the conservation of landfills to accommodate disposal of waste materials, and decreased consumption of limited natural resources.

Recycling materials associated with concrete has considerable relevance in reducing the environmental impacts of concrete. By using waste products from demolished buildings, roads, and off-spec material generated during construction it can help facilitate a circular economy within our construction sector. RAC would also generally be classified as inferior in terms of ultra-high performance but would be suitable for use as road sub-bases, footpaths, driveways, and other minor non-structural uses. Due to improvements in processing and material parsing, RAC can also be useful in structural work under certain conditions.

Recycled aggregates may introduce a few challenges – including, but not limited to, porosity, density and residual strength and durability that are potentially disadvantages compared with natural aggregates, which are generally not insurmountable through good quality control, water-cement ratios, and use of supplementary cementing materials..

As environmental sustainability becomes a matter of increasing concern, RAC is becoming known as a significant factor in green building. The implementation of RAC aids in achieving sustainable development goals (SDGs) through reducing carbon footprints, conserving raw materials, and supporting responsible waste management in construction activities. Globally, both governments and industries are implementing policies, certifications, and green building codes to include recycled aggregate concrete as standard practice.

In summary, Recycled Aggregate Concrete is a forward-thinking solution that addresses the concept of sustainability while providing further advantages for user groups around the world.

1.2 RAC is Important

Recycled Aggregate Concrete (RAC) is essential because it contributes greatly toward sustainable construction and environmental stewardship. Using RAC facilitates the reduction of vast construction and demolition waste, a large portion of which would end up in landfills and polluting the environment. It saves virgin materials, such as sand, gravel, and crushed stone, which are also facing depletion due to increasing demand from construction. By recycling the materials from the old structure, RAC reduces the demand for quarrying, and the associated energy and carbon cost to produce and transport new aggregates. It can save money, and promote consideration for green building certifications like LEED, which are smart for the economy as well as the environment.

LEED (Leadership in Energy and Environmental Design) certification is an international system developed by the U.S. Green Building Council (USGBC) for examining the environmental performance and sustainability of new buildings and construction projects. It exists to develop and encourage sustainable and energy-efficient rendering of buildings designed with environmental consideration for selection of materials for use in construction.

.1.3 (WSA) Wheat Straw Ash

Wheat Straw Ash (WSA) is a set of the ash acquired from the controlled incineration of wheat straw. Wheat straw consists of the dry stalks of the wheat plant that remain after the grain is harvested. Wheat straw is typically left, burned, or sometimes grazed on, but has the largest potential impact when you consider the current disposal and the contaminating factor when open burning occurs. Consequently, the value in WSA is in its potential for many new uses as ordinary waste completely turned into value added products.

WSA is composed of silica and many other minerals that provide it with pozzolanic activity. This makes it an exceptional construction material especially for the construction materials... the most ubiquitous concrete. WSA, when reduced to a powder, can be used as a partial replacement for Portland cement, it can improve some properties of the concrete, such as permeability and resistance to chemical attack from elements such as SO_2 and Cl^-. Furthermore, WSA is a means to lessen the carbon footprint of construction activities, while promoting sustainable development by reducing the use of Portland cement, which is responsible for CO_2 from energy.

Beyond concrete building materials, WSA has also been researched and used in the production of lightweight bricks, blocks, and other types of building materials. The use of Wheat Straw Ash not only supports sustainable construction methods, but also enhances agricultural waste stream management by decreasing landfill disposal and decreasing the open burning of agricultural waste. To maintain stable product quality, the production of Wheat Straw Ash involves controlled combusting of wheat straw over a range of temperatures that is very effective in reducing the overall carbon content and optimizing the chemical composition of wheat straw ash while decreasing the amount of total unburnt carbon and unburnt residue in the form of other impurities. The ash is passed through a 60micron sieve and at times grinded to the particulate size that meets specifications for utilization in concrete, cement, mortars, and other products.

To conclude, Wheat Straw Ash serves as an innovative and environmentally friendly practice for both agricultural waste disposal and a sustainable construction method. With wheat straw ash representing a large abundant by-product of this industry, WSA operates in accordance with principles of a circular economy and allows for more environmentally conscious building techniques in areas with heavy wheat production.

1.3.1 Why we use Wheat Straw Ash (WSA)

Wheat Straw Ash (WSA) is being seen as a useful component of construction, increasingly in the area of sustainable building. WSA is produced through burning wheat straw in a controlled manner and collecting the residue ash; wheat straw is the dry stalk that remains on the ground after the wheat grain are harvested (Figure 1). Wheat straw is often referred to as an agricultural waste product, but if used appropriately, it can be turned into a valuable resource.

One of the major factor why WSA has been gaining attention is its high silica content. Silica is a main ingredient in many pozzolans and is a beneficial material, that in conjunction with calcium hydroxide (formed as a byproduct from cement hydration) forms additional cementitious compounds in the concrete, and are used to improve the compressive strength, durability, and overall long-term performance of the concrete. In summary, WSA enhances the chemistry of the concrete mix, and a better building material will naturally create a better building, But the advantages of WSA extend far beyond improving concrete performance. One of the most challenging environmental issues, and the greatest contributor to construction's carbon footprint, is the carbon produced from cement. The production of cement requires high temperatures and energy, resulting in CO_2 emissions. By partially replacing cement with WSA in concrete mixes, the amount of cement needed is decreased, leading to greenhouse gas emission savings: it would be a legal-sized claim to say WSA is a viable option for greener construction.

Aside from reducing emissions, WSA addresses the issues of agricultural waste. In many farming land areas, wheat straw is burned in open fields, which pollutes the air and spreads risk to human health and well-being. As a usable product instead of waste, we not only lessen the environmental burden of burning but also increase the economic value from the waste it was following its end of life. This transition talks to circular economy principles, using waste as a resource wherever we can.

It may also save costs. Using WSA in concrete saves by partially replacing more expensive cement. Meaning it can be utilized to take costs away from construction without affecting construction, in some cases, sustainably. Projects like green buildings, eco-certified infrastructure. WSA offers an effective way to meet environmental goals while maintaining structural integrity.

CHAPTER 02: LITERATURE

2.1 Evaluating the Compressive Strength of Recycled Aggregate Concrete Using Novel Artificial Neural Network

Authors: Kennedy C. Onyelowe, Tammineni Gnananandarao.

This study investigates the use of artificial intelligence, particularly an Artificial Neural Network (ANN), in predicting the compressive strength of recycled aggregate concrete (RAC). In addition, methods of determining concrete strength can take significant time and effort requiring experimental testing, and although the reliability and validity of this format of testing is well established for new concrete, determining strength of recycled concrete can lead to variability in strength due to introducing recycled and untested materials. The researchers employed an ANN model that was capable of accurately predicting compressive strength given certain input parameters including desired mix proportions, properties of aggregates (including recycled aggregates), and curing conditions. The results indicated that the model had high predictive capability achieving a correlation coefficient (r) of 0.99, meaning the model has near-perfect predictive performance. This study not only reduced the reliance on experimental testing, but it also aided the field of sustainable construction by encouraging the efficient use of recycled materials in advanced and data-driven applications.

2.2 Methods for Improving the Durability of Recycled Aggregate Concrete: A Review

This review article delves into the various strategies to improve the durability and long-term performance of recycled aggregate concrete (RAC) which is generally seen as being less durable in comparison to traditional concrete. The authors summarize many new approaches including self-reinforcing recycled coarse aggregate —pre-joining (through a variety of pre-methods) aggregates to initiate and complete the bonding stage when making RAC—and new processing techniques to eliminate contaminants and enhance bonding performance. External spirals were used as a physical manner of improving the accommodating mechanics of RAC in structural cases. The paper incorporates both experimental and theoretical considerations to give a meaningful interpretation of the means of mitigating common durability problems inherent to the imposition of RAC.

2.3 A Study on the Properties of Recycled Aggregate Concrete and Its Production Facilities

The study evaluates the performance of concrete with recycled aggregates mechanically and durability-related, but puts emphasis on processing of the recycled aggregates. The study states we must improve the quality of the recycled aggregates before we can use them in concrete production we need to improve the quality of the material that will be incorporated into the concrete. The study used both physical treatments (washing, crushing and sieving) and chemical treatments to attempt to change surface characteristics to improve the bond the recycled aggregates had with the cement paste. The authors of the study propose improvements in better production facilities and quality control to ensure the recycled aggregates used in concrete would have the appropriate performance requirements for the construction applications. This study supported the idea of using recycled aggregates as a more viable and sustainable alternative in the building sector by improving both the material and processes.

2.4 Strength and Durability Evaluation of Recycled Aggregate Concrete – Heliyon

This paper offers a comprehensive evaluation of the mechanical characteristics and durability of concrete made from 100% recycled aggregates. The researchers compare the mechanical and durability parameters of the RAC mixes to the durability characteristics of natural aggregate mixes over a period of six months, examining the compressive, tensile, water absorption, and degree of environmental degradation on RAC made with totally recycled aggregates or totally natural aggregates. This study demonstrates that concrete containing 100% recycled aggregates can achieve adequate biological and mechanical properties and durability with the proper mix design and processing procedures. The study highlights the necessity of material testing and mix optimization with recycled materials, an asset to engineers and builders who wish to engage in sustainable building methods.

2.5 Performance of High Strength Recycled Aggregate Concrete Using Metakaolin

Authors: Ashish Kapoor, Abhishek Gupta, Dr. S.K. Verma

The study assesses how metakaolin, a reactive pozzolanic material, affects the performance of high-strength concrete produced with recycled aggregates in terms of compressive strength and concrete microstructure, reducing porosity, and increasing the bond between cement paste and aggregate overall. Moreover, metakaolin enhances resistance to moisture intrusion, as well as chemical attack that not only increases compressive strength but is also essential for durability in structural applications over time. This study considers the potential benefits and how some of the structural limitations of recycled aggregates can be addressed by better understanding how to use admixtures, paving the way for recycled aggregate utilization in a heavy structural context.

2.6 Compressive Strength Improvement for Recycled Concrete Aggregate

Authors: Dhiyaa Mohammed, Sameh Tobeia, Faris Mohammed, Sarah Hasan

This study investigates the potential for improving the strength of RAC with silica fume, a useful by-product in the production of silicon and ferrosilicon alloys. Silica fume is lauded for its fine particle size and very high pozzolanic reactivity, engendering a denser microstructure in concrete.

CHAPTER 03: RESEARCH METHODOLOGY

Concrete is the material predominantly used for homes and infrastructure in many Asian countries, and in particular developing countries. The traditional process is to combine cement, together with fine and coarse aggregates, and sand in appropriate proportions to make concrete, which is a strong and inexpensive construction method using natural materials. However, it also raises notable environmental issues, primarily from the cement production process which is responsible for significant global carbon emissions.

The cement production process involves a large release of CO_2 in to the atmosphere because of carbon in limestone, but more particularly through the energy processes required to produce the cement. Given the predicament of climate change and the need for a more sustainable approach to development, the construction sector is particularly committed to finding alternatives to reduce the overall impact to the environment.

There has not yet been a complete substitution of cement introduced, but one of the more viable alternatives is the option of replacement aggregates with recycled or alternative materials. Many of these approaches avoid the direct extraction of natural resources and can also produce positive environmental benefits. By using recycled materials or agricultural byproducts in the concrete mix, we can reduce carbon emissions, decrease the amount of construction and agricultural waste sent to landfill, and reduce the total amount of energy necessary to produce materials. Alternatively, these innovations can also facilitate aspirations to obtain green building ratings and certifications (e.g. LEED (Leadership in Energy & Environmental Design); BREEAM (Building Research Establishment Environmental Assessment Method)) by focusing on sustainability, reducing environmental impacts, and promoting resource-efficient practice.

Developing these types of eco-friendly construction materials runs on a multi-step process involving: reviewing literature and previous case studies, selecting substitute materials, proportioning mixtures, and laboratory analysis to test performance specifications of the structural product. The construction industry can come together to innovate and experiment during this process and pave the way to be more sustainable environmentally-friendly building practices..

3.1. Choosing the Right Materials

To produce the recycled aggregate concrete (RAC) mix for this study, the following materials were utilized, each selected for their specific role in ensuring the desired performance and sustainability characteristics:

- **Cement – Ordinary Portland Cement (OPC), 43 Grade**

  As the main binding material The concrete mix utilized Ordinary Portland Cement (OPC) 43 grade cement. A 43 grade OPC is used in general construction and is adequate strength and ensures relatively good workability. It meets IS 8112:2013, offers reasonable strength development for both structural and non-structural elements.

- **Recycled Coarse Aggregate (RCA)**

  The coarse aggregates were acquired from crushing concrete debris which was obtained from the roof slab of a demolished residential structure. These recycled aggregates were washed, sieved, and graded according to the relevant standards prior to utilization. RCA is benefiting sustainable construction practices outlined in this research by reducing reliance on natural stone aggregates, while decreasing the volume of construction and demolition (C&D) waste.

- **Natural Fine Aggregate – River Sand**

  The fine aggregate portion of the mix was clean river sand, free from clay, silt, and organic impurities. River sand was used specifically because the particle size distribution is relatively consistent and the smoothness of the surface provides good bonding and helps with the workability and finish of the concrete.

- **Pozzolanic Material – Wheat Straw Ash (WSA)**

  Wheat straw ash was used as a supplementary cementitious material. The ash was collected from a controlled combustion of wheat straw, and was then sifted and processed so that it could reach a fine enough grade to have pozzolanic activity. With high levels of silica content, WSA provides a source of silica that reacts with calcium hydroxide released during cement hydration to produce additional cementitious compounds which improve long term strength and durability of concrete, while providing a reduction in overall cement consumption.

- **Water Potable Quality**

  Clean and potable water was used for mixing and curing concrete. The water was free of visible impurities, including oils, acids, alkalis, salts, and organic matter, per IS 456:2000. Water purity is an important factor to achieve adequate cement hydration and properties of concrete.

3.1. Mix Design

In this investigation, the concrete mix was designed to specifically include recycled materials but still maintained structural integrity and performance. The concrete mix was prepared in a sustainable manner by partially replacing natural coarse aggregates with recycled coarse aggregates (RCA).

A replacement level of 30% recycled coarse aggregate was designated, meaning that 30% of the coarse aggregates in the mixture was made from crushed concrete that was obtained from a demolished residential roof. This replacement level was selected as a balanced ratio to gain environmentally-friendly advantages while not significantly harming the structural ability of the concrete.

The entire mix design process was performed using standard practices, ensuring that all the proportions of the cement, aggregates (fine and coarse), water, and the supplementary pozzolanic material—wheat straw ash (WSA)—were stated in order to produce expected workability, strength, and set time. The typical advancements required for additional water absorption from RCA to avoid early stiffening prior to compaction and to ensure the produced concrete performs similarly to that of conventional natural material concreted, were made.

The intention of this 30% replacement mix was to show how it is possible to use recycled materials in concrete production in a practical manner that is also environmentally sustainable, while still providing the required mechanical properties.

3.2 Experimental Procedure

The methodology for producing and testing the recycled aggregate concrete (RAC) involved systematic procedures beginning with the preparation of recycled aggregates, and followed with the mixing, casting and curing of concrete specimens. Each method was followed to ensure consistent and reliable results.

- **Preparation of Recycled Aggregates:**
  First, the recycled coarse aggregates (RCA) were processed for quality requirements suitable for concrete use. The RCA was obtained from demolished concrete roof slabs and underwent a sequence of treatments:

- **Crushing:**

  A mechanical crusher crushed large pieces of old concrete into smaller pieces. This helped break up the old concrete into aggregate-sized particles, which could be incorporated into the new mix.

- **Washing:**

  Once it was crushed, the RCA was extensively washed to remove contaminants such as dust, loose mortar, and other foreign material. It is hoped with the cleaning process, the risk of impurities affecting the bond between the aggregate and cement paste would be minimized.

- **Drying:**

  The washed aggregates were left to air dry under ambient conditions to remove surface moisture. Proper drying allows for more accurate batching of water during the mixing and helps manage the water-to cement ratio.

- **Sieving:**

  Ultimately, the dried RCA was sieved into appropriate size fractions defined by grading specifications. This allows for more uniformity in the mix, allowing better packing density and mechanical performance.

3.2.1 Concrete Mixing and Casting:

The mixing and casting process followed a structured and hands-on approach:

- **Batching:** All materials, including cement, aggregates (natural and recycled), wheat straw and water, were precisely weighed. This resulted in the mixtures being as consistent as possible.

- **Casting:** The fresh concrete was cast into standard 150 mm × 150 mm × 150 mm cube molds. The molds were filled with three equal layers (approximately 50 mm thick each).
- **Compacting:** The layer of fresh concrete was compacted immediately after placing, using a tamping rod (16 mm diameter x 600 mm length) and striking the concrete properly 35 times. This process will displace excess air trapped in the concrete and pack it properly in the mold.
- **Mold Preparation:** Before casting, all molds were sufficiently oiled to avoid concrete sticking and releasing easily. All molds had sufficient clamping to ensure no water or cement paste would leak out during the compaction phase.

3.2.2 Curing Process

3.2.3

After curing the concrete cubes were cast and labeled, the cubes were covered with a wet cloth for a period of 24 hours allowing for initial setting and protection against early moisture loss and early cement hydration.

After the 24 hours of initial setting in the wet cloth, the cubes were carefully removed from the forms and submerged into a curing tank in clean water. Controlled conditions of 29°C water temperatures were maintained during submersion, representing common curing practices. The specimens were cured for either 7 days or 28 days, representing early and later stage strength development.

3.2 Compressive Strength Test

The compressive strength test is a basic mechanical test employed in construction and civil engineering to assess a material's ability (e.g. concrete) to carry a load and withstand compressive forces. This test determines the maximum load a material can sustain before it fails (fractures) under compressive load.

For concrete, compressive strength is considered the most important property, as it relates to both the structural performance and overall durability of the material. This test offers important information to determine if a specified concrete mix can be used in different applications, bearing various loads in use.

For this study, the compressive strength test was performed on concrete cubes cast with 30% recycled coarse aggregate (RCA), and with the inclusion of wheat straw ash (WSA), which was used as partial replacement of cement. The cube specimens used were standard cube specimens whose dimensions are 150 mm × 150 mm × 150 mm. These cubes were prepared and cured for a complete curing of 7 days and 28 days in accordance with IS 516:1959.

After the final curing period had passed, each cube was tested on Compression Testing Machine (CTM). The cube was loaded and placed into the test machine such that the load applied on the surface of the cube was uniform. The test machine applied increasing increments of pressure on the cube up to failure point.

$$\textbf{Compressive Strength } (mp_a) = \frac{\textit{Maximum Load } (N)}{\textit{Cross-sectional7mm}^2 8} \text{.................. (equation 1)}$$

The purpose of this test is to assess how well the introduction of recycled materials (RCA, and WSA) impacts the strength performance of concrete. By comparing the results at both the 7 and 28-day marks, we can assess the strength development of the concrete mix over time, as well as the early strength of the concrete.

The findings from the test not only have implications for the practical applications of the mix, but they also contribute towards the larger research goal of producing sustainable and environmentally-friendly building materials with negligible reduction in structural performance.

3.3 Purpose of the Test

The main objective of the compressive strength test is to determine the load-bearing capability of concrete in compression. Concrete is typically used in construction applications to withstand heavy loads; for example, columns, beams, slabs, and foundations of buildings. Compressive testing is important for assessing compressive load capacity for one simple reason: compressive strength is vital for ensuring safety, durability, and long-term viability when concrete is used in construction applications.

In this particular study, 30% Recycled Coarse Aggregate (RCA) and wheat straw ash (WSA) are used as sustainable alternatives to regular materials. The compressive strength of the modified concrete mix, which includes these sustainable materials, must be assessed to check whether it can achieve compliance with acceptable level of performance in order to be used for practical purposes in construction.

In particular, the test will be used to:

In particular, the test will be used to:

• **Assess structural suitability:**
to evaluate if the concrete mix has the adequate compressive strength for the purpose of structural or non-structural applications.

• **Assess the Effects of Recycling:**
to determine how including RCA and WSA compares to normal mixes in relation to the mechanical strength of the concrete.

• **Assess Early and Ultimate Strength:**
By sampling the concrete mixes at 7 and 28 days of curing, the strength of the mix can be assessed to monitor how the strength develops with time, providing some feedback for the immediate performance and ultimate structural stability.

• **Conform to Sustainable Construction Goals:**
To assess if concrete can be made with sustainable materials like recycled aggregates and agricultural waste without losing strength, to show that these materials can be used effectively.

Overall, this test provides a scientific basis for making decisions on if eco-friendly concrete mixtures are suitable for actual applications, providing engineers with a useful criteria for decision-making.

3.4 Final Documentation

This project demonstrates how thoughtful selection of materials, careful planning, and the execution of processes can facilitate significant advancement in human and planetary well-being. In my concrete mix, the wheat straw ash an agricultural waste by-product, was utilized as an additive to compliment the bond between the recycled coarse aggerates, cement, and sand. Wheat straw ash has a 'wow' factor in its cheapness and availability (especially in the places where sector is targeted i.e., rural/agricultural), but it also has an inherent environmental benefit in reducing reliance on cement which is a major source of global carbon emissions. For me, wheat straw ash represents a clever and sustainable solution; it enables us to divert agricultural waste products for construction, offers a cost saving in construction costs, and facilitates a more environmentally sustainable method of construction. It demonstrates how sustainability can go hand-in-hand with creativity and innovation.

CHAPTER 04: TESTS AND PLANNING

4.1 Compressive Strength Test

The compressive strength test is an essential test method to determine the material's ability to withstand forces that would compress or decrease the size of the material. For construction and structural engineering applications, compressive strength tests are particularly important for concrete as concrete primarily handles compressive loads for buildings, roads, and other infrastructure.

In this study, a compressive strength test was performed on concrete specimens containing recycled coarse aggregate (RCA) at 30% substitution and wheat straw ash (WSA) at partial replacement of cement. The objective was to determine the effect of using sustainable materials on the mechanical properties of concrete and its resistance to crushing loads.

Concrete cubes of standard dimensions of 150 mm × 150 mm × 150 mm were cast and cured for 7 and 28 days in accordance with Indian Standards (IS 516:1959). After curating, the cube samples were tested on a compression testing machine (CTM). Throughout the testing period, each cube was placed in the CTM machine, and then a load was applied to the specimen. The load was increased until the cubes were structurally compromised. The maximum load at failure was determined and compressive strength was calculated using the following formula:

$$\textbf{\textit{Compressive Strength}}\ (\boldsymbol{Mp_a}) = \frac{\textbf{\textit{Maximum Load}}(\boldsymbol{N})}{\textbf{\textit{Area of the Cube Face}}\ (\boldsymbol{mm^2})}$$

There are several reasons to conduct this test:

• To evaluate structural strength and safety

• To compare performance of conventional concrete and recycled concrete

• To evaluate the effectiveness of wheat straw ash as a pozzolanic additive

In the end, the compressive strength testing is useful data for determining whether the modified concrete mix is suitable for practical construction use.

4.2 Standard Procedure for Compressive Strength Test

The compressive strength test is also performed in prescribed ways to allow measurement, use, and comparison of results. Below is a breakdown of the standard procedure used in testing concrete samples.

4.2.1 Sample Preparation

Before testing, it is critical that the concrete samples are placed in the standard conditions of:

- *Size and Shape - Concrete samples are typically cast as:*
  - Cubes - 150 mm × 150 mm × 150 mm
  - Cylinders - 150 mm diameter × 300 mm high
  - Prisms - typically used for certain structural test series

The cube format is the most common in compressive strength but is the shape used most often in several countries, for example India.

- Curing Conditions – Immediately after casting the concrete samples are left undisturbed for the initial setting time, which is generally accepted as 24 hours. The samples are then cured in water, at a controlled water temperature of approximately 29°C for the standard time of 28 days (although 7 days curing is often used to assess early strength). Curing is critical to ensure the hydration of cement and the development of strength.

4.2.2. Testing Equipment

- Testing occurs with a Universal Testing Machine (UTM) or a Compression Testing Machine (CTM) that has been designed to apply progressively increasing loads to concrete specimens in compression.

- The testing machine is properly calibrated to measure applied loads accurately

4.2.3. Test Procedure:

1. The compressive strength test is implemented in the following way:
2. 1. Placement of Specimen
3. The concrete cube or cylinder is placed in the center of the testing machine and suitably aligned so the load is supported evenly by the loading surfaces.

loading with the machine ensuring that the load is applied evenly thereby eliminating any sudden shocks or jerks.

4. 3. Observation and Recording
5. The load is applied continually until the specimen fails or the specimen has significant cracks. The maximum load at case of failure will be documented as the critical value needed in the calculation of compressive strength.

4.3 Slump Test

The slump test is an easy and accessible field test that assesses the workability or consistency of fresh concrete which has not yet set. It gives an indication of how easy the concrete will be to mix, place and compact..

4.3.1 Test Apparatus

1. ***Sump Cone (Abrams Cone)***
   - Height: 300 mm
   - Bottom Diameter: 200 mm
   - Top Diameter: 100 mm
2. ***Tamping Rod***
   - Steel rod, which has a 16 mm diameter and is 600 mm long with rounded ends
3. ***Base Plate***
   - Flat, non-absorbent surface (e.g., steel or glass)

4.3.2 Test Procedure (as per IS 1199 / ASTM C143)

1. Place the slump cone on a flat, moist, non-absorbent base.
2. Fill the cone in 3 layers, each approximately 1/3rd the height of the cone.
3. Tamp each layer 25 times with the tamping rod using uniform pressure.
4. After the top layer is filled and tamped, strike off the excess concrete to level the top.
5. Lift the cone vertically and carefully, in 5 to 10 seconds, without twisting or jerking.

4.3.3 Slump Measurement

Slump (mm) = Height of Cone – Height of Slumped Concrete

4.4 Precautions

- Conduct the test immediately after mixing.
- Use clean and damp tools.
- Avoid vibration or disturbance during measurement.
- Ensure uniform tamping.

4.4 Assesses Workability of Fresh Concrete

• It ensures that the concrete mix is the correct consistency to allow for correct placing, compacting, and finishing.
• Low workability, or high workability, can lead to honeycombing, segregation, or voids that all lead to a reduction in compressive strength.

4.4.2. Verifies Mix Proportions

- A slump that is too high or too low may indicate errors in the mix (e.g., too much water or not enough cement).
- Detecting this early allows corrective actions before casting cubes or placing concrete.

4.4.3. Ensures Uniformity Between Batches

- In site work, multiple batches of concrete are prepared. The slump test helps verify that each batch is consistent in quality.
- This reduces variability in compressive strength results.

4.4.4. Prevents Wastage of Testing Resources

- If a batch has abnormal slump, it's likely the compressive strength will be affected.
- Testing such a batch wastes time and materials if it's not representative of the target mix.

4.4.5. Early Quality Control Check

- Slump test is quick and on-site; compressive strength results take 7 to 28 days.
- A failed slump test can immediately flag quality issues, saving time and cost.

4.5 Treated Recycled aggregates before using:

We treat recycled aggregates before using them in construction to improve their quality and make them suitable for producing durable and high-strength concrete. Recycled aggregates come from demolition waste (old concrete, bricks, etc.), and without treatment, they can negatively affect the performance, strength, and durability of the concrete

4.5.1 Remove Contaminants

Recycled aggregates often contain:

- Dust, dirt, and clay
- Pieces of metal, plastic, wood, or glass
- Old mortar or cement paste

Why this matters:

These impurities weaken the bond between cement and aggregate, leading to reduced strength and durability problems in concrete.

4.6 Reduce High Water Absorption

Recycled aggregates have old mortar stuck to their surfaces, making them more porous than natural aggregates.

Why this matters:

- They absorb more water during mixing, changing the water-cement ratio.
- This can cause inconsistent concrete strength and poor workability.

4.6.2 Improve Strength and Durability

The presence of adhered mortar and cracks in recycled aggregates makes them weaker than natural aggregates.

Why this matters:

- Treated recycled aggregates lead to better compressive strength and more durable concrete.
- They reduce the risk of cracks and long-term degradation.

4.6.3 Ensure Proper Grading and Size

Recycled aggregates often have irregular sizes and poor grading.

Why this matters:

- Uniform grading is essential for workable and dense concrete.

- Treatment helps separate particles into the required size ranges.

4.6.1 Meet Standards and Specifications

Standards like IS 383, ASTM C33, and EN 12620 require aggregates to meet specific quality criteria.

Why this matters:

- Untreated recycled aggregates often don't meet these standards.
- Treatment ensures compliance with construction codes.

4.7 All tests Performed including Photos & Calculations

Slump Test

Fig.4.7 slump test

4.8 True Slump

A true slump happens when the concrete drops uniformly down, and retains its shape after the slump cone is removed.

4.8.6.1 The concrete mass simply settles down, without any collapse or shearing.

4.7 When True Slump is Acceptable:

- Common in good-quality concrete for general construction (beams, slabs, columns).
- Indicates that the mix has adequate water, proper mixing, and good cohesion.

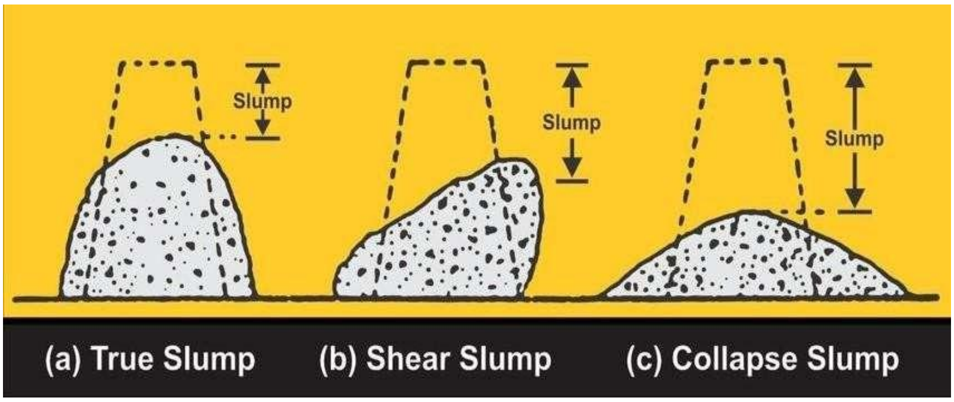
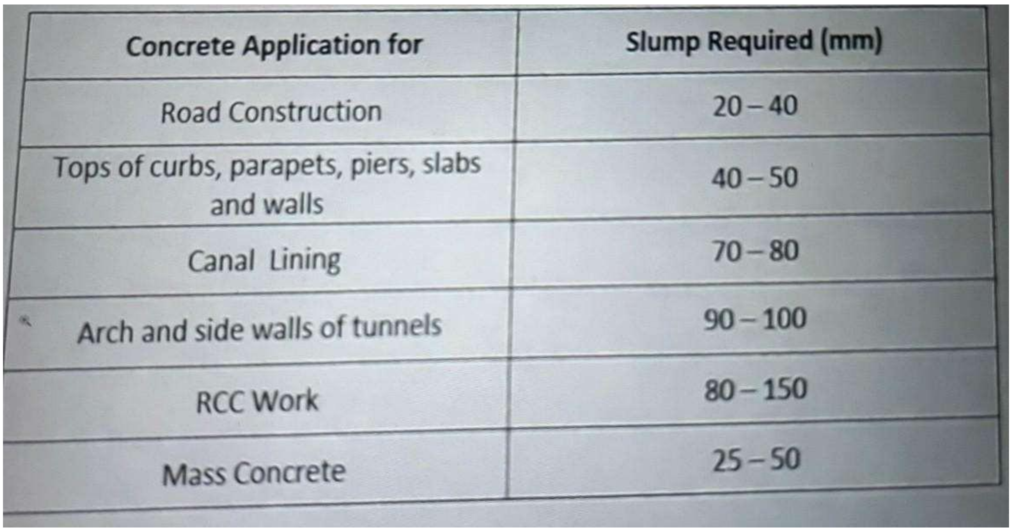


Fig 4.7.1 Types of slump



Concrete Application for	Slump Required (mm)
Road Construction	20 – 40
Tops of curbs, parapets, piers, slabs and walls	40 – 50
Canal Lining	70 – 80
Arch and side walls of tunnels	90 – 100
RCC Work	80 – 150
Mass Concrete	25 – 50

Fig 4.7.2 Table – Showing Workability

4.8.1 Testing – specimen 1

Fig 4.8.1 – Testing of 1st specimen

1st Sample Preparation:

- Shape: Usually cubes (150x150x150 mm)
- Curing: Specimens are cured under standard conditions (e.g., 28 days in water at 29°C).

M25 indicates a characteristic compressive strength of 25MPa at 28 days

We are using **Cement: Sand: Coarse Aggregate ratio of 1: 1: 2**

For this sample we are using river sand and river side natural aggregate (20mm max size)

Compressive Strength Formula:

{Compressive Strength} = Load/Area

- PPP: Maximum load at failure (N)
- AAA: Cross-sectional area of specimen (mm^2)

PPP in 1st case = **570 KN**

Area of cube = **22.5 mm^2**

{Compressive Strength} = **570/22.5 = 26.6 MPa**

To check if the specimen failed or passed, in 28 days concrete gains near about 99% of strength

For m25 = **(25*99)/100 = 24.75**

Our specimen has reached the CS of 26.6 MPa which is higher than 24.75

4.8.2 Testing specimen 2

Fig 4.8.1– Testing of 2nd specimen

2st Sample Preparation:

- Shape: Usually cubes (150x150x150 mm)
- Curing: Specimens are cured under standard conditions (e.g., 28 days in water at 29°C).

M25 indicates a characteristic compressive strength of 25MPa at 28 days

We are using **Cement: Sand: Coarse aggregate ratio of 1: 1: 2**

For this sample we are using river sand and crusher aggregate (15mm max size)

Compressive Strength Formula:

{Compressive Strength} = Load/Area

- PPP: Maximum load at failure (N)
- AAA: Cross-sectional area of specimen (mm^2)

PPP in 1st case = **540 KN**

Area of cube = **22.5 mm^2**

{Compressive Strength} = **540/22.5 = 24 MPa**

To check if the specimen failed or passed, in 28 days concrete gains near about 99% of strength

For m25 = **(25*99)/100 = 24.75**

Our specimen has reached the CS of 24 MPa which is lower than 24.75

4.8.2 Testing – specimen 3

Fig 4.8.2– Testing of 3nd specimem

3rdt Sample Preparation:

This sample contains WSA which is replacing cement by 30%

- Shape: Usually cubes (150x150x150 mm)
- Curing: Specimens are cured under standard conditions (e.g., 28 days in water at 29°C).

M25 indicates a characteristic compressive strength of 25MPa at 28 days

Wheat Straw Ash = we are replacing cement with **WSA by 30%**

The amount of cement replaced: **1*0.3 = 0.3**

The new amount of cement = 0.7

Adjusted mix ratio **Cement+ WSA: Sand: Coarse aggregate ratio of 0.7: 1: 2**

For this sample we are using river sand and crusher aggregate (15mm max size)

Compressive Strength Formula:

{Compressive Strength} = Load/Area

- PPP: Maximum load at failure (N)
- AAA: Cross-sectional area of specimen (mm^2)

PPP in 1^{st} case = **710 KN**

Area of cube = **22.5 mm^2**

{Compressive Strength} = **710/22.5 = 31.55 MPa**

To check if the specimen failed or passed, in 28 days concrete gains near about 99% of strength

For m25 = **(25*99)/100 = 24.75**

Our specimen has reached the CS of 31.55 MPa which is higher than 24.75

Hence, Specimen passed and we can see despite using crusher aggregate only with the help of WSA our specimen's strength has increased massively, if we use river side natural aggregate the strength may increase even more.

IMP -*Till now we have tested three specimens in which we have tested 1^{st} specimen using river side natural aggregate, in 2^{nd} specimen using crusher aggregate and the 3^{rd} one in which we have added a pozzolanic admixture wheat straw ash* ***(WSA)****, and we have identified that WSA increase the strength of concrete significantly. I am attaching the photos of WSA, River side natural aggregate and crusher aggregate*

Below shown pictures are the actual materials Iwe have used in testing:

Fig 4.8.3– Aggregates & WSA Sample

We will test additional samples, but this time using only recycled aggregates; everything else will remain unchanged.

1st Sample Preparation:

This sample contains WSA which is replacing cement by 30%

- Shape: Usually cubes (150x150x150 mm)
- Curing: Specimens are cured under standard conditions (e.g., 28 days in water at 29°C).

M25 indicates a characteristic compressive strength of 25MPa at 28 days

Wheat Straw Ash = we are replacing cement with **WSA by 30%**

The amount of cement replaced: **1*0.3 = 0.3**

The new amount of cement = 0.7

Adjusted mix ratio **Cement+ WSA: Sand: Coarse aggregate ratio of 0.7: 1: 2**

For this sample we are using river sand and recycled aggregate (20mm max size)

{Compressive Strength} = Load/Area

- PPP: Maximum load at failure (N)
- AAA: Cross-sectional area of specimen (mm²)

PPP in 1st case = **556 KN**

Area of cube = **22.5 mm^2**

{Compressive Strength} = **556/22.5 = 24.71 MPa**

To check if the specimen failed or passed, in 28 days concrete gains near about 99% of strength

For m25 = **(25*99)/100 = 24.75**

Our specimen has reached the CS of 24.71 MPa which is lower than 24.75

Hence, Specimen failed but normally the strength of recycled aggregate concrete is 10-25% lower than concrete, but here the difference is just 0.162% which proves that using WSA lowers the gap between both values.

specimen 1

Fig 4.8.4 – Testing of 1st specimen

2nd Sample Preparation:

This sample contains WSA which is replacing cement by 30% Shape:

Usually cubes (150x150x150 mm)

Curing: Specimens are cured under standard conditions (e.g., 28 days in water at 29°C).

M25 indicates a characteristic compressive strength of 25MPa at 28 days

Wheat Straw Ash = we are replacing cement with **WSA by 30%**

The amount of cement replaced: **1*0.3 = 0.3**

The new amount of cement = 0.7

Adjusted mix ratio **Cement+ WSA: Sand: Coarse aggregate ratio of 0.7: 1: 2** For this sample we are using river sand and recycled aggregate (15mm max size) Compressive Strength Formula:

{Compressive Strength} = Load/Area

- PPP: Maximum load at failure (N)
- AAA: Cross-sectional area of specimen (mm^2)

PPP in 1^{st} case = 525 KN

Area of cube = 22.5 mm^2

{Compressive Strength} = 525/22.5 = 23.33 MPa

To check if the specimen failed or passed, in 28 days concrete gains near about 99% of strength

For m25 = (25*99)/100 = 24.75

Our specimen has reached the CS of 23.33 MPa which is lower than 24.75

Hence, Specimen failed but normally the strength of recycled aggregate concrete is 10-25% lower than concrete and here the difference between both values is 6.09% which is still less than 10%

Testing – specimen 2

Fig 4.8.5 – Testing of 2nd specimen

3rd Sample Preparation:

This sample does not include WSA

- Shape: Usually cubes (150x150x150 mm)
- Curing: Specimens are cured under standard conditions (e.g., 28 days in water at 29°C).

M25 indicates a characteristic compressive strength of 25MPa at 28 days

We are using **Cement: Sand: Coarse aggregate ratio of 1: 1: 2**

For this sample we are using river sand and recycled aggregate (15mm max size)

Compressive Strength Formula:

{Compressive Strength} = Load/Area

- PPP: Maximum load at failure (N)
- AAA: Cross-sectional area of specimen (mm²)

PPP in 1st case = **470 KN**

Area of cube = **22.5 mm^2**

{Compressive Strength} = **470/22.5 = 20.88 MPa**

To check if the specimen failed or passed, in 28 days concrete gains near about 99% of strength

For m25 = **(25*99)/100 = 24.75**

Our specimen has reached the CS of 20.88 MPa which is lower than 24.75

Hence, Specimen failed but normally the strength of recycled aggregate concrete is 10-25% lower than concrete and here the difference between both values is 18.53%which is more than 10% but still less than 25%

Testing – specimen 3

Fig 4.8.6 – Testing of 3rd specimen

CHAPTER 05: ANALYSIS ON TEST DONE

Specimen	Cement Replacement	Aggregate Type	Max Load (KN)	Area (mm^2)	Compressive Strength (MPa)	Target (99% of M25)	Result
1st (Initial)	None	River side natural (20mm)	570	22.5	26.6	24.75	Passed
2nd (Initial)	None	Crusher (15mm)	540	22.5	24.0	24.75	Failed
3rd (WSA)	30% WSA	Crusher (15mm)	710	22.5	31.55	24.75	Passed
1st (Recycled)	30% WSA	Recycled (20mm)	556	22.5	24.71	24.75	Failed (0.16% diff)
2nd (Recycled)	30% WSA	Recycled (15mm)	525	22.5	23.33	24.75	Failed (6.09% diff)
3rd (Recycled)	None	Recycled (15mm)	470	22.5	20.88	24.75	Failed (18.53% diff)

Fig 5- Analysis on test

5.1 Unlocking Sustainable Strength:

Wheat Straw Ash (WSA) is a great way to improve the compressive strength of concrete, even if it is recycled or crushed aggregate, which is a low-quality aggregate. WSA has a lot of potential as a pozzolanic material and as a way to improve the use of sustainable concrete mixes. In typical use, recycled aggregates provide concrete with reduced compressive strength because of irregular shapes and adhered old mortar. However, WSA reduces the compressive strength reduction, making recycled aggregate a lot more credible and environmentally friendly method in construction.

Surprisingly, experimental evidence shows that concrete made partially with WSA and 20 mm recycled aggregate performs nearly equal to conventional concrete samples made with virgin materials. This is a good opportunity to reduce environmental impacts while maintaining structural integrity. WSA combined with well-graded larger-sized aggregates from natural sources results in concrete with compressive strength equal to or greater than non-WSA mixes because of improved bonding and less void content.

5.2 Important Points Regarding Recycled Aggregate

Currently, the construction industry is increasingly focused on sustainability, waste management and resource efficiency. The use of Recycled Aggregate Concrete (RAC) is an exciting aspect of this development as it can potentially provide a sustainable alternative for conventional concrete. RAC is produced by using recycled instead of natural coarse aggregates typically obtained during wrecking or from a construction surplus. Using recycled aggregates (both natural and cementitious) likely provides its challenges in terms of mechanical performance. However, the use of novel materials, for example, Wheat Straw Ash (WSA), is an intriguing way forward in making a more viable and sustainable material for use in 21st-century construction.

The purpose of this chapter is to summarize the findings of this experimental study and to consider what it might mean in the use of WSA with recycled aggregates in concrete. The discussion will address structural performance, material behaviour ,economical issues and environmental advantages to gain an understanding of this newer green technology.

5.3 Managing Strength Reduction in RAC: Challenges and Solutions

Reduced compressive strength, compared to concrete fabricated from natural aggregates, is one of the most widely cited disadvantages of utilizing recycled aggregates. This strength reduction stems from physical properties of recycled aggregates, including:

- Potential for increased porosity and water absorption
- Adhered mortar from previous use
- Irregular shapes that create the potential for poor packing
- Weak bonding with cement paste

Our experimental results indicated compressive strength reductions in the range of 10–25% when using recycled aggregate in an un-modified mix, although this strength drop is not a deal breaker. It can be effectively managed, and can be modified to some degree, with the inclusion of supplementary cementitious materials, especially WSA.

5.4 The Role of Wheat Straw Ash (WSA) in Strength Recovery

The incorporation of wheat straw ash (WSA) as a pozzolanic material has proved to be a potent tool in addressing the limitation of recycled aggregate concrete (RAC). WSA is made from an agricultural waste product also known as the ash remaining after burning wheat straw. The WSA has an abundance of silica which reacts with calcium hydroxide in the cement hydration process to form additional cementitious compounds that densify the concrete's microstructure, ultimately improving strength.

Through our study, we completed a mix using a replacement of 30% WSA for cement and yielded some positive results. For example, the concrete containing recycled aggregates as the 20mm size with WSA had a compressive strength of 24.71Mpa. Remarkably, this was nearly identical to the Standard of 24.75/24.80 Mpa. The negligible difference of just 0.16% evince that WSA not only compensates for strength loss within the process of recycling but it also is impacting the durability of concrete in the long run. WSA promotes a better bond between particles, internal voids are lessened, and WSA produced a higher quality, longer term, more durable matrix.

5.5 Importance of Aggregate Size and Quality

Subsequently, although WSA is very important for strength, we believe the quality and size of the aggregates used in RAC should also be highlighted. Our study has demonstrated results in which the larger aggregate (20mm) consistently outperformed the smaller aggregate aggregate (15mm) in every instance when tested in a compressive strength test. This can be attributed to:

- A larger surface area improves interlocking and mechanical bonding
- The total surface area is less and therefore will require less cement paste to coat
- A better load transfer (due to the reduced void ratio)

Cleanliness of aggregate or proper grading of the aggregates is also crucial. Dirty aggregates that are contaminated with too much dust, clay or unwashed materials can hinder bonding and/or hydration of the concrete and therefore lead to inconsistent results. For this reason, proper screening, sieving, and quality control must be exercised when preparing recycled aggregates for concrete manufacture.

5.5 Pre-Treatment of Recycled Aggregates: A Necessary Step

Prior to using recycled aggregates in concrete, pre-treatment steps are necessary. Recycled aggregates typically contain some portion of mortar or fine particles of dust and fines, while natural aggregates are usually cleaner and consistent. The steps in our test were:

- **Washing:** to remove dirt, fines, flavour remain and any harmful chemical residues
- **Sieving:** Use sieves to achieve the appropriate coarseness of aggregate and remove excess fines
- **Drying:** To rely on the expected water to cement ratios when mixing

The above steps helped us achieve consistency in aggregates and greater strength and durability of the concrete. They also support and result in predictable and reliable material through pre-treatment and lengthen the life of reusable aggregates which meets the demands of 21st century construction.

5.6 Environmental and Sustainability Advantages:

The use of recycled aggregate concrete (RAC), particularly when used in conjunction with Waste Straw Ash (WSA), provides clear environmental performance advantages. First and foremost, it decreases the demand for natural aggregates - river sand and quarried stone are precious natural resources and should not be squandered. A reduction in shipments of river sand or quarried stone minimizes ecological impacts, such as riverbed erosion and the destruction of different types of wildlife habitat.

Recycled aggregate concrete also helps with the management of construction and demolition waste that would have otherwise ended up in landfills. This diverts a waste stream to reduce landfill waste and encourages a circular economy in the construction industry.

The WSA we used for the project is an agricultural waste material that is often discarded as waste (typically ‘open burn’ for disposal). However, we can provide a productive use for this waste material, and in turn, this has contributed to:

- a reduction in carbon emissions resulting from the production of cement
- the reduction in air pollution caused from straw open burning
- a low-cost alternative to industrial wast straw ash admixtures available locally

Overall, the potential to minimize the environmental impact of construction activities is greatly improved, practicing green buildings and sustainable development.

5.7 Applications and Structural Potential

Although RAC has historically only been used in non-structural applications, the performance improvement seen from WSA incorporation broadens its applications. Even in untreated form, RAC is ideal for:

- Pavement blocks and kerbstones
- Partition walls
- Sub-base layers for roads
- Footpaths and landscaping structures

With the addition of WSA and aggregate processing, RAC could be used in lightly loaded structural elements such as:

- Loadbearing walls
- Columns in low-rise buildings
- Foundations for light structures

This is a great opportunity cost effectively and prudently use resources in construction methods in developing countries and/or rural areas that lack resources and material use.

5.8 Applications and Structural Potential

One of the strongest arguments for using RAC with WSA is cost. Recycled aggregates and natural aggregates can differ substantially in cost (especially for locally-sourced aggregates at demolition sites), and WSA is a low-cost aggregate as it is, effectively, a waste product from wheat farming, which occurs extensively in many areas. In addition, there is an opportunity to reduce cement consumption, one of the most costly and environmentally harmful components of concrete, by replacing up to 30% of cement with WSA. By bringing together two low-cost materials, concrete incorporating RAC and WSA represents direct savings to the manufacturer in raw materials, transportation, and waste disposal costs. Essentially, RAC and WSA represents value—both environmentally and for builders and developers who are cost conscious.

5.9 Final Thoughts and Future Scope

Based on this study, it can be concluded that Recycled Aggregate Concrete combined with Wheat Straw Ash is a strong and viable strategy for building green. Although there are trade-offs with mechanical performance, these can be mediated through appropriate material selection, mixing design, and pre-treatment.

Conceivably, future research can be focused on:

- long-term durability tests (freeze-thaw cycles; sulfate attack)
- Life Cycle Analysis (LCA) to measure environmental savings
- field implementation case studies to evaluate in situ performance

CHAPTER 06: CONCLUSIONS

6.1 CONCLUSIONS

The benefits of using Wheat Straw Ash (WSA) as a partial cement replacement exhibited particularly significant improvement in compressive strength for mixes, even at a 30% replacement level, regardless of coarse aggregate type. The effects are especially, dramatic with recycled or crusher aggregates (which tend to have the lowest strength values) due to the rough texture of the aggregate (with irregular shapes) along with old mortar that is often still attached to the aggregates themselves. These recycled aggregate often represents a significant loss of structural integrity on their own, and are not a favorable material to use in Standard construction. In totality, when the WSA is, blended with the recycled aggregate, we have seen the strength performance improve drastically, often getting within acceptable limits according to what construction considers acceptable. This strength enhancement phenomenon is mainly attributed to its pozzolanic properties and the fact that WSA reacts with the calcium hydroxide produced during the hydration process as well as producing more geosynthetic binding compounds that will densify the final concrete matrix. Improved compressive strengths of concrete, when produced containing recycled aggregates as opposed to not having the WSA in the mix; adds durability and strength to reclaiming concrete. This illustrates WSA is not just a filler or cost savings opportunity, but a functional additive, to mitigate typical weaknesses seen with recycled aggregates.

This combination of WSA and recycled aggregates could have a sustainability benefit. It benefits sustainable construction practices by reducing the amount of cement (one of the largest sources of carbon emissions) used in construction materials and creates a beneficial use for agricultural waste and demolition material. This combination addresses two substantial environmental issues: waste disposal and carbon reduction. In conclusion, the use of WSA in concrete production (especially with recycled aggregates) is a practical and sustainable direction toward a more environmentally friendly, more responsible construction process, without compromising the performance of the material.

Creating and investigating recycled aggregate concrete with wheat straw ash was enlightening and fulfilling. We set out with an idea to discover an answer to the construction sector's increasing structural needs while drastically reducing the environmental consequences. Sustainable development is no longer a choice but a necessity. This project tried to connect the space between material performance and environmental stewardship.

One of the challenges of modern construction is the excessive use of natural aggregates, as well as producing mass amounts of construction and agricultural waste. With the use of recycled aggregates into the concrete mix, we solved one of those problems, and with the incorporation of wheat straw ash, an agricultural waste product, we have creatively repurposed this vegetable waste product which was either burned or landfilled to the detriment of the environment.

Not only did we show that wheat straw ash can be environmentally friendly and structurally functional, we also demonstrated the use of recycled aggregates in a concrete mix which could positively impact the environmental footprint of concrete construction, thereby reducing the carbon footprint.

Through careful investigation, various mixtures, and rigorous testing, we found that the wheat straw ash in the concrete positively affected strength gain. The pozzolanic qualities not only improved binding in the concrete but also enhanced its microstructure. Overall, this resulted in greater compressive strength and durability.

Using this ash also reduced cement consumption, which is one of the biggest contributors of carbon emissions in concrete. So two environmental benefits arose from using it: reducing carbon emissions and reducing non-renewable resources.The project provided a comprehensive approach to sustainability through the entire life cycle, considering input (materials) and output (emissions and performance).

Concrete made with recycled aggregate is often sceptically received because of suspicion of lower mechanical strength or inferior structural performance compared to concrete made with virgin aggregates. However, this research showed that these limitations can be mitigated when it is used with other waste resources such as wheat straw ash. Their results showed full structural grades while paving the way for sustainable practices.

Another valuable result of the project was the demonstrated potential for a real application that was scalable.The materials are common to find,construction debris and wheat straw are plentiful in both urban and rural situations.

This project has also sent an important message to future researchers, engineers, and policymakers. The shift toward new material science must be done in conjunction with environmental sustainability. The improvement of a recycled aggregate concrete system through the replacement of one cement with up to 25% wheat straw ash shows that sustainable materials can meet or exceed the value of conventional materials, and this leads to the message regarding the need to shift characteristics of waste - from cost to opportunity.

Ultimately, this project was more than just a pure technical research project - it represented a genuine step forward in the development and future thinking of sustainable construction materials. development and future development. It reinforced the notion that strength, durability, and environmental sustainability are not competing traits but can be facilitated through thoughtful design and innovation in material selection.

The positive outcomes of this project are evidence of the viability of agro-industry synergy in the construction sector. Building with what we once called waste will help build a future that is not only stronger but sustainable as well.

As we look ahead, we hope to see more agencies like this one, taking the challenges we face in construction and turning them into opportunities, creating different benchmarks for projects going forward. This project is a powerful example of the duality of sustainable development and structural performance leading to a more responsible, resilient, and resource-efficient construction industry.

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