



## ASIAN BULLETIN OF BIG DATA MANAGEMENT

<http://abbdm.com/>

ISSN (Print): 2959-0795

ISSN (online): 2959-0809

### Experimental and Machine learning investigation of Potential strength of recycled aggregate concrete

\*Ali Akber Khan, Iftekhar Ahmed, Tahreem Aqsa, Houda Javed

#### Chronicle

##### Article history

**Received:** February 24, 2024

**Received in the revised format:** Feb 27, 2024

**Accepted:** Feb 28, 2024

**Available online:** Feb 29, 2024

**Ali Akber Khan, Iftekhar Ahmed, Tahreem Aqsa, Houda Javed are** currently affiliated with the Department of Environment Management NCBA&E Lahore, Pakistan.

**Email:** [Ali18april@Hotmail.Com](mailto:Ali18april@Hotmail.Com)

**Email:** [hydromod@yahoo.com](mailto:hydromod@yahoo.com)

**Email:** [Aqsa610@gmail.com](mailto:Aqsa610@gmail.com)

**Email:** [houdajaved@yahoo.com](mailto:houdajaved@yahoo.com)

#### Corresponding Author\*

**Keywords:** Recycled Aggregate Concrete, Sustainable Construction, Experimental Analysis, Machine Learning

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#### Abstract

Artificial intelligence (AI) has emerged as a powerful tool in a multitude of disciplines, with education being one of the most essential. The goal of this research is to investigate the impact of artificial intelligence (AI) on the acquisition of productive and receptive language skills among BS English students in Okara, Pakistan. The study used a qualitative research methodology, with semi-structured interviews with 150 students enrolled in the BS English program. The findings suggest that AI-based language learning systems improve students' language abilities by improving their writing, reading, listening, and speaking capabilities. However, flaws were revealed, notably when it came to deciphering complex linguistic aspects that required human judgment and when pupils relied too heavily on AI and ignored their thinking. According to the study, while AI has enormous potential in language acquisition, it should be paired with human-driven educational methodologies for the best results. Teachers and students are urged to adopt AI to improve students' learning opportunities and academic success.

## INTRODUCTION

Increasingly Concrete, a primary component of modern construction, has historically strained natural resources, leading to a shift in thinking towards more sustainable alternatives. Recycled Aggregate Concrete (RAC) is a viable solution to the global demand to mitigate environmental impact. It achieves this by rearranging construction and demolition debris, thereby promoting sustainability. The ecological consequences of traditional concrete production underscore the need to explore environmentally sustainable alternatives. Chandra and Berntsson (2002) argue that the conventional concrete industry has a significant impact on carbon emissions and resource depletion. Therefore, it is necessary to re-evaluate the materials and procedures used in this enterprise. This research aims to explore the untapped potential of RAC by analyzing its mechanical properties using a combination of experimental investigation and predictive modeling. The motivation for this research comes from the broader context of sustainable construction, where RAC appears as a potential contender. Tam et al. (2007) emphasizes the need to use sustainable resources in the construction industry especially focused on the significance of integrating recycled aggregates to reduce the environmental impact of concrete. By adding recycled aggregate for the process into concrete, we solve problems with waste and agree with the principles of circular economy. This is important because construction and demolition debris make up a significant amount of materials that are placed in landfills. This research is in line with the need for innovative solutions in

the field of building materials, especially those that contribute to waste reduction and environmental protection. The study's focus on RAC is rooted in the belief that it has the potential to generate substantial transformations in the construction followed with broader sustainability goals. The objectives is to perform a comprehensive experimental analysis of the mechanical properties of RAC, including compressive and flexural strength as well as durability. In addition, the study focuses on using machine learning methods to accurately predict the range of RAC, taking into account several significant factors. The authors Silva et al. (2014) highlights the importance of incorporating machine learning into materials research, particularly highlighting its ability to reveal complex relationships and patterns. The objective of this study is to gain a comprehensive understanding of RAC behavior by combining conventional testing methods with advanced predictive analytics.

## **BACKGROUND AND MOTIVATION**

The production of conventional concrete is permanently associated with significant environmental problems, including the depletion of resources and the emission of huge amounts of carbon dioxide. Chandra and Berntsson (2002) highlight the environmental impact of traditional concrete and emphasize the need for sustainable alternatives. Recycled Aggregate Concrete (RAC) has emerged as a viable approach to address these issues. Recycled aggregate, typically obtained from construction and demolition waste, is incorporated into the concrete mix in the RAC process. This not only addresses the issue of waste management, but is consistent with broader environmental goals. This research is motivated by the need to move towards construction approaches that are more environmentally sustainable. Tam et al. (2007) argue that the use of sustainable building materials such as RAC is essential to mitigate the environmental impacts of the construction sector. This study therefore seeks to expand the ongoing discourse on sustainable construction by examining the feasibility of RAC.

## **OBJECTIVES OF THE STUDY**

The primary objective of this research is twofold. The main goal of the study is to perform a thorough experimental analysis of the mechanical properties of concrete from recycled aggregate. This includes a thorough check of the compressive and flexural properties for strength as well as the durability of concrete mixes. The objectives are consistent with research conducted by Silva et al. (2014), which emphasizes the importance of conducting comprehensive experimental investigations to understand the behavior of new structural materials. In addition, the study attempts to use machine learning techniques to predict the durability of RAC, taking into account several significant factors. The goal of this study is driven by the dynamic field of materials science, where machine learning has shown promise in understanding complex relationships. The study seeks to achieve a thorough understanding of the potential effectiveness of RAC by combining conventional testing methods with current predictive analytics.

## **SCOPE AND IMPORTANCE OF THE TOPIC**

The primary purpose of this research is to comprehensively evaluate the efficiency of the targetted concrete through the analysis of different alternative mix designs and the use of recycled aggregate from different sources. The importance of the study lies in its ability

to offer valuable insights into sustainable construction methodologies. In order to effectively address the construction industry's current drive to integrate greener materials, it is essential to fully understand the benefits and limitations of recycled aggregate (RAC). This research contributes to the broader field by offering a critical perspective on the feasibility and effectiveness of RAC and addressing a significant gap in current understanding. The importance of resource allocation and conservation (RAC) in waste reduction and environmental protection is consistent with the principles of the circular economy, making it a major area of study in contemporary construction research.

## **LITERATURE REVIEW**

For Recycled concrete (RAC) literature provides a thorough understanding of the mechanical properties, environmental aspects and practical applications of this sustainable construction material. Chandra and Berntsson (2002) conducted a pioneering study investigating the use of recycled aggregate in concrete. They emphasized the need to understand the fundamental differences between recycled and natural aggregates. Their research laid the groundwork for future studies by highlighting the ability of recycled aggregates to reduce the environmental impact of concrete production. Tam et al. (2007) conducted a study investigating the specific properties of recycled aggregate.

They emphasized the importance of conducting comprehensive research to assess its robustness, durability and feasibility. Their study highlighted the importance of using recycled aggregate to provide comparable performance to traditional concrete while also addressing waste management issues. Furthermore, Silva et al. (2014) offered a modern perspective by exploring the integration of machine learning in materials research. Their research demonstrated the potential of machine learning algorithms to predict specific properties, which is consistent with the current study's goal of using predictive analytics to understand RAC durability. The literature highlights the transformative potential of RAC, highlighting its ability to integrate structural efficiency with environmental sustainability.

### **Introduction to Recycled Aggregate (RAC)**

Recycled Aggregate Concrete (RAC) serves as an ecological alternative to conventional concrete. It is characterized by the application of regenerated aggregate obtained from the waste. The integration of recycled resources into the concrete mix effectively solves the environmental problems associated with traditional concrete production. Chandra and Berntsson (2002) were pioneering researchers who clarified the concept of RAC and highlighted its ability to reduce dependence on natural resources and deal with the escalating problem of construction waste. RAC is a deliberate departure from the conventional linear way of using resources, which is in line with the principles of the circular economy. In order to assess the sustainability of RAC as a building material, it is essential to understand the basic concepts and characteristics that form its basis.

### **Properties of recycled aggregates**

The properties of the resulting concrete mix are significantly influenced by the properties of recycled aggregates, which are vital components of recycled aggregate concrete.

Tam et al. (2007) investigated the complex properties of recycled aggregates, water infiltration, and the concentration of hazardous compounds. These factors affect the ease of use, durability and damage resistance of the resulting RAC. The diverse composition of recycled aggregates presents unique challenges that require a thorough understanding to optimize their incorporation into concrete mixes. An essential aspect of creating informed mix designs that achieve a balanced mix of sustainability and structural integrity is the analysis of recycled aggregate properties.

### **Strength characteristics of ordinary concrete**

A thorough understanding of the strength characteristics of conventional concrete provides a benchmark for evaluating recycled aggregate concrete. The compressive and flexural strength, durability and workability of ordinary concrete are generally recognized and established properties. Possessing this knowledge base is critical to assessing the ability of RAC to meet or exceed the performance benchmarks set by traditional concrete. Siddique et al. (2015) emphasize the importance of a basic understanding of traditional concrete strength parameters in order to identify areas where RAC can provide equivalence or improvement. Thus, this specific segment of the literature review lays the foundation for the upcoming analysis of the mechanical characteristics of RAC.

### **A previous study on recycled aggregate**

Previous research efforts have significantly advanced our understanding of recycled aggregates. Saikia et al. (2012) conducted a thorough investigation to assess the effect of several factors, such as the ratio of recycled aggregate to cementitious admixtures, on the compressive strength of RAC. This research provides valuable information for improving mix designs and understanding the mechanical properties of RAC. Examining the methods and results of previous studies enables the synthesis of information, revealing trends, challenges and gaps in the existing literature. This subsequently governs the current investigation in terms of its scope and objectives.

### **Challenges and benefits in RAC**

Integrating recycled aggregate into concrete presents many challenges and opportunities. Problems arise from the internal heterogeneity of recycled aggregates, potential contamination and differences in properties compared to natural aggregates. To address these issues, it is essential to use an advanced approach to compound development and quality assurance protocols. At the same time, there are prospects for waste minimization, resource conservation and the potential for increased sustainability of construction practices. The gap between barriers and potential has been explored by several authors (Chandra and Bertsson, 2002; Tam et al., 2007), highlighting the importance of fully understanding the complex nature of using recycled aggregate in concrete in a comprehensive manner. This section provides the necessary context for the following sections and lays the groundwork for a thorough analysis of experimental and machine learning research on the potential lifetime of recycled aggregates.

## PROCEDURE FOR CONDUCTING AN EXPERIMENT

Experimental design is essential for a detail evaluation of the potential durability and performance of processed aggregates (RAC). This section offers a thorough explanation of the methodology used in the study, including material selection, mix ratio determination, sample preparation, and test method execution.

### Composition and proportions of the mixture

The choice of materials is decisive for the development of recycled aggregates. Recycled aggregate comes from waste generated produced during construction. The properties of these aggregates, as investigated in the literature review, affect the overall performance of the concrete mix. This study investigates the effect of varying percentage of recycled aggregate on strength characteristics. In addition, supplementary cementitious materials such as fly ash or slag can be considered to increase the sustainability and performance of the concrete mix (Saikia et al., 2012). The proportions of the mixture are carefully designed to achieve the required workability and strength, considering the specific properties of the processed total aggregate.

### Sample preparation

Thorough sample preparation is essential to guarantee reproducibility and reliability of experimental findings. In accordance with the relevant test requirements, we create cylindrical and prismatic specimens that are tailored to specific test procedures and ensure the correct size and shape. To ensure accurate results, the casting process requires the use of appropriate consolidation and curing procedures to minimize irregularities.

### Test procedures

The experimental procedure involves carrying out a series of experiments to assess the properties of amount of taken from concrete from recycled aggregates. Compressive strength evaluation is performed on cylindrical specimens using a universal testing machine (UTM) using defined procedures such as ASTM C39. Flexural strength tests, often performed on prismatic specimens, evaluate the ability of concrete to withstand bending forces and are performed according to ASTM C78 or comparable standards. Evaluating the long-term performance of RAC in various environmental conditions requires the performance of durability testing, which includes assessment of water absorption and resistance to chemical attack. These tests follow established standards such as ASTM C642 and ASTM C1202.

### Statistical analysis

Statistical analyzes are used to ensure the reliability and accuracy of experimental results. Descriptive statistics such as mean and standard deviation provide valuable insights into the central tendency and variability of the data. Statistical methods such as inferential statistics, specifically analysis of variance (ANOVA) or regression analysis, can be used to identify the key factors that influence the strength characteristics of recycled aggregate concrete. Statistical methods help in drawing meaningful conclusions from experimental data and improve the credibility of study findings. This carefully designed experimental setup aims to comprehensively evaluate the self-resistance of the recycled aggregate

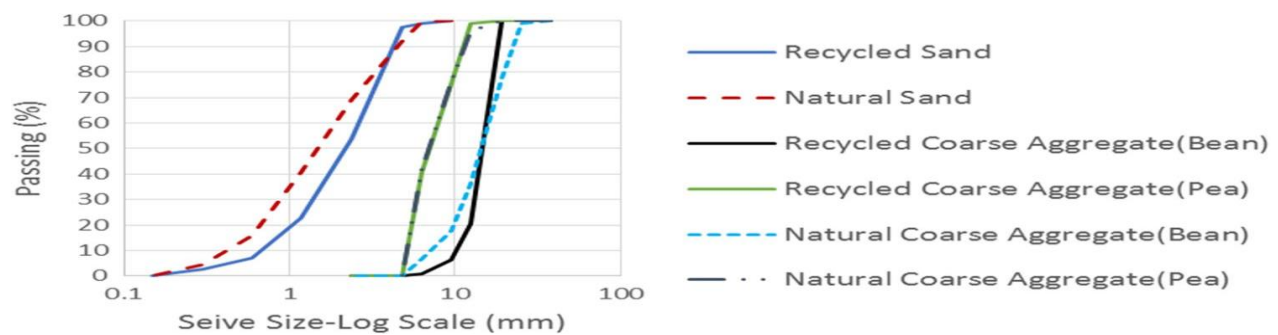
and lay the foundation for the subsequent follow up and interpretation of the data in the study query.

**PROPERTIES OF THE SUBSTANCE**

This study analyzes three unique concrete samples: NAC which is control sample and RAC which with and without fibers at two different time points, exactly 1 week and 4 weeks days. The cement is type II, manufactured by JOVIN, with a density of 3.1 grams per cubic centimeter and a surface area of 3840 grams per square centimeter. The cement composition is detailed in Table 1. In addition, the cement powder is exactly 400 kg/m<sup>3</sup> and the water-to-cement ratios were specifically chosen to be 0.4 and 0.450. The water extracted for the manufacture of concrete mixes according to ASTM. D. 1129.0 guidelines is potable water obtained from the city of Sari. Natural aggregate is composed of river sand and crushed gravel with a maximum acceptable or nominal size of 19.0 mm. The quality of recycled waste materials is influenced by various aspects, such as the approach to design and construction, the demolition procedure, climatic conditions and the utility value of the structure. Laboratories provide degraded concrete products for materials analysis and research purposes. The recycled materials used in this study were derived from laboratory samples of crushed concrete with different strength levels. In addition, the recycling process involves crushing concrete products into coarse and fine aggregate, which can be achieved using mechanical methods or manual labor.

**Table 1.**  
**Chemical composition**

Chemical composition	% SiO <sub>2</sub>	%CaO	%Al <sub>2</sub> O <sub>3</sub>	%Fe <sub>2</sub> O <sub>3</sub>	%Mgo	%SO <sub>3</sub>
Chemical composition of Portland cement type II	% SiO <sub>2</sub>	%CaO	%Al <sub>2</sub> O <sub>3</sub>	%Fe <sub>2</sub> O <sub>3</sub>	%Mgo	%SO <sub>3</sub>
	20.720	63.10	4.920	3.680	3.460	2.81



**Figure 1.**  
**The Particle size distribution curve**

**RESULTS AND EXAMINATION**

**Density and absorbency tests**

Three cubic specimens, each measuring 10 cm x 9 cm x 10 cm, were subjected to density and water absorption tests as per ASTM C 642.0 guidelines (ASTM 2013). The average taken of taken values of the data obtained from these results and tests are shown in the figures. Numerical values 3 and 4. Based on the facts shown in the chart. The mass volume

ratio of the RAC is less than the sample. Additionally, RACs show no discernible pattern of decline or expansion. The sample showing the minimum density is FRC-0.4, which contains fiber reinforced recycled aggregate concrete (FRC) with a water-to-cement ratio (W/C) of 0.4. The density of RAC decreased by approximately 2.480% compared to NAC. In addition, fiber-reinforced RAC has an average density that is 4.61% lower than that of NAC. The decrease in density of recycled aggregate concrete (RAC) compared to natural aggregate concrete (NAC) is attributed to the presence of pores in the recycled aggregate cement mortar (RA), which leads to a decrease in their density. The result is a reduction in RAC density. In addition, the incorporation of fibers into concrete causes pore expansion, which further reduces the density of fiber-reinforced recycled aggregate concrete (RAC). According to the data presented in the chart. Replacing aggregate (NA) with recycled aggregate (RA) results in higher water absorption rates in the test comparison results. In addition, the absorption capacity of recycled aggregate concrete (RAC) is approximately 54% compared to calculated natural aggregate concrete (NAC), but increases to 57% in the case of fiber reinforced concrete. Therefore, the control sample that does not use recycled materials shows the least water absorption in all phases.

**Pressure test to assess the material's resistance to pressure forces**

As the compressive strength assessment was carried out as per BS EN 12390-13.0 (Standard of 2011) guidelines on 10.0 cm x 10.0 cm x 10.0 cm cubic specimens at 7 and 28 days of age. Figure Shows average values of test results for both 7-day and 28-day age categories.

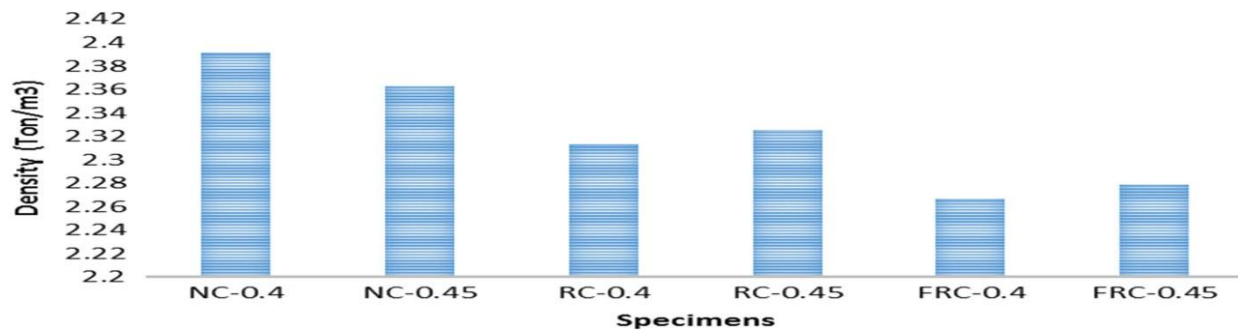


Figure 2. Display the density of the specimen

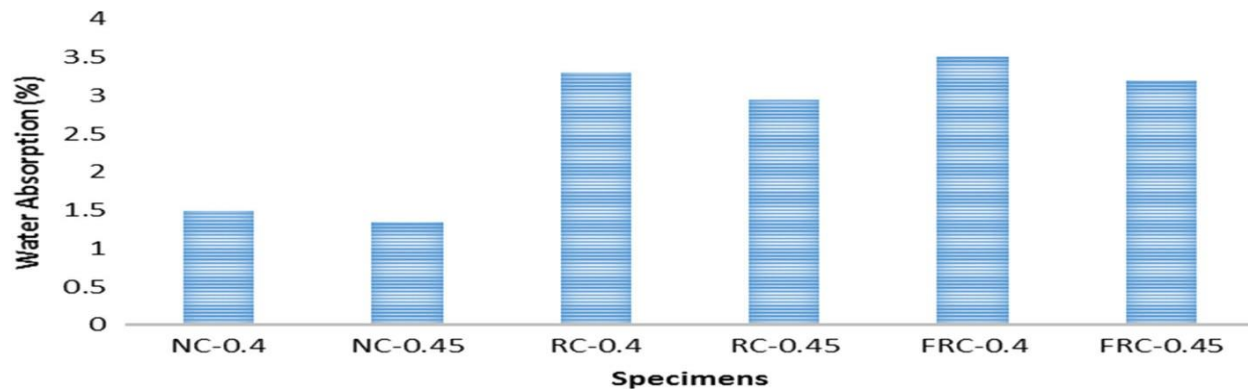
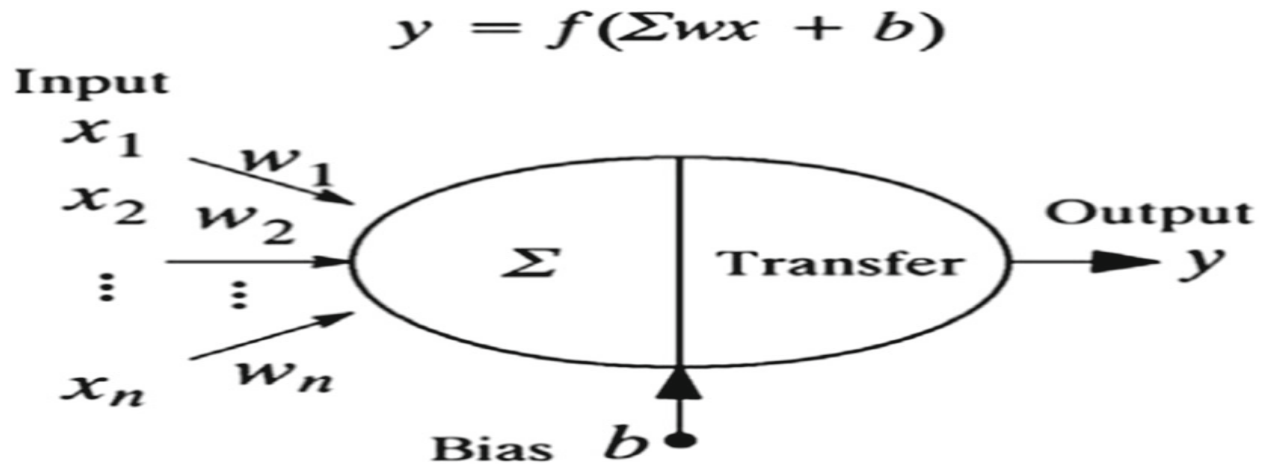


Figure 3. Water absorption of Specimens



**Figure 4.**  
**Compressive strength of specimens at ages of 7.0 and 28.0 days**

The average difference is 4%, but when the water to cement ratio reaches 0.45, the difference increases to 40%. In addition, fiber-reinforced recycled aggregate concrete (RAC) shows a 24% reduction in compressive strength compared to normal aggregate concrete (NAC) at a water/cement (W/C) ratio of 0.4. However, fiber-reinforced recycled aggregate concrete shows approximately 28% improvement in compressive strength when the water-to-cement ratio is 0.45. Compressive fiber strengthThe tensile strength of recycled aggregate reinforced concrete (RAC) decreases by 23% compared to RAC with a water-to-cement ratio of 0.4, and there is an average reduction of 19% when the water-to-cement ratio increases to 0.45. According to the data presented in the chart. As the water-to-cement ratio increases, the compressive strength increases continuously. In addition, the use of plastic fibers in recycled asphalt concrete (RAC) increases its F.

**Table 2.**  
**Aggregates properties**

Aggregates properties	Natural sand	NCA <sup>a</sup> (pea)	NCA (bean)	Recycled sand	RCA <sup>b</sup> (pea)	RCA (bean)
Water absorption (%)	2.6	1.5	2.06	7.43	3.5	2.99
Specific weight (kg/m <sup>3</sup> )	1.48	2.66	2.59	1.59	2.38	2.49
Crushing value (%)	-	51.82	58.52	-	> 90	> 90

Natural coarse aggregate

Recycled coarse aggregate

Refers to the pores created by the inclusion of fibers. Portland cement type II

Cement percentage 20.72 63.1 4.92 3.68 3.46 2.82

To assess the particle volume and volume distribution curve of both total natural and recycled aggregates has a significant effect on compressive strength, especially as the water-cement ratio increases. The compressive strength is primarily influenced by the durability of the aggregate, the perfection of the cement paste and the interaction of both components. In addition, the incorporation of fibers to have gradual improvement in the strength, provided the samples are sufficiently compressed.



## PREDICTION OF COMPRESSIVE STRENGTH

**Artificial Neural Networks (ANN)** An artificial neural network (ANN) is a commonly used model in soft computing. The system is inspired by the human nervous system and it is consisting of interconnected artificial neurons that have been assigned certain weights. Neural networks generally include three types of neural layers: input, hidden, and output layers. The final or outer layer is dependent on the combined activity of the hidden units and the weights that connect them to the outputs. The error function is defined as the difference between the output of the network and the target output. Subsequently, the deviation is iteratively adjusted to manipulate the weights and variances to reduce the errors. This iterative process, continues until the highest level of accuracy in finding the outputs is achieved. Validation is done indirectly during the learning phase. Therefore, the learning process stops when the frequency of validation failures starts to rise. The final phase of artificial neural network (ANN) modeling is the testing phase that is performed. The diagram depicts a mathematical neuron in a neural network that is specifically developed to evaluate network efficiency. The figure illustrates a schematic representation of a neuron and its sub-elements. The numerical value is 6.

### MODELING PROCESS

The modeling process involves a series of steps and techniques used to create a representation or simulation of a system or concept. Data obtained from previous studies on RCA were used to train a neural network (NN). In addition to the design, other designs proposed by various authors were used. A total of 124 experimental samples were used in this survey, which were subsequently used to train an artificial neural network (ANN). Mix design includes the weights of several components, including coarse and fine natural aggregate, recycled aggregate, cement, water, and admixtures, especially superplasticizer. Output measurement is quantified based on compressive strength. Table 4 presents the statistical data and range of variation for the input results and output results of elements of the ANN. To minimize negative effects on the results of the experiment, it is necessary to standardize and adjust the size of all input and target elements before starting training. The significance of scaling and passement is that function selectively identifies values only in the range of 0 and 1. In order to achieve accurate data scaling, minima and maxima values must be specified, i.e. values of 0.9 are used. The scaling functions is shown in Table 5.0.

### Neural network implementation

A backpropagation network was used to perform the sample mixture design. Therefore, this network is characterized as the most direct and efficient models networks. The data required for the network is divided into two distinct categories: training data, which makes up 70% of the total data, and test data, which makes up the remaining 30%. This network contains an input layer that accepts inputs indicating the number of components contained in the input of the network. In addition, it contains one or more hidden layers, each of which consists of several neurons, as shown in the figure. Figure 7. The figure shows a schematic representation of the input and potential layers of an artificial network (ANN). Figure 7. The optimal network has the maximum possible number of nodes among the hidden or invisible layer, which allows it to produce the desired correlation between the output and target values while minimizing the error. The primary

goal of this study was to train neural networks with hidden layers ranging from 5 to 20 nodes. The figures show the error values and correlations of these studied networks. Numbers 8 and 9.

**Table 3.**  
**Comparison of Input and output variables**

	Natural sand	NCA	RCA	Recycled sand	Cement	Water	Super plasticizer	Compressive strength-28 days
Mean	(kgs)	(kgs)	(kgs)	(kgs)	(kgs)	(kgs)	(kgs)	(MPa)
Maximum	781.150	520.540	381.31	32.290	373.52	187.30	0.8650	43.87
Minimum	15140	897.0	1126.80	668.0	449.0	271.0	4.90	60.0
Standard deviation	00	00	00	00	300.0	140.0	00	17.77
	407.190	248.140	353.570	111.81	45.52	22.91	1.47	8.8

### NEURAL NETWORK RESULTS

After selecting an ANN structure, it is important to refrain from using validation data to train the network. The accuracy of neural network compression strength estimation strongly depends on the data used for training. In the image shown. There are a total of 10 diagrams that visually represent the performance of the constructed neural network. These graphs show the curve of the training result along with the validating data and results, testing, and full data. In addition, the scheme. Figure 11 shows the mean square errors (MSE) that occurred during the training process of the neural network used to predict the strength of concrete mixers. According to the data presented in the chart. The correlation coefficients for the training, validation, and testing datasets are 0.9640, 0.9830, and 0.9550, respectively. A close proximity of these values to 1 indicates successful learning and there is a significant correlation between the performance of the neural network and the linear correlation coefficient between the modeled and predicted values. In the image shown. The regression value of the network chosen at different stages of the modeling process was shown, marked as 11, indicating a reduction in the mean squared errors (MSE). Figure 12 shows the variation of the network over many epochs. Plus the character. Figure 13 shows a comparison plot showing the experimental and expected strength values, indicating a substantial level of agreement between the two data sets.

**Table 4.**  
**Scaling functions for variables**

Input and target variables	Scaling functions
Natural Sand	$NCA_{scaled} = \frac{NCA - NCA_{min}}{NCA_{max} - NCA_{min}}$ $\in [0; 1]$
NCA	$NFA_{scaled} = \frac{NFA - NFA_{min}}{NFA_{max} - NFA_{min}}$ $\in [0; 1]$
RCA	$RCA_{scaled} = \frac{RCA - RCA_{min}}{RCA_{max} - RCA_{min}}$ $\in [0; 1]$
Recycled sand	$RFA_{scaled} = \frac{RFA - RFA_{min}}{RFA_{max} - RFA_{min}}$ $\in [0; 1]$
Cement	$C_{scaled} = \frac{C - C_{min}}{C_{max} - C_{min}}$ $\in [0; 1]$
Water	$W_{scaled} = \frac{W - W_{min}}{W_{max} - W_{min}}$ $\in [0; 1]$
super plasticizer	$ADD_{scaled} = \frac{ADD - ADD_{min}}{ADD_{max} - ADD_{min}}$ $\in [0; 1]$
Compressive strength-28 days	$f_{cu, scaled} = \frac{f_{cu} - f_{cu, min}}{f_{cu, max} - f_{cu, min}}$ $\in [0; 1]$

According to the data, the network with 7 nodes in the potential layer has excellent correlation coefficients compared to the networks with 8 and 9 nodes. This network has both the highest correlation coefficient and the lowest error rate. Therefore, a network with 7 nodes is optimal choice for the prediction of 28-day compressive strength.

### Support Vector Machine (SVM)

Support Vector Machine (SVM), in 2005 was introduced as a machine learning tool. The effectiveness of this unique methodology has been proven in comparison with conventional methods of classification of perceptron neural networks. SVMs differ from other types of neural networks in that they emphasize operational risk as an objective function and try to discover its optimal value, rather than focusing only on eliminating modeling or classification errors. In addition, this approach is quite effective in solving problems related to pattern recognition. Moreover, its ability to achieve exceptional performance, even with the limitation of a small amount of training data, makes it an ideal method for solving computational problems. This suggests that it performs satisfactorily when faced with difficult or costly data collection scenarios. A significant computational task involves accurately predicting the compressive strength of recycled concrete. A notable characteristic of these models is the support vector machine (SVM) unit architecture. This approach differs from neural networks because it refrains from using features such as layers, transfer functions, or the number of neurons. In addition, the amount of optimization parameters needed for a given problem is greatly reduced. However,

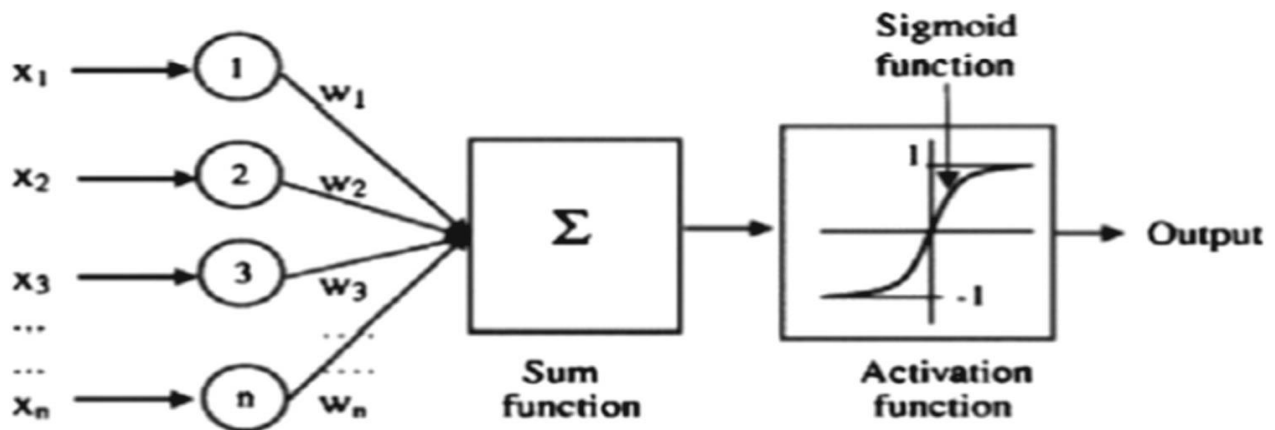


Figure 5. Schematic view of artificial neural network's structure

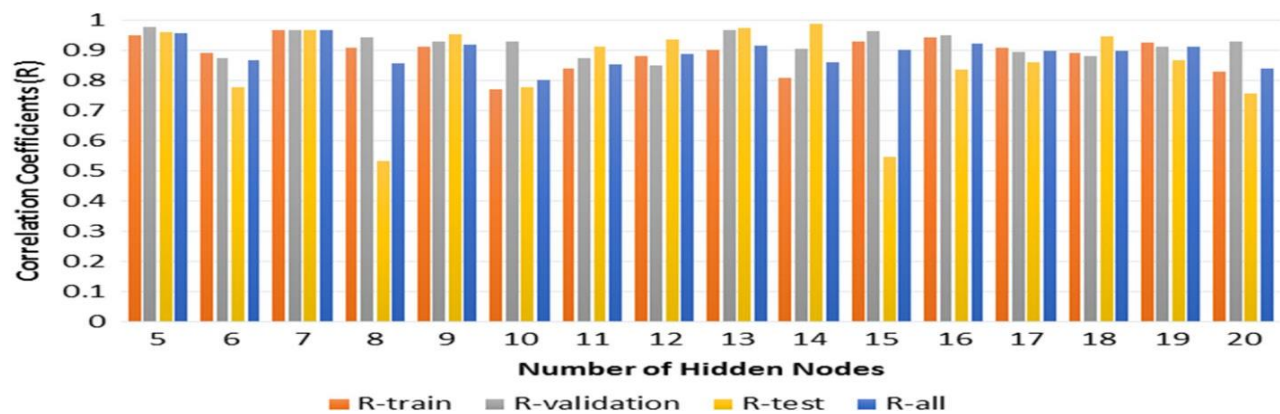
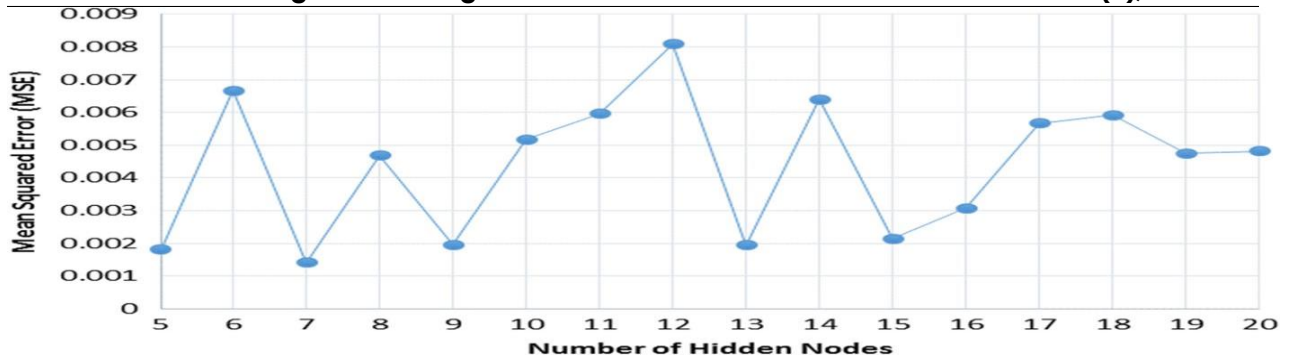


Figure 6. Correlation



Due to the structure of SVMs, to generalize when confronted with small amounts of data is desirable. To build an SVM, C and e must be set by the user. C can be between 0 size and infinity, the role of which is to create a balance between minimizing experiential risk and maximizing it.

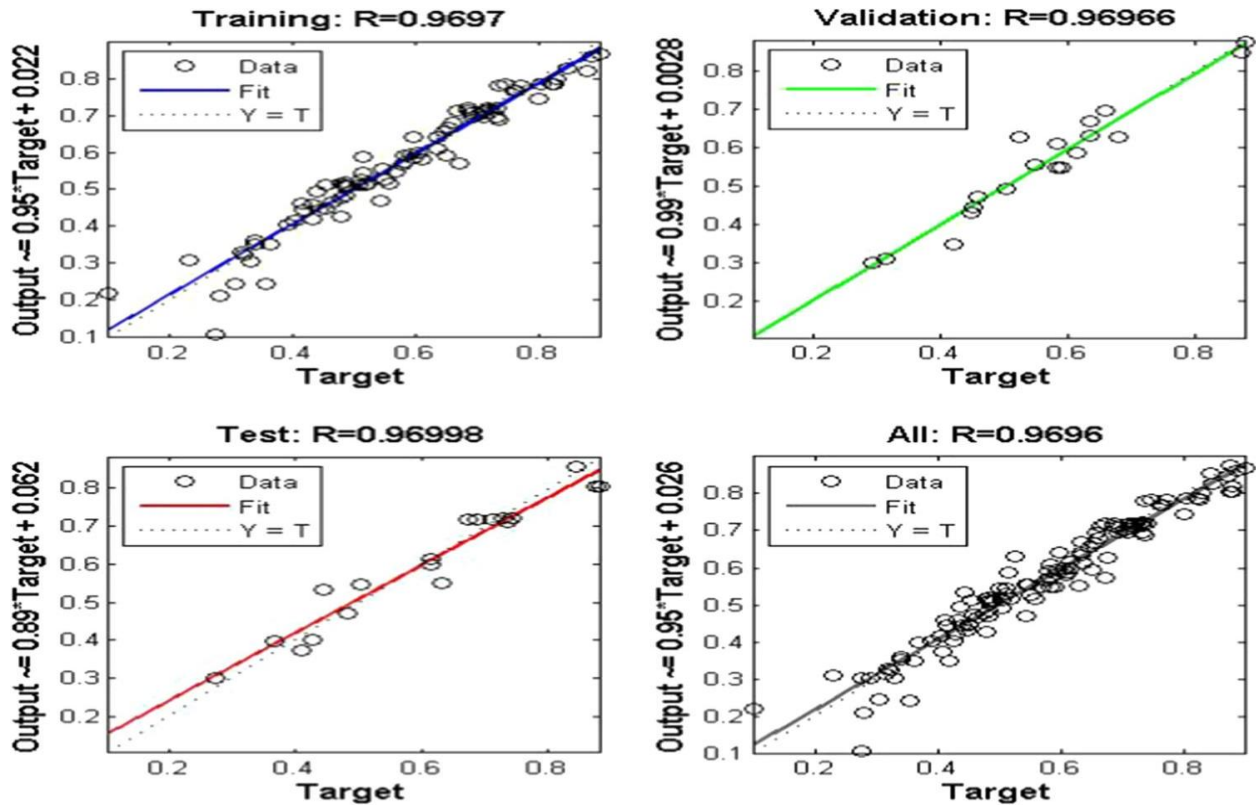


Figure 7,8,9,10.

Regression

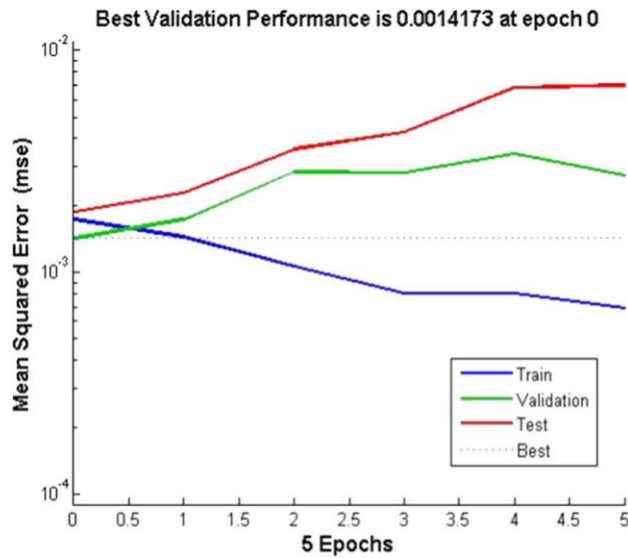


Figure 11. Mean squared errors (MPa2)

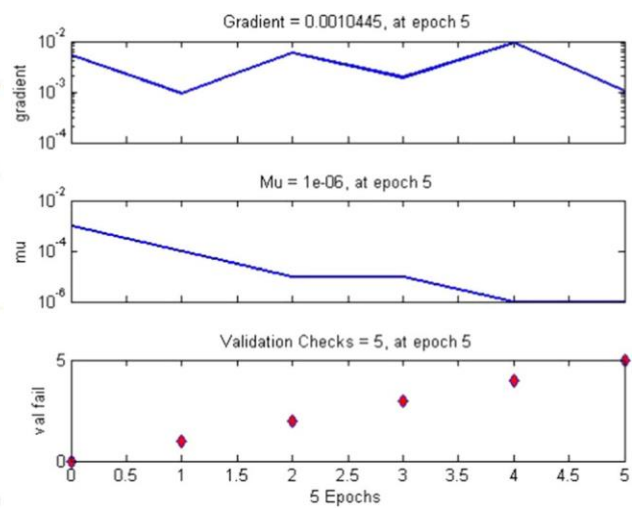


Figure 12. Trend in the network during the teaching step

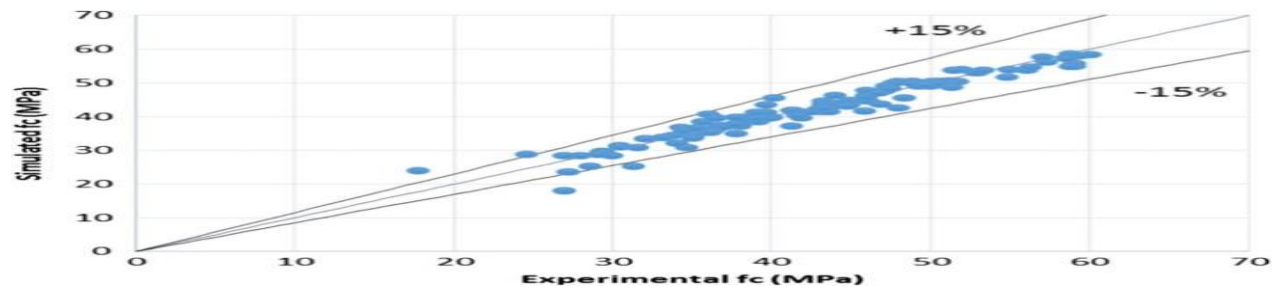


Figure 13. Experimental (MPa)

Giant. 13 Comparison of results. These parameters helps to show how structural risk is minimized. MLR has been used in several research studies due to its utility. Equation 1 reflects the multiple linear regression (MLR) equation as reported by Tu"mer and Edeballi in their 2015 publication.

Multiple linear regression (MLR)

Equation (1) denotes a linear regression model containing several independent variables (x1, x2, ..., xn) and their respective coefficients (a1, a2, ..., an). The variable e denotes the error term.

$$Y_{pre} = a_0 + a_1x_1 + a_2x_2 + \dots + a_nx_n + e \quad (1)$$

In relation 1, Ypre denotes the expected value of the dependent variables x1 to xn. The independent predicted variables are represented by a0, which stands for the value of Y when all independent variables (x1 through xn) are set to zero. The coefficients a1 through an correspond to the calculated regression coefficients, while e indicates the error in the regression model.

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## INTEGRATION OF EXPERIMENTAL AND MACHINE LEARNING RESULTS

Integrating empirical findings with machine learning predictions is a critical step in our inquiry to offer a holistic view of the potential durability of recycled aggregate (RAC). This section examines the correlation between actual and predicted strengths, evaluates machine learning predictions, and explores the implications of these combined findings for the development and use of recycled aggregates.

### **Correlation between experimental and predicted force**

Establishing a robust correlation between empirically determined RAC strength and predictions made by machine learning models is essential to the objectives of the study. Statistical techniques such as regression analysis are used to quantify the correlation between observed and expected strengths. The coefficient of determination (R-squared) and other performance metrics provide a clear and accurate assessment of the quality and reliability of the machine learning model in accurately capturing the complex dynamics that affect RAC intensity. This correlation study serves as a validation tool that verifies the predictive capabilities of the machine learning approach and instills confidence in generalizing the results beyond the experimental dataset.

### **Findings derived from machine learning predictions**

Machine learning predictions provide deep insight into the complex relationships between several input parameters and the durability of recycled aggregates. Property importance analysis demonstrates the comparative importance of many factors affecting concrete strength. A machine learning model that has gained knowledge from experimental data has the ability to identify non-linear patterns and interactions that conventional statistical methods could not detect. This observation facilitates the identification of key attributes that require special attention in RAC design and quality assurance. In addition, machine learning projections improve our ability to predict how RAC performs under different conditions and provide a valuable tool for engineers and practitioners to optimize mix designs for specific purposes.

### **Implications for designing recycled aggregate concrete**

The extensive findings have a significant impact on the development and production of recycled aggregates. Correlation analysis and machine learning predictions provide valuable insights that improve concrete mix design strategies by providing guidance on the optimal mix of recycled aggregate, other admixtures, and other mix influencing factors. The findings of the study provide valuable insights for the development of RAC mixes that include increased strength and durability, thereby facilitating the use of sustainable construction methods. In addition, the machine learning model uses a comprehensive data set to offer engineers a predictive tool for estimating RAC performance under various conditions. This enables informed decision-making in construction projects.

In addition, the combined findings increase the understanding of recycled aggregate as a reliable and environmentally friendly building material. This research expands the field of concrete engineering by combining traditional experimental methods with modern machine learning techniques. It also highlights the potential for creative approaches to

address the challenges and opportunities associated with recycled aggregates. Implications extend beyond the laboratory to provide practical knowledge to engineers, policy makers and industry stakeholders dedicated to promoting sustainable construction practices.

## **CONVERSATION**

The discussion section provides a comprehensive overview of the results obtained from experimental and machine learning experiments. It delves into the interpretation of the data, acknowledges the limitations of the study, and outlines potential areas for future research.

## **ANALYSIS OF FINDINGS**

A thorough understanding of the correlation between experimental results and machine learning results is necessary to properly assess the findings. The lecture begins by elucidating the discovered correlation between empirically determined and machine learning predicted strengths of Recycled Aggregate Concrete (RAC). The data is evaluated to identify significant patterns and trends that offer insight into the factors that have a significant impact on RAC strength. The debate also considers the significance of these findings in the wider context of sustainable construction and highlights how a combination of experimental and machine learning approaches leads to a more comprehensive understanding of RAC capabilities. In addition, this analysis examines specific cases of accurate predictions and discrepancies between actual and expected strengths, providing a more comprehensive understanding of the challenges associated with modeling RAC behavior.

## **STUDY RESTRICTIONS**

Recognizing study limitations is critical to contextualizing findings and improving future research efforts. Potential limitations may arise from the inherent variability of recycled aggregates, which may lead to ambiguity in experimental findings. Additionally, the accuracy of a machine learning model's predictions depends on the perfection and inclusiveness of the training dataset. Other factors such as environmental conditions during the testing process may also contribute to variations. The discussion section openly acknowledges these limitations and clarifies the methodology used in the study. The study emphasizes the implementation of mitigation techniques such as rigorous statistical analysis and careful experimental design. Recognizing the limitations underscores the need for careful analysis of the findings and provides suggestions for future research.

## **PROSPECTS FOR FUTURE RESEARCH**

In order to advance the discourse on recycled aggregates, future research directions were identified. Based on the knowledge gained from the current study, suggestions are made for improving experimental protocols, expanding datasets, and improving machine learning models. Particular emphasis is placed on areas where the incorporation of experimental and machine learning techniques can be improved. The text includes suggestions for investigating the long-term durability of RAC, exploring alternative machine learning methods, and integrating real-world design scenarios into predictive models.

Additionally, the debate suggests a collaborative effort between academics, industry and regulatory organizations to facilitate the tangible integration of RAC into construction projects. Prospective areas for future research include identifying new admixtures, fine-tuning mix compositions for specific applications, and developing standardized guidelines for designing recycled aggregate concrete (RAC). The discussion section enriches the continuing expansion of knowledge in the field of sustainable construction and recycled materials by outlining these promising avenues. Finally, the discussion section unifies the findings of the study, puts them into a wider context, and sets the stage for further investigation and progress in the field of recycled aggregate research. It plays a key role in the dissemination of knowledge, guiding scientists and practitioners towards a more sustainable and informed approach to concrete engineering.

## **CONCLUSION**

The conclusion summarizes the significant aspects of the research, offers a brief overview of the findings, outlines the practical implications and highlights the contribution of the study to the field of recycled aggregates (RAC).

## **OVERVIEW OF RESULTS**

The research results provide a comprehensive summary that includes significant discoveries regarding the potential durability of recycled aggregate concrete. A combination of empirical studies and machine learning predictions highlights the complex correlation between recycled particles and concrete compressive strength. Condensed analysis of significant trends, relationships and factors enables a comprehensive understanding of RAC performance behavior. The summary outlines the empirically derived strengths, accuracy of machine learning forecasts, and any observed deviations. This section serves as a brief guide for the reader that presents the basic results of the study.

## **PRACTICAL APPLICATIONS**

The research findings are compiled to provide guidance to industry practitioners, engineers and policy makers regarding the implementation of recycled aggregates. A concrete mix design study guide provides valuable insights that increase the potential for achieving optimal strength and durability. The discussion of practical implications goes beyond the laboratory and provides guidance for the sustainable use of recycled materials in real-world construction efforts. Suggestions are provided to improve quality control, material selection and implementation of construction practices in line with the general objectives of sustainable construction. This section serves as a link between academic research and practical application, highlighting the tangible benefits of incorporating recycled aggregates into concrete for sustainable and green construction techniques.

## **EFFECT ON DISCIPLINE**

The research study sheds light on the importance of recycled aggregate and highlights its role in increasing knowledge and influencing the adoption of sustainable construction methods. The integration of experimental analysis and machine learning methodology



represents an innovative approach that facilitates a comprehensive understanding of the potential effectiveness of RAC. The study contributes to the development of specific engineering methods by filling gaps in existing research and using modern computing techniques. New perspectives derived from a combination of experimental and predictive data represent a valuable addition to the expanding body of information on the use of recycled materials in construction. In addition, the study establishes a foundation for future research efforts by presenting new avenues for exploration and improvement in the development and application of recycled aggregates. This section defines the significance of the research and places it in the wider context of sustainable materials in construction, thereby promoting further scientific discourse and tangible advances in the field.

## DECLARATIONS

**Acknowledgement:** We appreciate the generous support from all the supervisors and their different affiliations.

**Funding:** No funding body in the public, private, or nonprofit sectors provided a particular grant for this research.

**Availability of data and material:** In the approach, the data sources for the variables are stated.

**Authors' contributions:** Each author participated equally to the creation of this work.

Conflicts of Interests: The authors declare no conflict of interest.

**Consent to Participate:** Yes

**Consent for publication and Ethical approval:** Because this study does not include human or animal data, ethical approval is not required for publication. All authors have given their consent.

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