Compressive Strength Prediction of Concrete Containing Used Cooking Oil Using Ann

Dumpala Suneel Kumar, B. Ajitha

Abstract: To mitigate the detrimental impacts of disposing of used cooking oil (UCO) into the environment, which adversely affects marine life, human health, and agricultural outputs, this research proposes a novel approach incorporating this waste material into the concrete industry as a chemical admixture. To investigate this, an initial experimental program is designed to examine how used cooking oil affects various fresh properties and compressive strength at 3, 7, and 28 days of age of concrete. Concrete batches of M40 grade are meticulously prepared with varying proportions (ranging from 0% to 2%) of used cooking oil. To predict strength characteristics, an Artificial Neural Network (ANN) is employed, consisting of three layers. The input layer comprising quantities of cement, coarse aggregate, fine aggregate, water content, super plasticizer, and the percentage of the chemical admixture (UCO), hidden layer for predicting the network system and the output layer providing the concrete's compressive strength.

Keywords: Compressive Strength, Used Cooking Oil, Artificial Neural Networks (ANN).

I. INTRODUCTION

Concrete is a composite material that is a mixture of binding material, aggregate (such as sand and gravel or crushed stones), water, and sometimes admixture. The Cement acts as a binder to hold the aggregates together, and the water facilitates the chemical reaction that hardens and strengthens the concrete. Concrete is known for its excellent compressive strength, which enables it to withstand heavy loads. It also has high durability, flexibility, and affordability. Concrete has reached around 90% of its final strength after four weeks of water curing. But as calcium hydroxide gradually transforms into calcium carbonate as a result of its absorption of carbon dioxide over time, it keeps getting stronger for decades after that. As a result, it is suggested for a variety of construction activities. After water, concrete is the material that is utilized the most on Earth. Concrete continues to be a vital material in the modern world, with ongoing research and innovations focused on improving its sustainability and performance. As new technologies are practices emerge, the possibilities for concrete applications continue to expand, shaping the future of construction.

Nowadays environmentally friendly innovations are more popular. Many wastes are being used to replace the resources that are readily accessible on the market. Although the powerful super plasticizer function has been proposed by earlier researchers, the replacement admixtures are a novel idea that has to be investigated. The building sector as well as the global use of concrete may be affected economically and technically by new types of cost-effective admixtures.

Used Cooking Oil (UCO) is the oil that has been previously used for cooking or frying food [4]. Consuming used cooking oil is not recommended for its ability to turn into trans-fat after each repeated use. To avoid the formation of trans fat, cooking oil should be used a maximum of three times [5]. Most of their waste cooking oil is sold to street vendors and small-town markets instead of reaching the biodiesel industry [6]. Ultimately, this used cooking oil is disposed into the drain and on the ground. Improper disposal of used cooking oil, such as pouring it down the drain or disposing of it in landfills, has been a serious issue. It might contain hazardous substances for the environment. It can impact the ecosystem in addition to being hazardous to plants and animals [1]. Additionally, when oil meets water, it harms aquatic and marine life.

A. Artificial Neural Network

Artificial neural networks are produced from the inspiration and research of the human nervous system. Neural networks learn to execute tasks by examination of past experiences and produce a result for various sampling situations. An enormous number of interconnected processing nodes, or neurons, make up ANNs, which are capable of learning to recognize patterns in incoming data. Edges are the connections between nodes. The weight of each node determines how strongly it is connected to other nodes. To form an output signal, each neuron absorbs input signals, weights them, and then transmits the weighted sum through an activation function. The input layer gets the beginning data, the output layer provides the final output, and there might be one or more hidden layers in between. The hidden layers offer intermediary processing and allow the network to develop layered representations of the incoming data. During the training phase, an artificial neural network learns by altering the weights associated with each neuron based on the input data and wanted output. ANNs are commonly used in some tasks and applications, including image identification, facial recognition, classification, regression and prediction.

Dumpala Suneel Kumar*, PG Scholar, Department of Civil Engineering, JNTUA College of Engineering, Ananthapuramu, India. Email: dsuneelkumar8@gmail.com, ORCID ID: 0009-0002-7667-483X.

B. Ajitha, Associate Professor, Department of Civil Engineering, JNTUA College of Engineering, Ananthapuramu, India. Email: ajitha123.civil@jntu.ac.in, ORCID ID: 0000-0003-4715-8131.
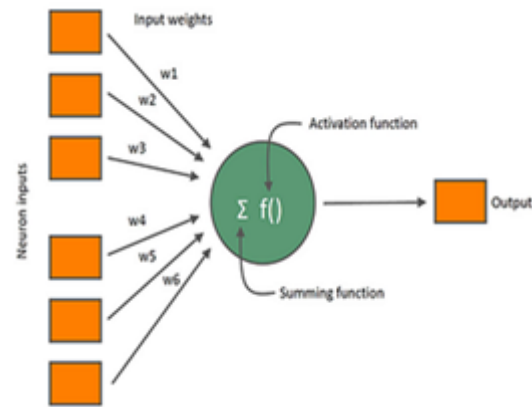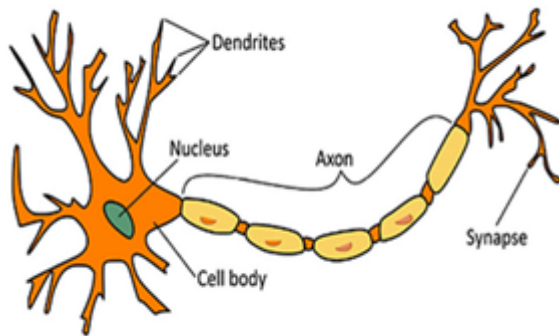
Figure 1: Biological Neuron and Artificial Neural Network.

B. Scope of the Work

This study deals with experimental results when concrete is mixed with used cooking oil and ANN application of predicting the future strength of concrete containing used cooking oil.

- To determine the compressive strength of concrete when cooking oil is mixed with concrete.
- To identify the optimum dosage of used cooking oil.
- To predict future strength by ANN approach.
- Comparing the results of experimental and ANN to calculate deviation compressive strength.

C. Objectives of Research

This present study used cooking oil as a chemical additive in concrete. ANN is used to predict future strengths.

- Discuss the impact of introducing used cooking oil on the characteristics of freshly prepared and cured concrete.
- Artificial neural network prediction to find compression strength from experimental results.
- Optimization of experimental and artificial neural network results.

II. LITERATURE REVIEW

[1] **M Chandrashekar et al., (2016)** have concluded that the progressive increase in the proportion of waste cooking oil negatively impacted the workability of concrete while maintaining a constant water-cement ratio (0.5). Moreover, positive outcomes were observed in the compressive strength of concrete cubes containing added waste cooking oil (WCO), signifying the viability and compatibility of utilizing WCO as an additive within the concrete matrix. Notably, the concrete cubes with 1.5% WCO addition demonstrated a noteworthy increase of 2.67% in compressive strength on the 28th day, compared to the compressive strength of standard concrete cubes tested on the same days. Consequently, the optimal proportion of waste cooking oil (WCO) was determined to be 1.5%.

[2] **B Salmia et al., (2013)** This study found that the slump value increased from 1mm to 18mm as the proportion and quantity of used cooking oil were elevated from 0.25 percent to 2.00 percent, representing a significant 72 percent increase compared to the control test. In terms of compressive strength, using cooking oil produced a similar 16.8% increase in strength compared to the control test. Seven samples

overall, each representing a different percentage of UCO, were created for the experimental phase: the control test, 0.25 percent, 0.50 percent, 0.75 percent, 1.00 percent, 1.50 percent, and 2.00 percent. Notably, based on its performance, UCO's ideal contribution was determined to be 1.50 percent. [3] **Sourav Das et al., (2015)** This paper undertakes the concrete mix design process through a combination of empirical relationships and engineering expertise. For training the Artificial Neural Network (ANN) model, an extensive database of mix proportions for M25-grade concrete is established, using PPC cement. The model's input parameters consist of Target Mean Strength, Workability represented by slump, and materials used in concrete. Subsequently, the trained network is validated using a distinct set of five mix proportions that were not included in the training phase. The resultant average percentage inaccuracy is quantified at 0.193%. Comparatively, when contrasted with linear regression analysis, the ANN model demonstrates superior efficiency.

III. METHODOLOGY

The methodology used in the experimental procedure is to determine the compressive strength of concrete in comparison with ANN results with minimum error obtained to predict future mix strengths.

A. Materials Used

a. Cement:

The 53 Grade Ordinary Portland Cement from Penna is used throughout the experiment. The specific gravity of Portland cement is 3.15. It was brand-new and lump-free.

b. Fine Aggregates:

As a fine aggregate, locally - obtained natural sand with a maximum size of 4.75 mm was chosen, which complies with IS 383-1970 grading zone II. The specific gravity of fine aggregate is 2.58, which may be purchased from nearby vendors.

c. Coarse Aggregates:

Locally available crushed granite with a maximum particle size of 20 mm was utilized as coarse aggregate. The specific gravity of coarse aggregate is 2.74.

d. Water:

Oils, acids, alkalis, salts, biological matter, and other pollutants that might harm concrete should not be present in the water used to mix concrete, including the free water on the aggregates.

e. Used Cooking Oil:

In the making of concrete, they serve as additives. The street food shop is a good place to get used cooking oil [3]. From street food vendors, used cooking oil (UCO) was collected in this work.

f. Super Plasticizer:

To make high-strength concrete, superplasticizers (SP) are added to fresh concrete to increase its workability and enable the water content to be dropped. Fosroc Conplast SP 430 Dis is the material utilized in this investigation.

B. Mix Proportions

To attain M40 grade strength, the concrete was designed following IS 10262- 2009, and a water-to-cement ratio of 0.36 was employed. Seven distinct mixes of Concrete with varying proportions containing UCO (0, 0.25, 0.50, 0.75, 1, 1.50 and 2%) were tested to analyse the strength characteristics in terms of Compressive Strength. Nine cubes are cast for each mix and tested for hardened properties. The table shows the designed proportions of the basic ingredients in concrete.

Table 1: Mix Proportions of Different Mixes.

S. No	Material	
1.	Cement	431Kg/m³
2.	Fine aggregate	630Kg/m³
3.	Coarse aggregate	1232Kg/m³
4.	Water	155Kg/m³
5.	UCO	0%,0.25%,0.50%, 0.75%,1%,1.50%,2%
6.	Superplasticizer	4.31Kg/m³

a. Casting of Specimen

The necessary components were weighed for these mixed proportions. All components were blended into a homogenous mix after being added to the water and used cooking oil. Before being added to the dry components in the mixer, substances like spent cooking oil diluted with water. The final casting of the mixtures was carried out right away after the testing for fresh characteristics. Test samples were cast, and they were then kept in the casting chamber for 24 hours at a temperature of around 20°C. After 24 hours, the specimens were removed from the mould.

b. Curing:

After 24 hours in moist air, the samples are removed from moulds and marked. Then remain immersed in water throughout the test. The curing water should be 27±2°C in temperature and ought to be examined every seven days.

IV. RESULTS & DISCUSSIONS

A. General:

Listed below is a discussion of the properties that were evaluated while concrete was in its fresh condition and its hardened state, along with the experimental findings that were made.

B. Fresh Properties of Concrete:

The workability test is conducted to the test of newly laid concrete. The slump test was chosen as the workability test for this investigation. Concrete's fluidity and consistency are indicated by its slump value. It measures how easily concrete can be shaped. Higher slump values indicate more workable concrete, whereas lower slump values indicate less workable concrete. The values for slump for various concrete mixtures are displayed below.
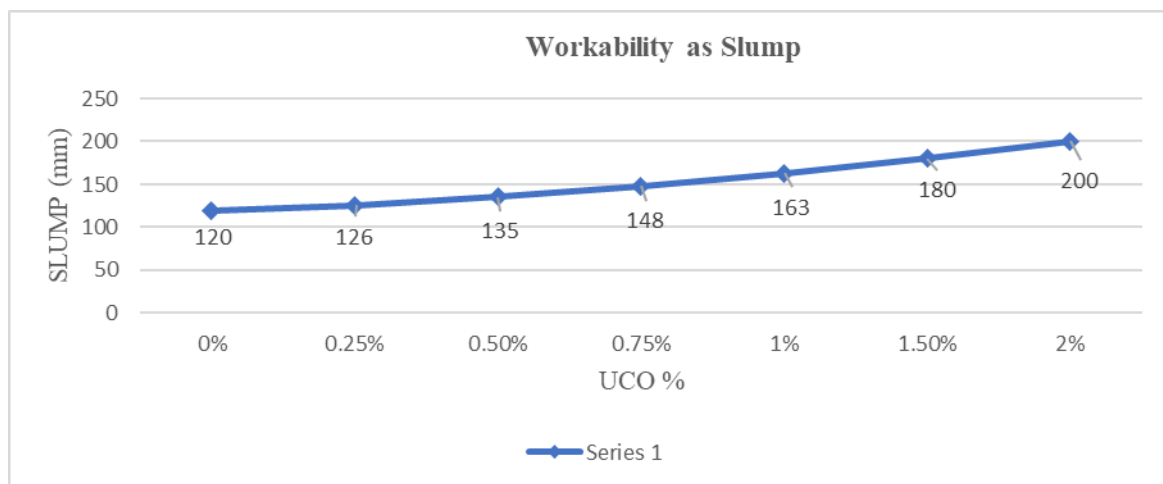

Figure 2: Slump Values of Different Mixes in Mm.

The findings demonstrate that, compared to the slump of the control mix, the mix's slump values were enhanced by the inclusion of used cooking oil. When the dose of used cooking oil (UCO) was raised to 0, 0.25, 0.50, 0.75, 1, 1.5 and 2%, the value of the slump gradually increased from 120mm to 200mm.

C. Hardened Properties of Concrete:

In the present study, the M40 mix design is developed by adding Used Cooking Oil (UCO) to concrete in varying amounts while making no other changes to the mix design's properties. After this, 63 samples were examined after 3, 7, and 28 days of curing. The proportion of used cooking oil ranged from 0 to 2% by weight of cement. In this study M40 mix design is made by adding used cooking oil with varying percentages in concrete and no other modifications in the qualities of the mix design. The presented graph depicts compressive strength on the Y-axis and the percentage of used cooking oil (UCO) on the X-axis. The graph visually presents the experimental outcomes regarding compressive strength variation as used cooking oil content changes. There is an observed enhancement in concrete compressive strength with an increase in used cooking oil percentage up to 1%. However, beyond this point, there is a significant decline in strength as the used cooking oil percentage reaches 2%.
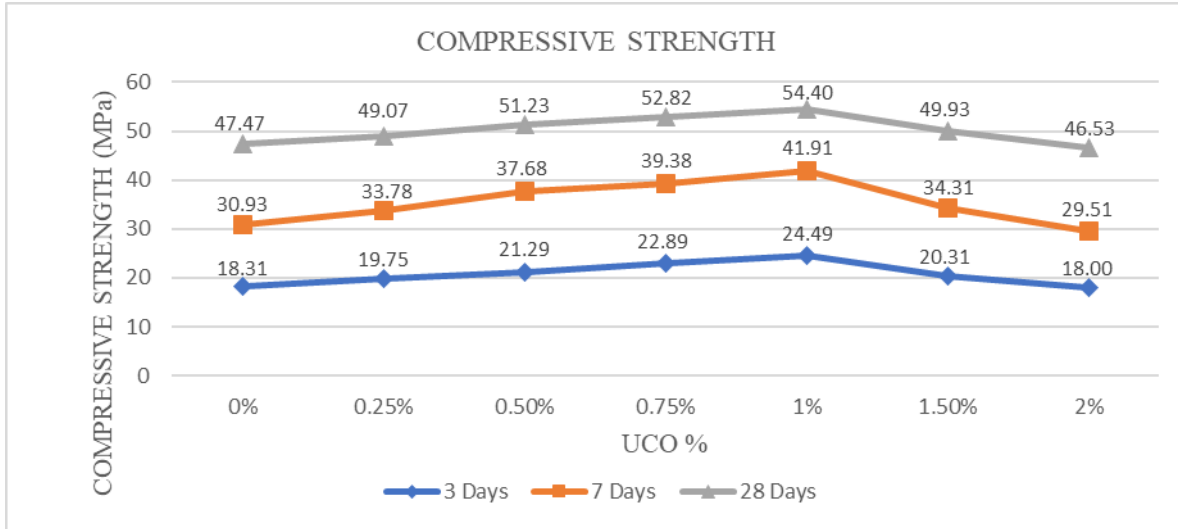

Figure 3: Compressive Strength Values of Different Mixes in MPA.

D. ANN Training Process:

A Multi-Layer Feed-Forward Neural Network (MFFNN) comprises a minimum of three layers: input, output, and a hidden layer. In each layer, neurons receive weighted inputs from the preceding layer and transmit their outputs to neurons in the subsequent layer [7][9][10]. The weighted input signals are aggregated through summation and then processed by a nonlinear activation function. The network's outputs are compared against actual observed results, and the network error is iteratively adjusted through training until it reaches an acceptable threshold. The neural network is trained using the feed-forward-back propagation approach with one hidden layer, and the ideal number of neurons is determined by trial and error. Two neurons are first added to the hidden layer of an ANN model, and over time, the number of neurons is raised to twenty. To identify which model is most suited for an ANN model, many performance characteristics are compared against each model.
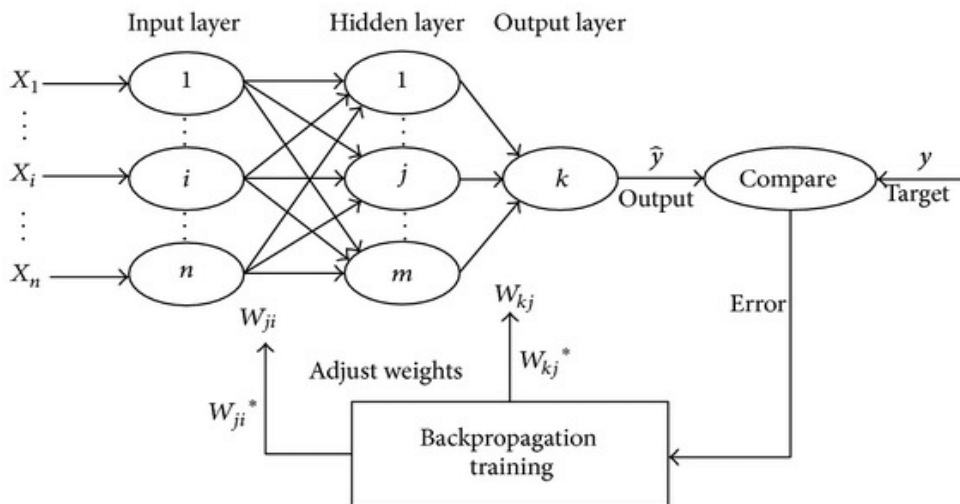

Figure 4: Multilayer Feed-Forward Neural Network Backpropagation

E. ANN Results:

The prediction of concrete strength when incorporating used cooking oil employs the Artificial Neural Network (ANN) technique [8]. The input parameters encompass cement content, coarse aggregate, fine aggregate, water content, concrete age, superplasticizer content, and the percentage of used cooking oil.

The focus is on predicting compressive strength. This prediction is accomplished using the tool, employing both the Graphical User Interface (GUI) and Command Script methods. The training and testing of experimental data are executed through iterative processes, striving for an acceptable output with minimal error. The performance plot of the network consists of three distinct colored lines: blue for training data, red for test data, and green for validation data, encompassing the entire dataset. This graphical representation displays parallel lines for testing, training, and validation, indicating their close alignment. The term "epochs" denotes the iterations during which data is adjusted, aiming to minimize the mean square error. Following the learning, testing, and training stages, the error histogram for compressive strength testing emerges. This histogram plot illustrates the distribution of errors, segmented into 20 bins, or divisions, reflecting various levels of errors. The plots are also color-coded to differentiate between test, training, and validation data.
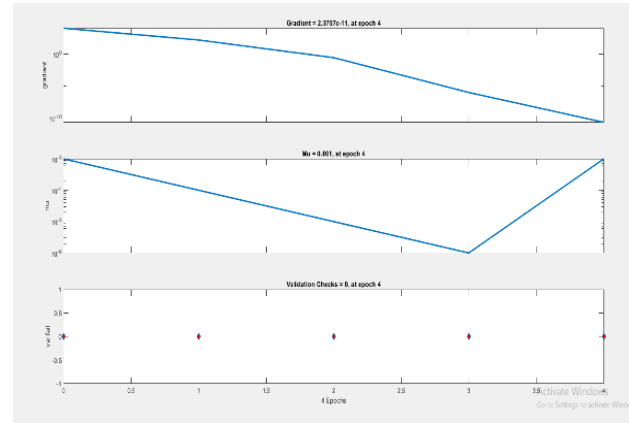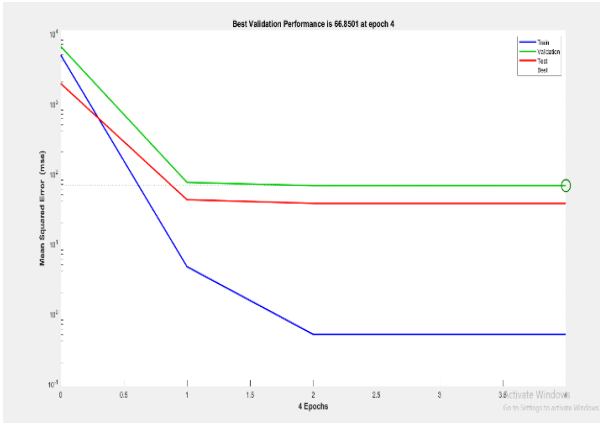

Figure 5: Performance Plot for Compressive Strength.

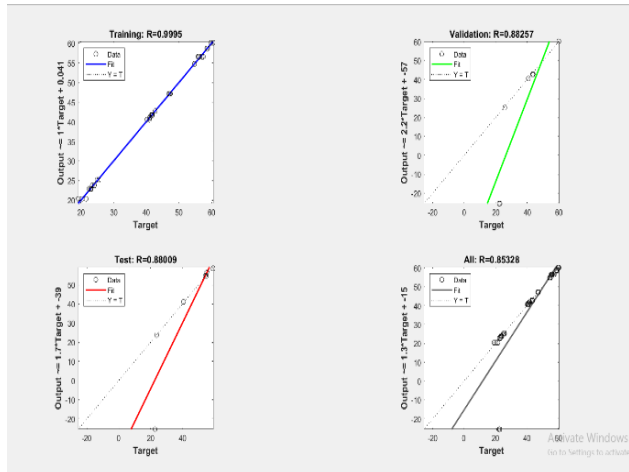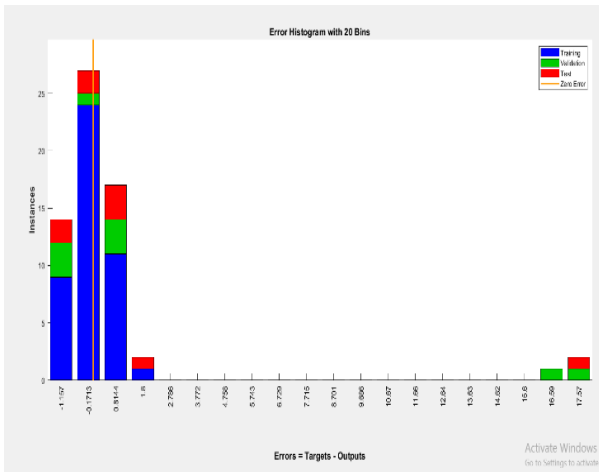**Figure 6: Training State for Compressive Strength.**

Figure 7: Error Histogram for Compressive Strength.

Figure 8: Regression Plot for Compressive Strength.

Table 2: Experimental and ANN Results for the Compressive Strength for 28 days

S. No	Quantity of Cement kg/m3	Fine Aggregate kg/m3	Coarse Aggregate kg/m3	Water Content kg/m3	Superplasticizer kg/m3	Percentage of UCO	Curing Period	Compressive Strength	Predicted ANN Values	Errors Noted
1	431	630	1232	155	4.31	0	28	47.87	47.269999	0.6000001
2	431	630	1232	155	4.31	0	28	45.87	47.269999	-1.3999999
3	431	630	1232	155	4.31	0	28	48.67	47.269999	1.4000001
4	431	630	1232	155	4.31	0.25	28	49.96	49.045000	0.9149994
5	431	630	1232	155	4.31	0.25	28	49.11	49.045000	0.0649994
6	431	630	1232	155	4.31	0.25	28	48.13	49.045000	-0.9150006
7	431	630	1232	155	4.31	0.50	28	50.62	53.020001	-2.400001
8	431	630	1232	155	4.31	0.50	28	53.02	53.020001	-1.11E-06
9	431	630	1232	155	4.31	0.50	28	49.96	53.020001	-3.060001
10	431	630	1232	155	4.31	0.75	28	52.53	52.375000	0.1549996
11	431	630	1232	155	4.31	0.75	28	52.22	52.375000	-0.1550004
12	431	630	1232	155	4.31	0.75	28	53.64	52.375000	1.2649996

13	431	630	1232	155	4.31	1	28	53.69	54.400000	-0.7100001
14	431	630	1232	155	4.31	1	28	54.00	54.400000	-0.4000001
15	431	630	1232	155	4.31	1	28	55.51	54.400000	1.1099999
16	431	630	1232	155	4.31	1.5	28	49.64	50.044999	-0.4049999
17	431	630	1232	155	4.31	1.5	28	50.80	50.044999	0.75500001
18	431	630	1232	155	4.31	1.5	28	49.29	50.044999	-0.7549999
19	431	630	1232	155	4.31	2	28	47.47	46.645002	0.82499705
20	431	630	1232	155	4.31	2	28	46.18	46.645002	-0.4650029
22	431	630	1232	155	4.31	2	28	45.82	46.645002	-0.8250029

V. CONCLUSION

- Used cooking oil has a higher degree of workability than the control sample. According to the outcomes of the slump, the used cooking oil acts as a lubricant in the concrete, making it easier to work with.
- The optimal dosage of used cooking oil is 1%. An increase in the percentage of used cooking oil from 0% to 1% enhances the compressive strength of concrete, demonstrating favourable outcomes specifically when 1% of used cooking oil is added to the concrete mixture.
- The utilization of an ANN model for predicting concrete's mechanical properties yields highly accurate results with minimal error.
- By employing an artificial neural network (ANN) model developed in MATLAB and considering variables affecting concrete properties, it becomes possible to forecast concrete's compressive strength. The achieved R-value of 0.85, which closely approximates 1, signifies a robust correlation between predicted and measured values.
- This model contributes to the regulation of quality and cost-effectiveness in construction. It enables adjustments in mix proportions to prevent instances where the required design strength is not achieved by the concrete or to avoid overly strong concrete.
- The multi-layered feed-forward network model provides rapid predictions based on influential parameters. Such computational capabilities are of great importance to civil engineers, facilitating the reduction of mix variations, which ultimately translates to cost savings.

ACKNOWLEDGMENT

DECLARATION STATEMENT

Funding/ Grants/ Financial Support	No, we did not receive.
Conflicts of Interest/ Competing Interests	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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AUTHORS PROFILE

Dumpala Suneel Kumar, Pursuing M.Tech in Civil Engineering department at Jawaharlal Nehru Technological University Ananthapuramu College of Engineering Autonomous, Ananthapuramu, Andhra Pradesh, INDIA, Pin: 515002, under the specialization of Computer Aided Structural Engineering. He did his B.Tech in Civil Engineering from Jagan's College of Engineering and Technology, Nellore, affiliated to JNTU, Ananthapuramu, in 2019. He participated in the professional development programme on 'Advanced stabilization techniques in construction activities' conducted by NITTTR, Chennai. He participated in the professional development programme on 'Construction Techniques for Earthquake Resistant Structures' conducted by NITTTR, Chennai. He participated in the AICTE Recognized Faculty Development Programme on 'Making Villages Smart' conducted by NITTTR, Chandigarh.

B. Ajitha, M.Tech, (Ph.D) is currently working as Associate Professor and Head of Civil Engineering department, Jawaharlal Nehru Technological University Ananthapuramu College of Engineering Autonomous, Ananthapuramu, Andhra Pradesh, INDIA, Pin: 515002. Her areas of interests are Hybrid network and data structure. She did her M.Tech in Civil Engineering from JNTU, Hyderabad. She is published 70 research papers in various national and international journals, national and international conferences, workshops and symposiums. She is having 23 years of teaching experience. She is member of industrial consultancy service (ICS) group at JNTU college of Engineering, Ananthapuramu for the past 11 years and actively involved in generating funds to the University. She is Co-ordinator of SC/ST book bank and women empowerment cell of JNTUA College of Engineering, Ananthapuramu.