International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-12 Issue-11, October 2023

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 comprises quantities of cement, coarse aggregate, fine aggregate, water content, superplasticiser, and the percentage of chemical admixture (UCO), a 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 most widely used material on Earth. Concrete remains a vital material in the modern world, with ongoing research and innovations focused on enhancing its sustainability and performance. As new technologies are practised, new possibilities for concrete applications continue to emerge, shaping the future of construction.

Nowadays, environmentally friendly innovations are more popular. Many waste products are being used to replace resources that are readily available on the market. Although earlier researchers have proposed the powerful superplasticiser function, the replacement admixtures are a novel concept that warrants further investigation. The building sector, as well as the global use of concrete, may be affected both 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 because it can be converted into trans fat through 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 of 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 may contain hazardous substances that are harmful to the environment. It can impact the ecosystem in addition to being dangerous to plants and animals [1]. Additionally, when oil and water mix, it harms aquatic and marine life.

A. Artificial Neural Network

Artificial neural networks are inspired by and derived from the research of the human nervous system. Neural networks learn to execute tasks by examining past experiences and produce a result for various sampling situations. An enormous number of interconnected processing nodes, or neurons, comprise ANNs, which are capable of learning to recognise 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 receives the initial data, the output layer provides the final output, and there may 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 adjusting the weights associated with each neuron based on the input data and the desired output. ANNs are commonly used in some tasks and applications, including image identification, facial recognition, classification, regression and prediction.

Manuscript received on 01 September 2023 | Revised Manuscript received on 12 September 2023 | Manuscript Accepted on 15 October 2023 | Manuscript published on 30 October 2023.
*Correspondence Author(s)
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.

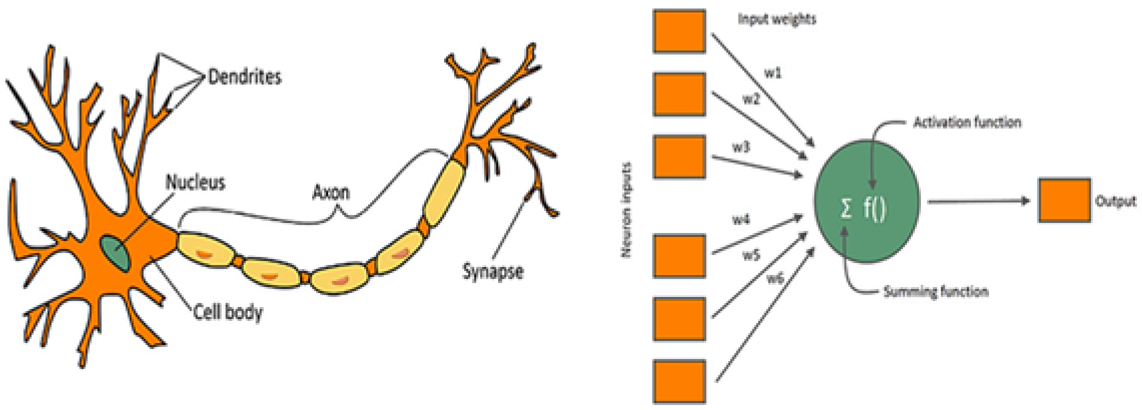

Figure 1: Biological Neuron and Artificial Neural Network.

B. Scope of the Work

This study deals with experimental results when concrete is mixed with used cooking oil and the application of ANN for 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 the ANN approach.
- Comparing the results of experimental and ANN to calculate the deviation in 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 a 1.5% WCO addition demonstrated a significant increase of 2.67% in compressive strength on the 28th day, compared to the compressive strength of standard concrete cubes tested on the same day. 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 were created overall, each representing a different percentage of UCO, for the experimental phase: the control test, 0.25%, 0.50%, 0.75%, 1.00%, 1.50%, and 2.00%. 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 the Target Mean Strength, Workability represented by the slump, and the 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%. Compared to linear regression analysis, the ANN model demonstrates superior efficiency.

III. METHODOLOGY

The methodology used in the experimental procedure aims to determine the compressive strength of concrete in comparison with ANN results, with the goal of minimising error in predicting 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.

Retrieval Number: 100.1/ijitee.K972710121123
DOI: 10.35940/ijitee.K9727.10121123
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

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]. In this work, used cooking oil (UCO) was collected from street food vendors.

f. Super Plasticiser:

To produce high-strength concrete, superplasticisers (SP) are added to fresh concrete to enhance its workability and allow for a reduction in the water content. Fosroc Conplast SP 430 Dis is the material utilized in this investigation.

B. Mix Proportions

To achieve an M40 grade strength, the concrete was designed by 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/m^3
2.	Fine aggregate	630Kg/m^3
3.	Coarse aggregate	1232Kg/m^3
4.	Water	155Kg/m^3
5.	UCO	0%,0.25%,0.50%, 0.75%,1%,1.50%,2%
6.	Superplasticizer	4.31Kg/m^3

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 the cooking oil. Before being added to the dry components in the mixer, substances like spent cooking oil are diluted with water. The final casting of the mixtures was carried out immediately after testing for fresh characteristics. Test samples were cast and then stored in the casting chamber for 24 hours at approximately 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 the 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 evaluated in both the fresh and hardened states of concrete, along with the experimental findings obtained.

B. Fresh Properties of Concrete:

The workability test is conducted on 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.

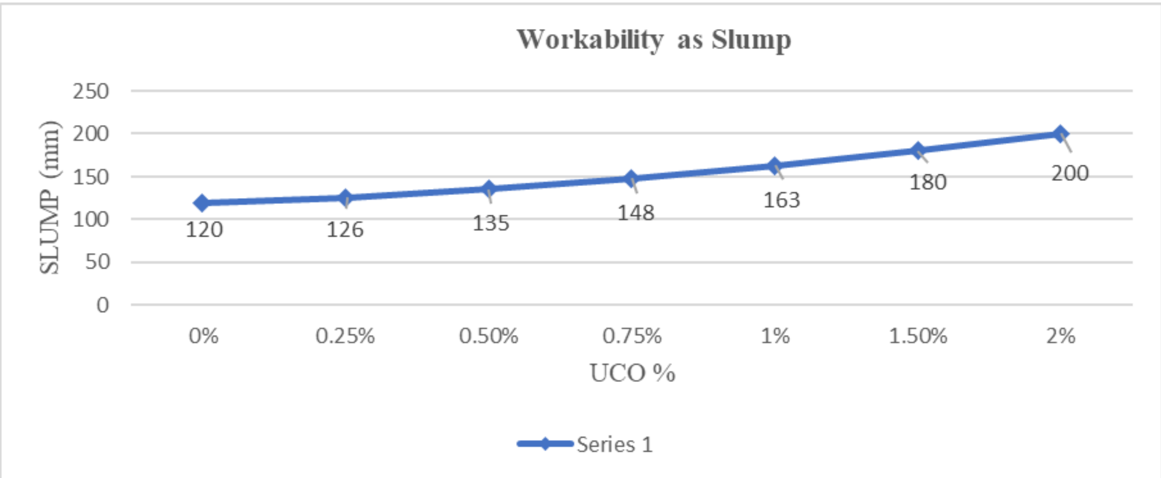

Figure 2: Slump Values of Different Mixes in Mm.

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

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 maintaining the other properties of the mix design unchanged. 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, the M40 mix design is created by adding used cooking oil with varying percentages to the concrete, with no other modifications to the mix design's qualities. 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 the variation in compressive strength as the content of used cooking oil changes. There is an observed enhancement in concrete compressive strength with an increase in the percentage of used cooking oil up to 1%. However, beyond this point, there is a significant decline in strength as the percentage of used cooking oil reaches 2%.

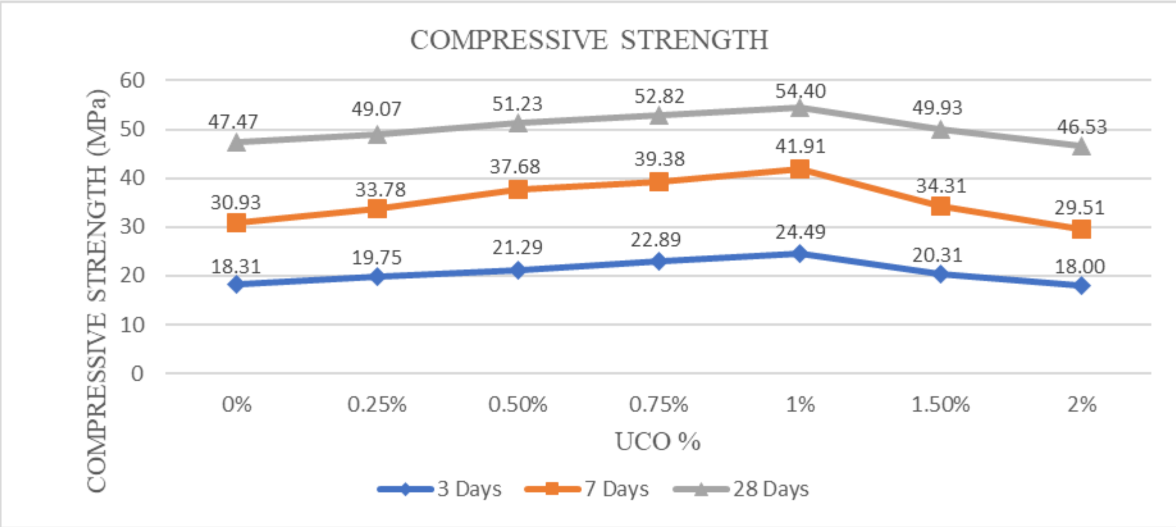

Figure 3: Compressive Strength Values of Different Mixes in MPA.

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. 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 backpropagation approach with one hidden layer, and the ideal number of neurons is determined through 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 suitable for an ANN, various performance characteristics are compared against each model.

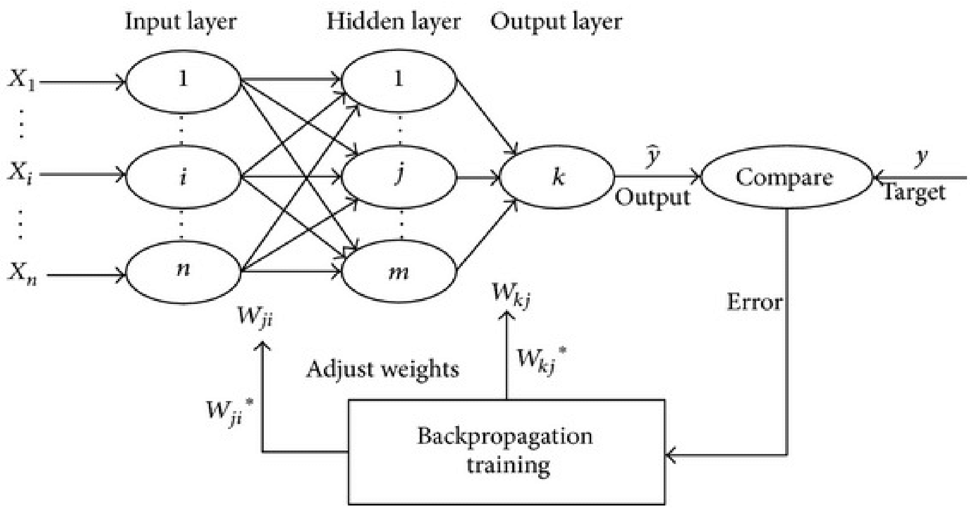

Figure 4: Multilayer Feed-Forward Neural Network Backpropagation

E. ANN Results:

The prediction of concrete strength when incorporating used cooking oil employs the Artificial Neural Network (ANN) technique. 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

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

ISSN: 2278-3075 (Online), Volume-12 Issue-11, October 2023

network consists of three distinct coloured lines: blue for the training data, red for the test data, and green for the validation data, encompassing the entire dataset. This graphical representation displays parallel lines for testing, training, and validation, indicating their close alignment. The term "epochs" refers to the iterations during which data is adjusted, aiming to minimise the mean squared 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, which reflect various levels of error. The plots are also colour-coded to differentiate between test, training, and validation data sets.

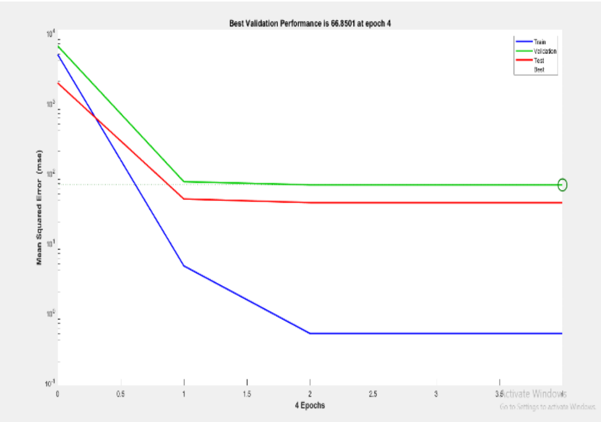

Figure 5: Performance Plot for Compressive Strength.

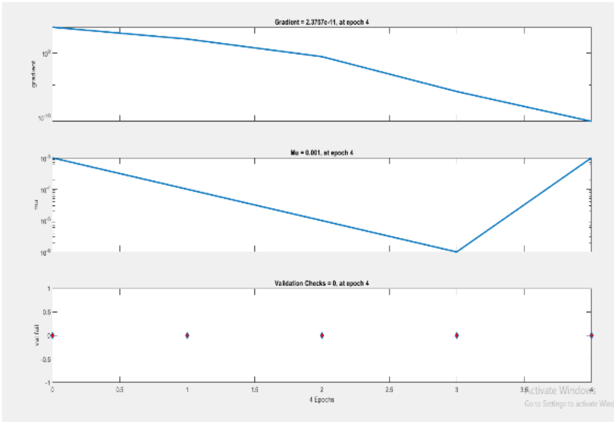

Figure 6: Training State for Compressive Strength.

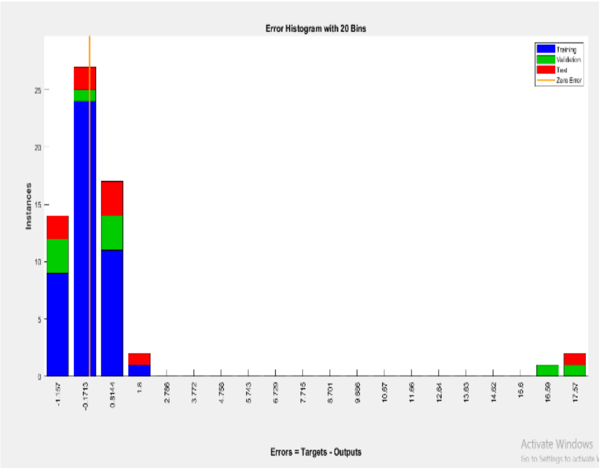

Figure 7: Error Histogram for Compressive Strength.

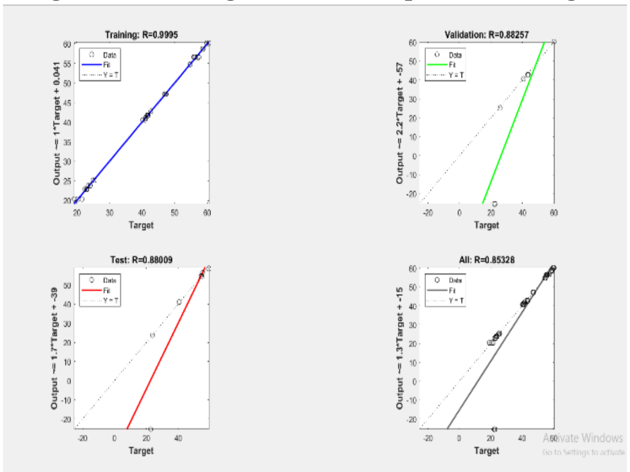

Figure 8: Regression Plot for Compressive Strength.

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

Retrieval Number: 100.1/ijitee.K972710121123
DOI: 10.35940/ijitee.K9727.10121123
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

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 the construction industry. It enables adjustments in mix proportions to prevent instances where the concrete does not achieve the required design strength 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, as they facilitate the reduction of mix variations, which ultimately result in cost savings.

ACKNOWLEDGMENT

I would like to express my sincere gratitude to my guide, Smt. B. Ajitha, M.Tech (Ph.D.), Associate Professor and Head of the Civil Engineering department, who encouraged and supported me technically throughout work.

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 or consent to participate, as it presents evidence that is already publicly available.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	All authors have equal participation in this article.

REFERENCES

1. An Upper Bound for the Number of Reachable Positions (1996), S. Chinchalkar, ICCA Journal 19, pp. 181–183. https://doi.org/10.3233/ICG-1996-19305
2. Council for the District of Tendring. Cooking oil waste.
3. B. Salmia. The Effects of Used Cooking Oil on Various Types of Concrete, 2012 PhD Thesis, Universiti Teknologi PETRONAS, Malaysia.
4. Malaysian website Flexnews, 2009. Food Service Malaysia 2009 HRI Food Service Sector
5. 9 February 2011. Wild Asia. Biofuel: a product of cooking oil recycling.
6. Bio Man Jang Sdn. Bhd. Biodiesel.

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 completed his B.Tech in Civil Engineering from Jagan's College of Engineering and Technology, Nellore, affiliated with JNTU, Anantapuramu, 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-recognised Faculty Development Programme on 'Making Villages Smart,' performed 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 interest are hybrid networks and data structures. She did her M.Tech in Civil Engineering from JNTU, Hyderabad. She has published 70 research papers in various national and international journals, conferences, workshops, and symposia. She has 23 years of teaching experience. She has been a member of the Industrial Consultancy Service (ICS) group at JNTU College of Engineering, Anantapuramu, for the past 11 years. She is actively involved in generating funds for the University. She is the Co-ordinator of the SC/ST Book Bank and Women Empowerment Cell at JNTUA College of Engineering, Anantapuramu.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)/ journal and/or the editor(s). The Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP) and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.