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The Effect of Metakaolin and Steel Fiber on Mechanical Properties of Concrete

[1]Achintya Sahoo[#], [2]Farhad Jahan, [3]Sarbajit Panda

[1]Assistant Professor, Department of Civil Engineering, Raajdhani Engineering College, Bhubaneswar

[2]Assistant Professor, Department of Civil Engineering, Templecity Institute of Technology and Engineering, Bhubaneswar

[3]Assistant Professor, Department of Civil Engineering, Trident Academy of Technology, Bhubaneswar

Email: achintya@rec.ac.in

Abstract— The mechanical properties of plain and metakaolin (MK) concretes with and without steel fiber were experimentally studied, and the results are reported in this paper. Ordinary Portland cement was partially substituted with MK at weight percentages of 3%, 6%, 9%, 12%, 15%, and 18% in order to create metakaolin reinforced concrete. Fiber reinforced concrete is made from steel fiber that is 50 mm long and 0.70 mm in diameter. concrete is designed with water to cement (w/b) of 0.464. After seven, twenty-eight, and fifty-six days of curing, the first compressive strength and split tensile strength were determined by substituting cement for metakaolin. Once more The efficiency of MK and steel fiber reinforcement was measured using several percentages of steel fiber (0.25%, 0.5%, and 1% of the cement weight). Then the compressive, split tensile strength of the concretes were investigated. After a 7- and 28-day curing period, all tests were carried out. It was discovered that the compressive strength and split tensile strength increased up to 9% when metakaolin was substituted, after which they decreased. At 9% replacement of metakaolin, it provides the most value. The strength of metakaolin-reinforced concrete is also increased by adding steel fiber in varying percentages. Additionally, the water absorption test was examined. The findings showed that the mechanical qualities of the concrete were considerably impacted by the addition of MK and the use of several kinds of steel fibers.Keywords: Metakaolin, Steel Fiber, Mix design 0f M20Concrete, Testing of Cubes, Testing of Cylinder.

I. INTRODUCTION

Two billion tons of concrete are utilized annually all over the world, making it one of the most widely used building materials. Because it provides significant strength at a comparatively low cost, it is appealing in many applications. Concrete may typically be made from materials that are readily available locally, can be formed into a large number of different structural forms, and requires little upkeep while in use. The high energy costs and CO2 emissions linked to the production of cement, however, have raised environmental concerns and prompted calls to lower utilization of additional materials to reduce cement consumption. As an SCM, Metakaolin (MK) complies with ASTM C 618, Class N pozzolan requirements. The beneficiation of metakaolin (MK) as an additional cementing element in concrete to improve its qualities has gained popularity over the past 20 years. MK is unique in that it is neither a by-product of an industrial process nor completely natural. In order to remove the chemically bound water and break down the crystalline structure, purified kaolin clay is calcined at temperatures between 650 and 900 C to create MK, an ultrafine pozzolana. MK requires a rigorous manufacturing procedure, in contrast to other industrial by-product materials. Seel fibers are also frequently utilized to improve concrete's hardness, impact resistance, and ability to shrink and crack. The characteristics of concrete are improved when reinforced with a single type of fiber. The primary benefit of a steelfiber system, according to Bentur and Mindess, is that it offers a system that is more robust and rigid, enhances ultimate strength and fracture stress, and is more ductile and flexible, all of which contribute to enhanced toughness.

II. MECHANICALPROPERTIES

A. Strength

B. Compressive and spilt tensile strength

Concrete strength can be increased by partially replacing it with MK. Whether MK or silica fume results in stronger increases is unclear, though. In the future, MK may be used more in HSC and HPC if it is found to boost strength as much as or more than silica fume. Strength is mentioned in the great majority of papers about MK integration. Concretes with 5% and 10% MK by weight of Type I cement, with a w/cm of 0.40, were created by Caldarone et al. [Caldarone, 1994] and shown improved strengths at ages of up to 365 days. Compared to concrete that had the same amount of silica fume added, these specimens demonstrated strengths that were, on average, 10% higher. The specimens made with 5% MK at 365 days demonstrated the group's greatest strength of 11.35 ksi, followed by 10% MK, 10% silica fume, and 5% silica fume (9.21 ksi). At all ages, the control specimens exhibited the lowest strengths. Similar findings

were reported by Wild et al. [Wild, 1996], who evaluated concretes that were created at an aw/cm of 0.45 with cement that complied with BS12:1989 and ranged in age from one to ninety days. For greatest long-term strength enhancement, he discovered that 20% replacement with MK was ideal. Table 2.3. Compressive strengths of metakaolin-concretes [Wild, 1996] summarizes the findings of Wild

MK (%)	Density (kg/m^3)	Compressive strength (N/mm^2)				
		1 day	7 days	14 days	28 days	90 days
0	2490	19.07	50.23	57.10	62.60	72.43
5	2440	21.50	53.80	58.97	63.50	71.63
10	2460	22.43	62.30	69.23	71.00	80.07
15	2470	20.23	64.80	74.67	76.00	83.70
20	2480	19.33	66.47	75.73	82.47	85.13
25	2470	15.73	62.50	69.77	73.93	82.23
30	2480	14.53	60.53	72.33	76.73	81.80

These authors came to the conclusion that when MK partially replaces cement in concrete, it contributes to strength in three basic ways. These include the pozzolanic reaction of MK with CH, the filler effect, and the acceleration of PC hydration. Wild et al. state that the pozzolanic response contributes most to strength between 7 and 14 days of age, the filler effect is instantaneous, and the acceleration of PC hydration has its greatest effect during the first 24 hours. Additionally, Wild et al. came to the conclusion that MK's beneficial impact ends after 14 days. regardless of the level of replenishment. The table above suggests differently, and additional researchers did not confirm this conclusion [Ding, 2002]. The effect of particle size on reaction rate was further demonstrated by Wildet al. [Sabir, 2001], who demonstrated that raising the specific surface of MK from 12 to 15 m2/g lowers the age at which maximum strength enhancement occurs in MK mortars. MK was able to react more quickly due to the larger surface area, which accelerated the rate at which strength evolved. The optimum level of cement replacement by MK increased as a result of this increase in fineness, allowing for the replacement of more cement with MK without causing the system to lag because of dilution. Curiously, the long-term (90 day) strength was unaffected by this decrease in fineness.

II. LITERATURE SURVEY

Coronary heart disease, peripheral disease, cerebrovascular disease, rheumatoid arthritis, and congenital heart disease are among the several forms of cardiovascular disease [2]. Coronary Heart Disease (CHD) causes a waxy material to build inside the coronary arteries. According to estimates, the prevalence of coronary heart disease might reach up to 7% in rural India and up to 12% in metropolitan regions [20]. A heart attack's symptoms include chest back pain, elbow pain, arm pain, left shoulder pain, breathing difficulties, nausea, or lightheadedness. Heart attack risk factors include obesity, diabetes, poor diets, tobacco use, and physical inactivity [5]. Angiography of the heart and stress tests. The three methods used to diagnose coronary heart disease are an MRI, CT scan, and electrocardiogram (ECG) [22]. Coronary heart disease prevention strategies include quitting smoking, getting regular exercise, maintaining a healthy weight, lowering blood cholesterol, and routinely managing diabetes and hypertension [23]. Early detection is necessary for those with cardiovascular disease or those who are at high risk. Therefore, improved cardiovascular disease management techniques are quite important.

III.PROPOSED SYSTEM

Pre-processing methods in the proposed study include filling in default values, eliminating noise, deleting records with incomplete data, and classifying features for different levels of decision-making. Using risk indicators such as age, sex, kind of chest pain, exang, oldpeak, resting blood sugar, cholesterol, resting electrographic findings, thalach, slope, fasting blood sugar, and the number of major vessels colored by flourosopy and thal, the primary goal of this study project is to forecast heart disease. This research makes use of data mining classification techniques such as K-Nearest Neighbor (KNN) and Logistic Regression.

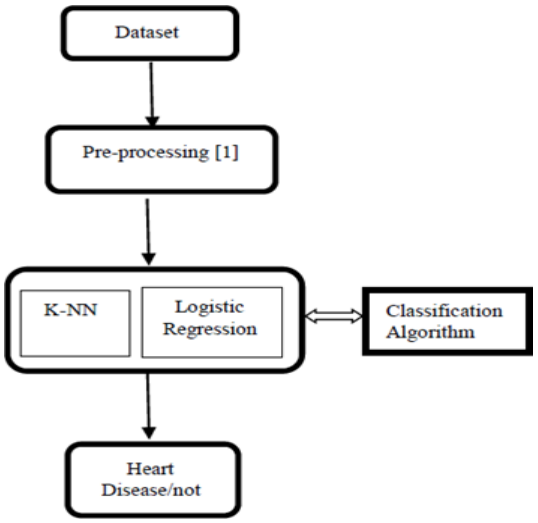

Fig 1: Proposed system for prediction of cardiovascular diseases

Figure 1 explains the suggested system flow. Dataset collection is the first step in the process, followed by pre-processing techniques. Heart

disease is predicted using classification algorithms such as Logistic Regression and k-Nearest Neighbor (k-NN).

DATA SET

For prediction of cardiovascular diseases, the data set of total 303 records with 13 attributes are obtained from machine learning repository of UCI [32]. Table 1 show all the 13 risk factors. The records are separated into two datasets: training dataset and testing dataset. The records for individual set are selected randomly.

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
63	1	1	145	233	1	2	150	0	2.3	3	0	6
67	1	4	160	286	0	2	108	1	1.5	2	3	3
67	1	4	120	229	0	2	129	1	2.6	2	2	7
37	1	3	130	250	0	0	187	0	3.5	3	0	3
41	0	2	130	204	0	2	172	0	1.4	1	0	3
56	1	2	120	236	0	0	178	0	0.8	1	0	3
62	0	4	140	268	0	2	160	0	3.6	3	2	3
57	0	4	120	354	0	0	163	1	0.6	1	0	3
63	1	4	130	254	0	2	147	0	1.4	2	1	7
53	1	4	140	203	1	2	155	1	3.1	3	0	7

Fig 2: A sample data set

Figure 2 presents 303 records with 13 risk factors from A1 to A13 from machine learning repository of UCI.

No	Name	Description
A1	Age	Age in Years
A2	Sex	1=male, 0=female
A3	Cp	Chest pain type: 1 = typical angina 2 =atypical angina 3 = non-anginal pain 4 = asymptomatic
A4	Trestbps	Resting blood sugar(in mm Hg on admission to hospital)
A5	Chol	Serum cholesterol in mg/dl
A6	Fbs	Fasting blood sugar>120 mg/dl(1= true, 0=false)
A7	Restecg	Resting electrocardiographic results(0 = normal, 1 = having ST-T wave abnormality, 2 = left ventricular hypertrophy)
A8	Thalach	Maximum heart rate
A9	Exang	Exercise induced angina
A10	Oldpeak	ST depression induced by exercise relative to rest
A11	Slope	Slope of the peak exercise ST segment (1=upsloping, 2=flat, 3= downsloping)
A12	Ca	Number of major vessels colored by fluoroscopy
A13	Thal	3= normal, 6=fixed defect, 7= reversible defect

Table 1. Explanation of attributes

IV. DATA MINING TECHNIQUES

To discover unidentified patterns from the data various mining techniques are utilized and data analysis is implemented by data mining techniques.

A. Techniques used in Data Mining

(a) k-Nearest Neighbor (kNN)

The k-Nearest Neighbor (kNN) algorithm is a non- parametric process used for classification. The input for both the cases includes k closest training models in the feature scope. The missing values of a feature are imputed in this process of imputation, utilizing the given number of features that are identical to the feature whose values are missing. A distance function is used to decide the similarities of two attributes. Both for classification and regression, it is effective to attach weight to the contributions of the neighbors, so that the nearer neighbors add more to the average than the remote ones.

Advantages are:

k-nearest neighbor(k-NN) forecasts both qualitative & quantitative features

- For individual attribute with missing data, formation of predictive model is not necessary
- Features with diversified missing values can be evaluated easily
- Consideration of correlation structure of the data is captured

Disadvantages are:

- In evaluating large database, k-NN algorithm is very time-consuming because it explores through all the dataset looking for the largest identical examples.
- Selecting k-value is very critical.

(b) Logistic Regression Algorithm Logistic regression is applicable to forecasts whether a patient has coronary heart disease, established on observed characteristics of the

patient.

Logistic Regression seeks the following:-

1. Models the feasibility of an event appearing
2. depending on the values of the autonomous variables, that can be absolute or numerical
3. Estimates the possibility that an event appears for a arbitrarily selected observation against the possibility that the incident does not occur
4. Predicts the result of a set of features on a binary response variable
5. Classifies observations by evaluating the possibility that a conclusion is in a specific category

Advantages are:

- Logistic regression is robust
- Logistic regression does not estimate a linear connection between the Independent and Dependent Variable
- Logistic regression manipulates nonlinear effects Disadvantage is:
- Logistic regression needs huge sample size to produce stable conclusions

B. Comparison between k-NN and Logistic Regression Algorithm

Features	k-Nearest Neighbors (k-NN)	Logistic Regression
Training	k-NN requires no training	Logistic regression requires some training
Parameter Tuning	K needs to be tuned in k-NN	Logistic regression doesn't need any parameter tuning
Decision Boundary	k-NN can determine non-linear boundaries as well	Logistic regression determines a linear classifier
Predicted Values	k-NN predicts just the labels	Logistic regression predicts possibilities, which are a part of the confidence of prediction

V. RESULTS

Train:Test / Algorithm	75:25	80:20	90:10	95:5
KNN	54%	54%	62%	67%
Logistic Regression	57%	54%	66%	67%

Fig 3: Results of classification algorithms

Figure shows accuracy of k-NN & Logistic Regression approach for different training and testing data.

Graph of k-NN & Logistic Regression approach

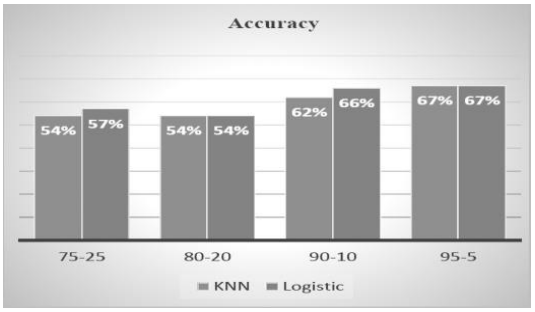

Fig 4: Accuracy of k-NN & Logistic Regression algorithm for different testing and training data

Green and blue colour in the graph shows accuracy of k- NN & Logistic Regression algorithm respectively with percentages of accuracy mentioned in the graph with dataset of 75:25, 80:20, 90:10 and 95:5 as training and testing ratio.

VI. CONCLUSION & FUTURE SCOPE

The major challenge in medical systems is the prediction of cardiovascular diseases. The objective of proposed work is to present an analysis of various data mining classification techniques with their advantages and disadvantages. Total data set of 303 records and 13 risk factors from UCI are selected in this research work. Results shows accuracy for k-NN & Logistic regression algorithm with different number of training dataset and testing dataset. Accuracy graph shows that logistic regression algorithm is better than k-Nearest Neighbor (k-NN) for 75:25 and 95:5 ratio of dataset. Based on literature study only two classification

algorithms namely k-Nearest Neighbor (k-NN) and Logistic Regression have been achieved so far. There is still scope for improvement in performance evaluation parameters like accuracy. So other classification approaches can be executed and tested.

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