Study of Combined Effect of Metakaolin and Steel Fiber on Mechanical Properties of Concrete

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Abstract—This study reports the results of an experimental study on mechanical properties of plain and metakaolin (MK) concretes with and without steel fiber. To develop the metakaolin reinforced concrete, Ordinary Portland cement was partially replaced with MK 3%,6%,9%,12%,15%,18% by weight of the total binder content. steel fiber with length 50 mm and diameter 0.70 is utilized to produce fiber reinforced concrete. concrete is designed with water to cement (w/b) of 0.464. First compressive strength and split tensile strength were calculated by replacing metakaolin with cement at the end of 7 days,28 days,56 days of curing period. Again The effectiveness of MK and steel fiber reinforcement with different percentage of steel fiber i.e 0.25%,0.5%,1% of the weight of cement were taken. Then the compressive, split tensile strength of the concretes were investigated. All tests were conducted at the end of 7 days,28 days of curing period. It was found that for replacement of metakaolin the compressive strength and Split tensile strength were increases upto 9% replacement of metakaolin and decreases after that. It gives the maximum value at 9% of replacement of metakaolin. Addition of steel fiber to the different percentage of metakaolin also increase the strength then that of metakaolin reinforced concrete. Moreover, water absorption test was also investigated. The results revealed that incorporation of MK and utilization of different types of steel fibers significantly affected the mechanical properties of the concrete.

Keywords: Metakaolin, Steel Fiber, Mix design 0f M20Concrete, Testing of Cubes, Testing of Cylinder.

I. INTRODUCTION

Concrete is one of most extensively used construction materials in the world, with two billion tons placed worldwide each year . It is attractive in many applications because it offers considerable strength at a relatively low cost. Concrete can generally be produced of locally available constituents, can be cast into a wide variety of structural configurations, and requires minimam maintenance during service. However, environmental concerns, stemming from the high energy expense and CO2 emission associated with cement manufacture, have brought about pressures to reduce cement consumption through the use of supplementary materials.Metakaolin (MK) is an SCM that conforms to ASTM C 618, Class N pozzolan specifications. MK is unique in that it is not the by-product of an industrial process nor is it entirelynatural;For the last two decades, there has been a growing attraction inthe beneficiation of metakaolin (MK) as a supplementary cementing material in concrete to enhance its properties. MK is an ultrafine pozzolana, manufactured by calcination of purified kaolin clay at a temperature ranging from 650 to 900 C to drive off the chemically bound water and destroy the crystalline structure. Unlike other industrial by-product materials, MK needsa thorough process of manufacturing.Seel Fibers are also commonly used to enhance the shrinkage cracking, toughness and impact resistance of concretes. Concrete reinforcement with a single type of fibers improves mentioned properties of concrete.According to Bentur and Mindess the main advantage of a steelfiber system is that it provides a system which is stronger and stiffer, improves the crack stress and ultimate strength, which is alsomore flexible and ductile, leads to the improved toughnes.

II. MECHANICALPROPERTIES

A. Strength

B. Compressive and spilt tensile strength

Partial replacement with MK can improve concrete strength. However, it is notclear whether MK or silica fume produces greater increases in strength. If it is determined that MK increases strength as much or more than silica fume, MK might find greater application in HSC and HPC in the future. The vast majority of papers about MK incorporation make some mention of strength. Caldaroneet al. [Caldarone, 1994] produced concretes with 5% and 10% MK by weight of Type I cement, with w/cm of 0.40, which showed enhanced strengths at ages up to 365 days. These specimens showed strengths an average of 10% greater than concrete incorporated with the same amount of silica fume. At 365 days, the specimens prepared with 5% MK

showed the highest strength of the group, 11.35 ksi, followed by 10% MK, 10% silica fume, and 5% silica fume (9.21 ksi). Control 0specimens had the lowest strengths at all ages.Similar results were reported by Wild et al. [Wild, 1996], who tested concretesranging from one to 90 days in age, produced at aw/cm of 0.45 with cement complying with BS12:1989. He found that 20% replacement with MK was optimal for achieving maximum long-term strength enhancement.A summary of Wild et al.'s results is shown Table 2.3.Compressive strengths of metakaolin-concretes [Wild, 1996].

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 concluded that there are three elementary factors influencing the contribution that MK makes to strength when it partially replaces cement in concrete.These are the filler effect, the acceleration of PC hydration, and the pozzolanic reaction of MK with CH. According to Wild et al., the filler effect is immediate, the acceleration of PC hydration has maximum impact within the first 24 hours, and the pozzolanic reaction makes the greatest contribution to strength somewhere between 7 and 14 days of age. Wild et al. also concluded that the positive contribution made by MK does not continue beyond 14 days, irrespective of the replacement level. This result was not confirmed by other researchers [Ding, 2002] and the table above indicates otherwise. Wildet al. [Sabir, 2001] later showed that increasing the specific surface of MK from 12 to 15 m2/g reduces the age at which maximum strength enhancement occurs in MK mortars, illustrating the effect of particle size on reaction rate. Because of the increased surface area, MK was able to react more rapidly, leading to a faster rate of strength evolution. This increase in fineness also resulted in an increase in the optimum level of replacement of cement by MK, meaning that more of the cement could be replaced by tis MK without the system suffering a lag due to dilution. Interestingly, this change in fineness did not influence the long-term (90 day) strength.

II. LITERATURE SURVEY

The different types of cardiovascular diseases are Coronary heart disease, peripheral disease, cerebrovascular disease, rheumatic and congenital heart diseases [2]. A waxy substance forms inside the coronary arteries in Coronary Heart Disease (CHD). In rural India, the incidence of coronary heart disease is estimated to be up to 7 percent and in urban areas it is up to 12 percent [20]. Symptoms of heart attack are chest pain, pain in the arms, pain in left shoulder, elbow pain, back pain, difficulty in breathing, vomiting or feeling faint. Tobacco, unhealthy diets, hypertension, obesity, diabetes and physical inactivity are the risk factors of heart attack [5]. Coronary angiography, Stress testing. Electrocardiogram (ECG), CT scan and an MRI scan are the different standards to determine coronary heart disease [22]. Preventive measures of Coronary heart disease includes no smoking, exercise every day, controlling weight of the body and managing blood cholesterol level, regularly controlling diabetes and high blood pressure levels [23]. The people who are at great risk or people with cardiovascular disease requires early detection. Hence, more competent methods of cardiovascular disease are of great concern.

III. PROPOSED SYSTEM

In proposed research, pre-processing techniques consists of noise elimination, removing records with missing data, fill in default values and classification of features for decision making at distinct levels. The main objective is to predict heart disease in this research work by using risk factors like age, sex, chest pain type, exang, oldpeak, resting blood sugar, cholesterol, resting electrographic results, thalach, slope, fasting blood sugar, number of major vessels colored by flourosopy and thal. The data mining classification techniques like K-Nearest Neighbor (KNN) and Logistic Regression are used in this paper.

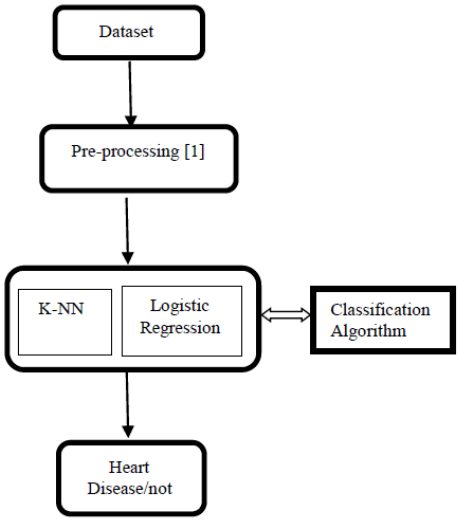

Fig 1: Proposed system for prediction of cardiovascular diseases

Figure 1 describes the proposed system flow. The first stage of the process is to collect dataset then pre-processing technique are done. Classification algorithms like k-Nearest Neighbor (k-NN) and Logistic Regression are used to predict the heart diseases.

IV. 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 shows

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.

Table 1. Explanation of attributes

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

V. 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 depending on the values of the autonomous variables, that can be absolute or numerical
2. Estimates the possibility that an event appears for a arbitrarily selected observation against the possibility that the incident does not occur
3. Predicts the result of a set of features on a binary response variable
4. 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

VI. 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

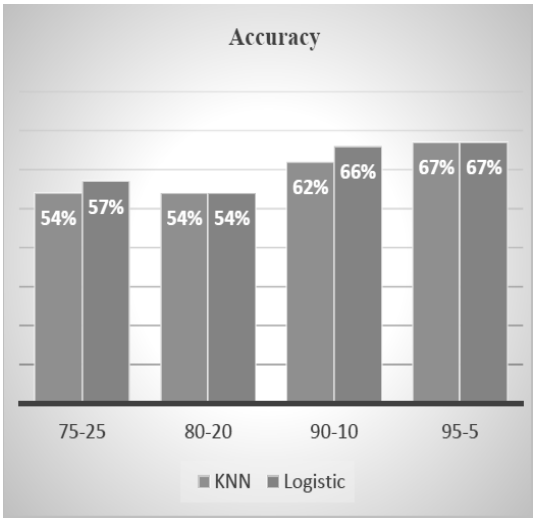

Fig 4: Accuracy of k-NN & Logistic Regression algorithm for different testing and training data

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.

VII. 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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