Predicting Compressive Strength of Concrete

Using

Machine Learning

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1. **Introduction** 
   1. **Overview:**

Concrete is the most widely used building material around the world due to its various advantages over other materials, e.g., integrity, durability, modularity, economy, etc. For better understanding the behavior of concrete-made structures under external loadings and developing corresponding design methodologies, it is of great importance to study the mechanical properties of concrete. Among the various indices of properties of concrete, compressive strength is the most fundamental one since it is directly related to the safety of the structures, and it is required in the performance determination of the structures during the whole life-cycle, from new structural design to old structural assessment. However, as it is known to all, concrete is made up of different components, e.g., coarse/fine aggregates, cement pastes, additional mixtures, etc., and these components are randomly distributed over the entire concrete matrix. Such a complicated system makes it a great challenge to accurately predict the compressive strength of concrete material.

**G**enerally, the most direct way to obtain the compressive strength of concrete is through physical experiments. Usually the cubic or cylinder specimens were prepared according to certain designed mixture ratio and then cured for a required time. After that by using the compressive test instrument the compressive strength can be obtained easily. However, this approach is costly in both time and money, thus the working efficiency will be very low. Differing from the traditional experimental ways, also some empirical regression methods are proposed to predict the concrete compressive strength with the given designed mixture ratio of different components in concrete. Unfortunately, the concrete mixture and compressive strength shows a strongly nonlinear relation, thus it is difficult to derive an accurate regression expression for this problem. The third way to capture the concrete behaviour is numerical simulation etc. However, as mentioned before, the coupling of randomness and nonlinearity makes it different to accurately reproduce the concrete behavior

On the other hand, with the development of artificial intelligence (AI) in recent years, it is a trend to use machine learning (ML) techniques to predict the concrete compressive strength. ML is a branch of AI, and can be used for several objectives, e.g., classification, regression, clustering, etc. Predicting concrete compressive strength is just one application of the regression function of ML. Compared with other traditional regression method, ML adopts certain algorithms that can learn from the input data themselves and gives highly accurate results for the output data, which shows an obvious advantage over the traditional regression methods

However, most of the above-mentioned algorithms are individual learning ones, while there is another family of ensemble learning algorithms which is more accurate, robust and powerful. The basic idea of ensemble learning models is to train several weak learners using the training data, and then integrate the weak learners to construct a strong learner. The weak learners are actually based on the individual learning algorithms, e.g., ANN or SVM. Therefore, the predicting accuracy and robustness of ensemble learning models (namely, the strong learner) will be obviously improved. There are three major groups of algorithms for ensemble learning, i.e., bagging, boosting and stacking, whose differences can be found in the review paper

**1.2 Purpose:**

In recent years, the ML methods have become popular as they allow researchers to improve the prediction accuracy of concrete properties and are used for various engineering applications. The ML methods have been used to increase the prediction accuracy of concrete properties, and the data derived from the literature sources were used

Regression models tend to be used for the prediction of the compressive strength of high-strength concrete. These models also demonstrate how the concrete compressive strength depends on the mixing ratios.

Previous studies evaluated the amount of the concrete component materials and compared their results to the published data. In this study, the ML regression methods were compared to predict the compressive strength and slump values of the cube samples. The samples were prepared by accounting for seven simultaneously controllable effect variables in the laboratory.

1. **Literature Survey**

**2.1 Existing Problem**

This is generally determined by a standard crushing test on a concrete cylinder. This requires engineers to build small concrete cylinders with different combinations of raw materials and test these cylinders for strength variations with a change in each raw material. The recommended wait time for testing the cylinder will take some days to ensure correct results. This consumes a lot of time and requires a lot of labour to prepare different prototypes and test them. Also, this method is prone to human error and one small mistake can cause the wait time to drastically increase**.**

**2.2 Proposed Solution**

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1. **Theoretical Analysis**

**3.1 Block Diagram**

Predicting Compressive Strength of concrete

Data Preprocessing

Data Collection

Create an HTML File

Model Building

Splitting Data into Train and Test

**3.2 Hardware / Software designing**

* Python, Python Web Frame Works
* Python for Data Analysis
* Python For Data Visualization
* Data Pre-processing Techniques
* Machine Learning
* Regression Algorithms

1. **Experimental Investigation**

**Range of various parameters**

1. Cement (component 1)(kg in a m^3 mixture) = 102-540
2. Blast Furnace Slag (component 2)(kg in a m^3 mixture) = 0-359.4
3. Fly Ash (component 3)(kg in a m^3 mixture) =0-200.1
4. Water (component 4)(kg in a m^3 mixture) = 121.75-247
5. Superplasticizer (component 5)(kg in a m^3 mixture) = 0-32.2
6. Coarse Aggregate (component 6)(kg in a m^3 mixture) = 801-1145
7. Fine Aggregate (component 7)(kg in a m^3 mixture) = 594-992.6
8. Age (day) =1-365
9. **Flowchart**

Data Preprocessing

Splitting Data & Training Data

Model Building

Test Data

Train Data

Machine Learning Model Training

20

80

Working on Regression Model for Predicting the Accurate Model

Evaluation

Application Building

Create HTML file

Python Code

1. **Result**

We have analysed the Compressive Strength Data and used Machine Learning to Predict the Compressive Strength of Concrete. We have used Linear Regression and its variations, Lasso, Ridge and Random Forests to make predictions and compared their performance. Random Forest Regressor has highest accuracy and is a good choice for this problem.

1. **Advantages and Disadvantages**

**Advantages:**

Using Machine learning to predict the strength of the concrete will be time and more accuracy in predicting the approximately close value can be done easily. Its more trust worthy and cost effective .It also reduces the man power for doing the experiments to find the strength of the concrete in different unknown situations.

**Disadvantages:**

There is a 8% chances that the outcome will not predict the approximate value in that situation it can be troublesome.

1. **Applications:**

* Can predict the strength of the concrete using the inputs provided.
* Implementable on the website

1. **Conclusion**

* Maximum accuracy received is 92 %.

A total of 1030 sample data collected from the experimental test were used to develop the Random Forest Regression model for predicting compressive strength.

1. **Future Scope**

This model can predict the outcome with many different inputs within seconds. The model will save a lot of time of the construction companies and the civil engineers. Experiment cost is also reduced with creates a bigger opportunity for construction companies in cost effectiveness work.

1. **Bibliography**

**Data repositories**

Kaggle.com

**Source Code:**

**IMPORTING LIBRARIES**

import numpy as np

import pandas as pd

import matplotlib.pyplot as plt

**IMPORTING DATASET**

dataset=pd.read\_csv('Concrete\_Data.csv')

dataset

**HANDLING MISSING VALUES**

dataset.isnull().any()

dataset.describe()

**HANDLING OUTLIERS**

from scipy import stats

z=np.abs(stats.zscore(dataset))

z

threshold=3

np.where(z>threshold)

dataset=dataset[(z<3).all(axis=1)]

dataset

**SEPERATING DEPENDENT AND INDEPENDENT ATTRIBUTES**

x=dataset.iloc[:,:8].values

x

y=dataset.iloc[:,8].values

y

**DATA VISUALISATION**

for i in range(0,8):

plt.scatter(x[:,i],y)

plt.show()

**SPLITTING INTO TEST AND TRAIN PARTS**

from sklearn.model\_selection import train\_test\_split x\_train,x\_test,y\_train,y\_test=train\_test\_split(x,y,test\_size=0.2,random\_state=0)

**BUILDING THE MODEL**

from sklearn.ensemble import RandomForestRegressor

rf=RandomForestRegressor(n\_estimators=25,criterion='mse',random\_state=0) rf.fit(x\_train,y\_train)

**TESTING THE MODEL**

y\_pred=rf.predict(x\_test)

y\_pred

y\_test

**FINDING ACCURACY**

from sklearn.metrics import r2\_score

r2\_score(y\_test,y\_pred)

**SAVING THE MODEL**

from joblib import dump

dump(rf,'Concrete.save')

Use this link to find the Predicting Compressive Strength of Concrete Using Machine Learning **:- https://python-flask-app-quici-quick-camel-dd.eu-gb.mybluemix.net/**