CHAPTER 1 INTRODUCTION

1.1 GENERAL

This chapter is focused on the history of developing the CBR test method for the design of road and airfield pavements. Furthermore, the problems related to the test method and the objectives have also been discussed briefly in the present investigation.

1.2 BACKGROUND

The CBR test was originally devised by California State Highway Department (Porter, 1939) before World War II, finding that soils having a specific CBR value always required the same pavement thickness to prevent plastic soil deformation. After that, the test was incorporated by the Army Corps of Engineers for the design of flexible pavements (Davis, 1949). The flexible pavement design is reckoned to calculate the thickness of road and airfield pavements through systematic consideration of traffic loading and subgrade supporting strength utilizing the mechanistic-empirical theory.

Civil engineers frequently use the CBR test, particularly for measuring the mechanical strength of subgrade, sub-base and base course soil/material and for stiffness modulus of road and airfield pavements (M Amarnatha Reddy et al., 2001). The test may be performed on either re-compacted samples in the laboratory, undisturbed samples cut from the field, or in-situ surface of subgrade formation (Black, 1961). It is an indirect measure representing a comparison of the shear strength of subgrade material (at known density and moisture content) to the strength of the standard crushed rock, generally having a maximum particle size of less than 19 mm.

Conventionally, CBR tests can be conducted in the laboratory and field using IS 2720 (Part 16) (1987) and IS 2720 (Part 31) (1990), respectively, specifications. Both laboratory and in-situ tests are based on the principle of penetrating a standard dimension plunger into a soil specimen at a rate of 1.25mm/min (detailed information on the test has been provided in section 3.3.4). The pavement design engineer generally uses the test value for estimating the thickness of the pavement layers, which are to be laid over the subgrade (Purwana et al., 2012; Putri et al., 2012; Sukumaran et al., 2002). Subgrades with higher CBR values will have thinner pavement than those with lower CBR values if similar type of materials are used.

1.3 PROBLEM STATEMENT

The road transportation network plays a significant role in developing the infrastructure and economy of the country. Moreover, the network is widely used to transfer passengers and goods from one place to another. Therefore, the connectivity between the village roads, village to district roads, district to state highways, state to national highways and national highway to expressway are essential for the passengers' ease. Consequently, the Ministry of Road Transport and Highways (MoRTH) department has planned to construct many new expressways and NH throughout the country. In addition, numerous existing roads are under construction maintenance through various infrastructure development plans.

The designed construction of these projects stresses the testing of materials required for the construction. As discussed earlier, the CBR test is one of the comprehensive tests used for the last few decades to design the pavement. However, laboratory soaked CBR test requires soil as material (almost 6 kg), more effort to prepare the test specimen, and 96 hours (4 days) soaking period to simulate the field conditions of inundation. Additionally, if the properties of soil change within small stretches of highway, then preserving such a massive quantity of soil and conducting the CBR test in the laboratory is laborious and time-consuming.

Laboratories are also often overburdened due to the long queue of materials testing, which causes a delay in testing, the testing reports, and ultimately the design of construction projects. Furthermore, the test method includes the material transportation cost (from construction site to testing laboratory), testing charge, and finally, the dumping of tested materials, which became more exhaustive and increase the project's final cost.

Although not a fundamental material property, it has a long history in pavement design. It is reasonably correlated with the index (Atterberg’s limits, gradational parameters, etc.) and soil's engineering properties (compaction parameters etc.) as investigated by several researchers in the past (Bassey et al., 2017; Katte et al., 2019; Lim et al., 2014; Wroth and Wood, 1978). The basic reason for selecting these index and engineering properties in developing the CBR prediction model is that these properties require less time (see Table 1.1) in the laboratory and the basic soil properties. In addition to its laborious nature, the test method is six times slower than other geotechnical parameters.

Table 1.1 Time taken by the geotechnical parameters in the laboratory testing

S. No.	Geotechnical parameters	Laboratory testing time (days)
1	Atterberg’s limit (LL, PL and PI)	1
2	Gradation parameters (dry and wet sieve size analysis)	1
3	Proctor compaction parameters (MDD and OMC)	1
4	California bearing ratio	6

Prediction of soaked California Bearing Ratio (CBR) value of soil, in particular, for fine-grained soil, good amount of literature is available with predictive equations/models. These models have certain merits and demerits as discussed below:

Merits:

- These models help in prediction of soaked CBR value in short time with lesser effort in the laboratory thereby saving time and cost.

- The level of accuracy is fare enough for geographical area covered under respective studies.
- Models developed through AI technique with lenghtier range and large datasets are likely to be more accurate in predicting the CBR value.

Demerits:

- Some models have shorter range of applicability.
- Some models were developed with limited dataset.
- Some models were developed through random data division approach which sometimes might be accountable for fading some of the substantial features of the training dataset.
- Some models have utilized algorithm's hyper-parameter and complicated approach which might be difficult for field engineers to comprehend.

1.4 OBJECTIVES OF THE STUDY

The developing nations have taken a massive assignment of road-building activities to support their growing economy. Cost estimation based on the preliminary assessment is an essential task for finalizing the funding proposals of a project. A quick and reliable evaluation of CBR helps to hasten the process. Methods for predicting the CBR value through the index and engineering properties have been in vogue for quite a long time. The efforts made in the past in this direction are reviewed in this dissertation with the quest to work out the research gaps.

The research offered in this dissertation attempts to predict the soaked CBR value of fine-grained plastic soils through machine learning algorithms. The principal objective of this study was to reduce the amount of time required to evaluate the CBR value. The present study also fulfilled the following sub-objectives, which were framed to obtain the above main objective;

1. To study the correlation between the soaked CBR value and index/engineering properties.
2. To develop an appropriate model for predicting the CBR value of fine-grained soil from Atterberg's limits, gradational and compaction parameters.
3. Application of several machine learning (ML) algorithms in predicting the CBR value of fine-grained soils and their comparative analysis.
4. To investigate the significance of numerous data divisional approaches on adopted ML algorithms in predicting the soaked CBR value of fine-grained plastic soils.
5. To investigate soil origin's influence on the developed models' predictive ability.
6. Development of computational tool for predicting the soaked CBR value of fine-grained plastic soil.

1.5 SCOPE OF THE STUDY

Following is the scope of the study:

(i) The study addresses fine-grained plastic soils for developing the soaked CBR prediction model. Out of a total of 1011 dataset, 287 samples were tested in the institute laboratory while 724 samples were tested in the field laboratory. Soil groups encountered on the project highway in eastern Uttar Pradesh were studied for various geotechnical properties. A good number of data were available for soil types like CL (700 data) and CL-ML (277 data), fewer data were available for MH (6 data), CH (27 data) and ML (1 data).

(ii) Laboratory investigations were conducted to obtain geotechnical parameters like gravel, sand and fine content; liquid limit, plastic limit and plasticity index; maximum dry density and optimum moisture content; and soaked California bearing ratio.

(iii) With the major objective of predicting the soaked CBR value using other geotechnical parameters, multi expression programming and eXtreme gradient boosting algorithms of machine learning were used. Additionally, three data divisional approaches like statistical, K-Fold and fuzzy C-Means clustering were adopted.

(iv) The final selected model shall be employed to generate a Graphical User Interface (GUI) in Python named "CBR Prediction Tool" for the benefit of field engineers.

1.6 ORGANIZATION OF THE DISSERTATION

The present research work was documented into five different chapters as follows:

CHAPTER 1: This introductory chapter highlights the background of the study. The problem statement is defined along with the objectives and scope of the study.

CHAPTER 2: This chapter presents the literature review of the study. The literature pertaining to the factors influencing the California bearing ratio value of soil and estimation models developed by the previous researchers for various types of soils is adequately discussed. Additionally, various machine learning algorithms were summarized. Lastly, analyzes the dataset from a descriptive statistic point of view, using various performance measurement parameters and data divisional approaches used in model development.

CHAPTER 3: Deals with the laboratory experiments performed to obtain the dataset for mathematical analysis.

CHAPTER 4: This chapter highlights the correlation analysis of CBR value results with Atterberg's limits, gradational parameters, and compaction parameters of fine-grained soil. Furthermore, a brief discussion of the development of the CBR value predictive model and the comparative analysis of implemented ML algorithms were presented.

CHAPTER 5: Summarizes the major findings and conclusions drawn from the present investigation. Recommendations and the scope for future studies were also outlined.

The step by step methodology adopted to develop the CBR prediction model is shown in Figure 1.1

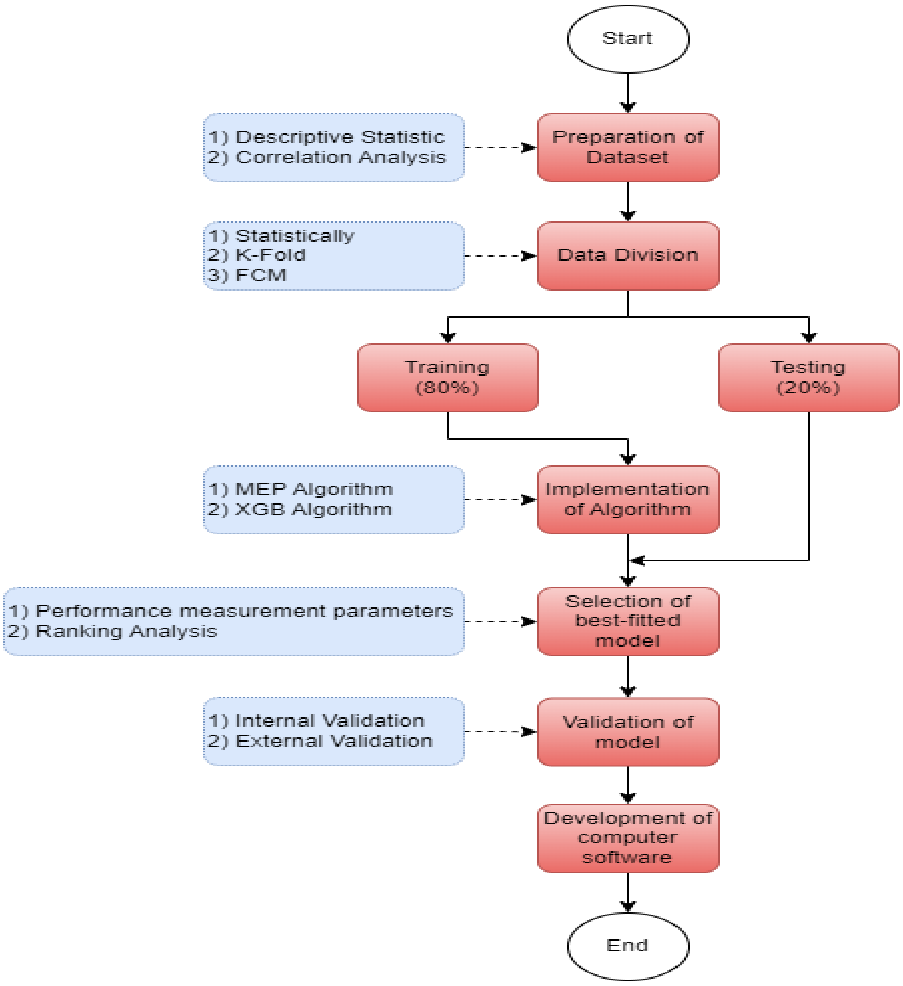

Figure 1.1 Methodology adopted to develop the CBR prediction model