DEVELOPMENT OF MOBILE APP FOR THE SOIL CLASSIFICATION

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ABSTRACT

The classification of soils in Geotechnical engineering is carried out in order to have a fairly accurate idea of its average properties. Various systems have been developed by researchers and are available in literature for classifying the soils. These systems were based on a set of properties, which can be determined experimentally. Different system uses different properties of the soil as the basis for the classification. Further, the classification systems in literature were available in the form of tables, graphs, or flow charts. Erroneous classification of the soil was sometimes made by the individual as one has to refer to many tables and graphs for the same. An Android based mobile app was developed in this paper to classify the soil and minimize the efforts required to refer to the tables and graphs. Further, some of the classification systems reported in literature require improvement and the same is also proposed in this paper. Finally, the results shown by different systems have been compared. The application is not only useful for teaching purpose in class, but also provides a useful utility to the consultants and the practicing engineers.

Keywords: Soil Classification, Mobile App, Android Studio, Java Programming, XML language, Soil Classification Systems, Classification System Improvement.

INTRODUCTION

Soil classification is the placing of a soil into a group of soils all of which exhibitsimilar behavior. The correlation of behaviour with a group in a soil classification system is usually an empirical one and developed through considerable experience. Most of the soil classification systems were based on the index properties of soils in order to place the soil in a group. The most commonly used index properties are particle size and plasticity characteristics. Mobile phones and mobile phone apps in the recent decade has enabled the common man to have access to not only communication facility, but also the computational power anywhere at any time, thereby reducing the dependency on big organizations and experts. With the popularity and easy availability of smartphones, the door for plethora of e-applications is opened for the masses. Civil Engineers working at various levels of construction and planning activities are faced with the challenge of designing, testing, and monitoring of various public related works. In this regard, not only they have to be aware of various codes and standards, but also have to take decisions, which have a serious impact on the quality and the execution plan of the project. For example, to make an assessment for the construction site, soil classification is one of the essential activities in site selection. The present research aims at the development of mobile application for the classification of soils. This developed app can classify the soil based on five different systems of classifications.

1. Background

While referring to flow charts, graphs, and tables, very often the user may end up with erroneous results. Automation of the classification system and making it available on smartphone not only reduces the possibility of human error, but also improves upon the decision making time regarding subsequent constructional activities. Most commonly used classification systems are defined by various US based organizations, such as the United States Department of Agriculture (USDA) Textural Classification System, the Unified Soil Classification System (USCS, 1987), American Society for Testing Materials (ASTM), and American Association of State Highway and Transportation Organisation (AASHTO) System. For soil classification in Indian context, Indian Standard Classification (ISC) system was adopted by the Bureau of Indian Standards. The ISC system is in many respects, similar to the Unified Soil Classification System (USCS). The parameters considered for classification vary from one classification system to another, which primarily is determined from the perspective of the purpose for which the soil is considered. For example, for road construction, AASHTO system is used, USDA is used for agricultural purpose, and ASTM and USCS is generally used for the determination of general engineering behaviour. These classification systems are shown in Table1.

Study of Table 1 reveals that the AASHTO and USCS classification system do not include classification of organic soils. A corrective approach was introduced in these classification systems by Huang, Fatel, Santagate, and Bobet (2009) in classifying the organic soils.

The efforts for automating the classification of soil are also undertaken by various researchers and organizations. Of these, the initial work is reported by Hoffmann (2014). The researcher developed MATLAB code for the USDA classification system. Emmanuel and Chukwuma (2015) reported a MATLAB code for the AASHTO classification system. This code can be used on standalone systems. On commercial front, a web based commercial Geosystem software (http://geosystemsoftware.com) is also available, which can classify the soil based on a classification system and can be used remotely as well. An Android based application for soil classification has been developed by Randhawa and Krishna (2014). The application classify soil samples on the basis of their percentage sieve passing values according to various Soil Classification Systems, such as ASHTO (according to AASHTO M-145-9), USCS (according to ASTMD 2487-06), and ISSCS (according to IS 1498).

Classification Systems	Parameters Used	Remarks
AASHTO (1928)	Particle size distribution, liquid limit, plasticity index, GI	Does not include classification of organic soils
USDA (1938)	Grain size of sand, silt and clay	Provide only textural classification
USCS (1942)	Gradation, grain size, LL, PI	No provision for mixed and organic soils
IS: 1498-(1970)	Gradation, grain size, LL, PI	Provision of medium compressibility
ASTM D 2487-6 (2006)	Gradation, grain size, LL, PI, LLR	Classify all types of soils

Table 1. Classification Systems

With the exceeding popularity and ease of use, mobile phones have come a choice of computational platform for the application, which have frequent use and can make the information available anywhere at any time. Since the civil engineers spend most of the time either in testing labsor in the fields conducting the experiments, mobile phones are not only handy, but offer enough computation power for the soil classification related analysis. Further, mobile app for classifying the soils using USCS, AASHTO, and USDA are available on the playstore (application distribution platform). The application available on the play store is insufficient to classify all types of soil effectively as it is based on present classification systems which are not complete as evident from Table 1.

The above literature indicates that no single mobile app is available, which includes all important classification systems with a provision to classify the organic soils as well. Therefore, an attempt has been made in this paper to develop and demonstrate a mobile application for the soil classification; which can classify soil based on five classification systems including improved ISC, USSC, and AASHTO system. The work presented in this paper was an extension of the work comprising mobile app for an ASTM system of soil classification as reported in Kumar, Dutta, and Dutta (2015). The reported algorithm and classification system is based on USCS classification system and can classify all type of soils effectively.

2. Proposed Improvement in the Classification Systems

On the basis of the correction, as suggested by Huang et al. (2009), an improved classification (Table 2) has been proposed for an AASHTO system of classification.

Group Classification	Granular material (35% or less passing no. 200 seieve) A-1			A-2				Silty-Clay Materials (more than 35% Passing No. 200 sleve)			A-7				
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5	A-7-6	A-7-6-O	0-A-7-6	A-8
(a) Sleve Analysis: Percentage passing															
1. 2.00 mm (No 10)	50 max														
2. 0.425 mm (No 40)	30 max	50 max	51 min												
3. 0.075 mm (No 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min	36 min	36 min	36 min	36 min
(b) Characteristics of fraction passing 0.425 mm (No 40)															
1. Liquid limit				40 max	41 min	40 max	41 max	40 max	41 max	40 max	41 min	41 min	41 min	41 min	41 min
2. Plasticity index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	11 min	11 min	11 min	11 min	11 min	11 min	11 min
3. Organic content											3 max	3 max	3 max	3 max	3 max
(c) Usual types of significant constituent materials	Stone fragments Gravel and sand		Find sand	Silty or Clayey Gravel Sand				Silty soils		Clayey soils				Organic clay	Organic soils
(d) General rating as sub grade	Excellent to Good				Fair to Poor									Un Acceptable	

Table 2. Proposed Improvements in AASHTO System of Classification

Classification of soil is based on particle size and characteristics of fraction passing 0.425 mm. A new characteristic such as organic content along with liquid limit and plasticity index of the soil has been introduced. The effect of organic content can be seen in A-7 group, which is mainly clayey type of soil. On the basis of organic content, a new nomenclature was introduced in A-7 group and also if the soil has high organic content it was declared as A-8 group. Further, the usual types of significant constituent materials such as for A-7-6-O, it would be clay with organic for O-A-7-6 it would be organicclay which is influenced by organic content were also added. General rating as subgrade has also been given for organic soil as Unacceptable since organic content is not required in subgrade material. Further, to improve DSC and USCS, many new nomenclatures were introduced in the concerned classification systems as shown in Figure 1. These introduced nomenclatures were based on the influence of organic content. It was found that organic content could be present in fine grained soil, which may be

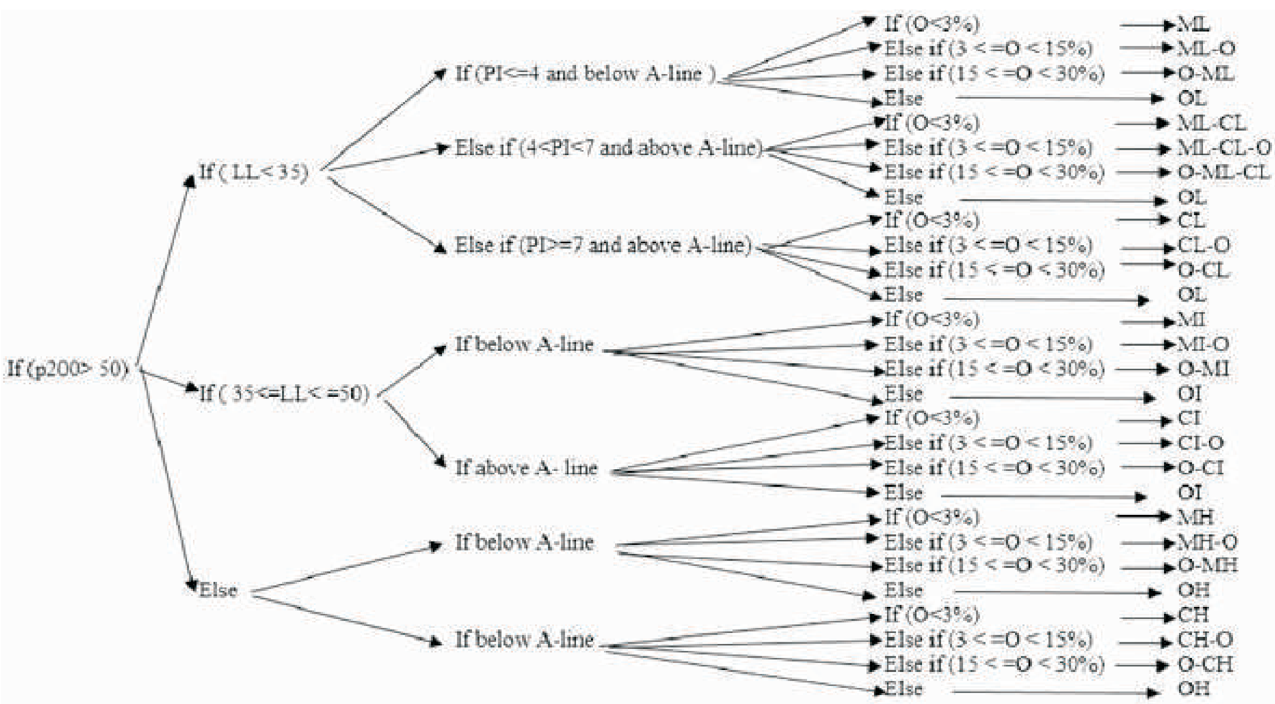

Figure 1. Algorithm for ISC Classification System

either silt or clay. Accordingly, the nomenclature in both the soil type was introduced. The influence of organic content was considered if it was greater than 3%. Further the improvement in ISC and USCS were similar, the only difference was in ISC, influence of organic content on section of medium compressibility (35 <= LL< = 50) was also considered as evident from Figure 1. Thus by introducing improvement, complication in interpreting the soil classification result improved.

3. Algorithm and App Development

Each classification system was thoroughly studied and observed and then an algorithm was prepared separately for different systems. These algorithms were used to prepare source code in Java or in C programming. Sample algorithm for each classification system has been shown and discussed separately in Figures 1 - 4. Figure 1 shows the sample algorithm used for Indian Soil Classification with fine grained soil (percentage passing No. 200 sieve) was greater than 50%. A similar approach was adopted for coarse grained soil and merged with the main code. For fine grained soil, additional coding for the plasticity chart was prepared and included in the main code for classification. Further, as evident from Figure 1, there were many new nomenclature introduced in the algorithm, which was decided by percentage of organic content in the soil. The influence of organic content was considered if it exceeds 3% in the soil. The attempt of including new nomenclature was made to broaden the domain of classification system as the system was not able to classify organic soil effectively. Unified Soil Classification System (USCS) was similar to Indian Soil Classification (ISC) with the only difference, that USCS have not considered intermediate plasticity. There was either liquid limit < 50 or liquid limit >= 50 for low or high compressibility, respectively. Thus similar approach was adopted for algorithm preparation and coding as prepared for Indian Soil Classification.

American Society for Testing Materials (ASTM) classification system identifies three major soil divisions: coarse-grained soils, fine-grained soils, and highly organic soils. These three divisions were further subdivided into a total of 15 basic soil groups and each soil group have a number of group names. Figure 2 shows the sample algorithm of fine grained soil of low plasticity. As evident from Figure 1, soils were classified by group symbols and group names. For example, one can have a soil with a group symbol, CL-ML, and group name, which described the soil, as "Sandy Silty Clay" if the gravel content was less than 15%. And if gravel content was equal or

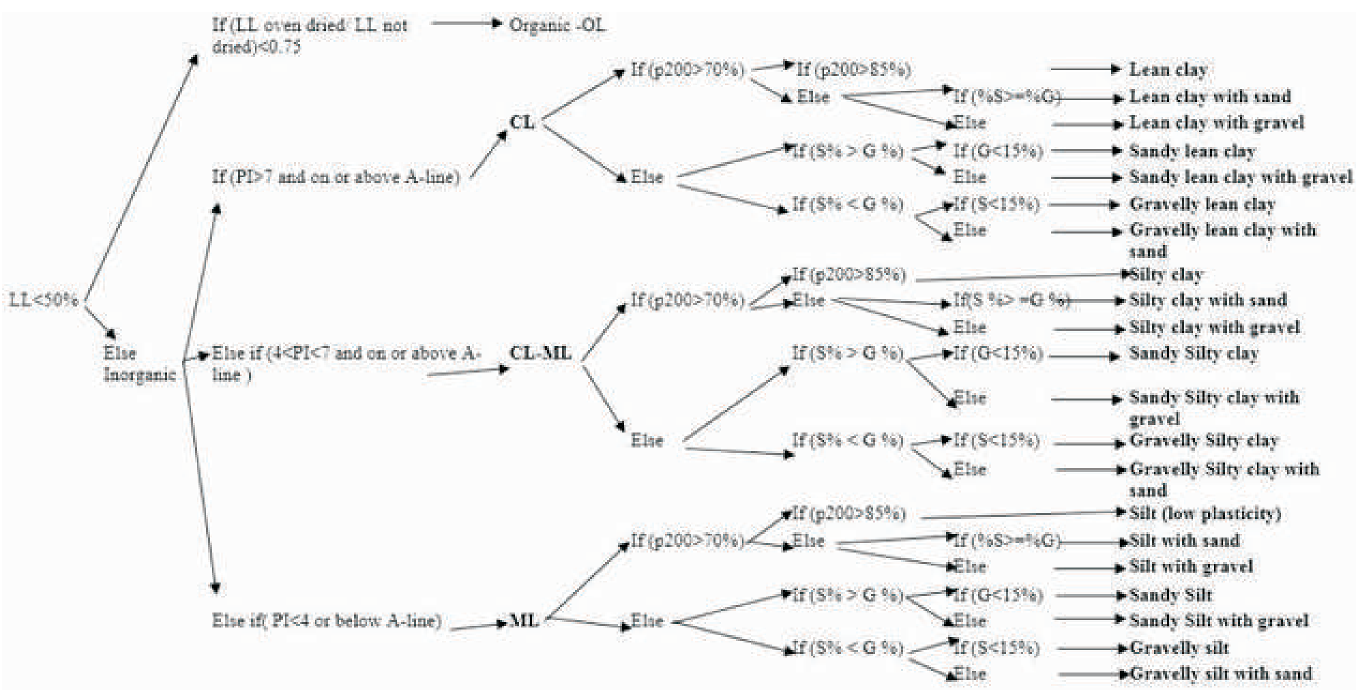

Figure 2. Algorithm for ASTM Classification System

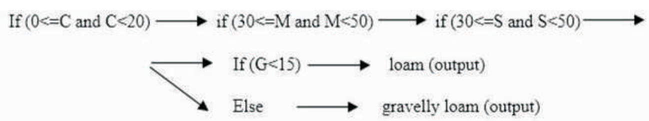

Figure 3. Sample Algorithm for USDA Classification System

If (p200<= 15) → if (p40<=30) → If (p10<= 50) → If (PI<= 6)

Then group classification= A-1, A-1-a

Group index, GI= (.2*a + .005*a*c + .01*b*d)

Where a= (p200-35); b= (p200-15); c= (LL-40); d= (PI-10)

Usual type of constituent material= Stone fragments gravel

General rating as subgrade= Excellent (depends on GI value)

Figure 4. Sample Algorithm for AASHTO Classification System

more than 15%, then the group name would have been " Sandy Silty Clay with Gravel". This standard can identify about hundred types of soil groups and provides a better scheme for mixed soils, i.e., Soils consist of mixtures of sand, gravel, and clay. A similar approach was adopted for coarse grained soil and merged with the main code. ASTM D2487-6 was an improved version of USCS and included organic soil classification by introducing the term liquid limit ratio, which is the ratio of liquid limit oven dried to dried sample. If the liquid limit ratio was less than 0.75, the soil was classified as organic soil.

United State Department of Agriculture (USDA) classification was based on particle size. On the basis of particle size, soil was divided in to gravel, sand, silt, and clay. But USDA have given triangular classification chart in which input variable was only sand, silt, and clay thus U.S. Bureau of Public Road suggested a correction as,

Corrected percentage of sand = Percentage sand x (100/(percentage of sand+silt+clay))

Similar correction can be used for corrected silt and clay. The textural classification of the soil would be done based on the corrected percentages. This classification system can identify eleven types of soil mixture. The sample algorithm for Loam type of soil is shown in Figure 3. Similarly, algorithm for others ten cases were prepared and merged with the main code.

The sample algorithm for AASHTO classification system is shown in Figure 4. Along with the group classification, group index, usual type of constituent material and general rating as subgrade was linked and shown in the result. Similarly, algorithm of all other cases were written and merged to prepare a single main code.

As evident from Figure 5 in the result, the triangular chart also appeared, showing the resultant highlighted soil area

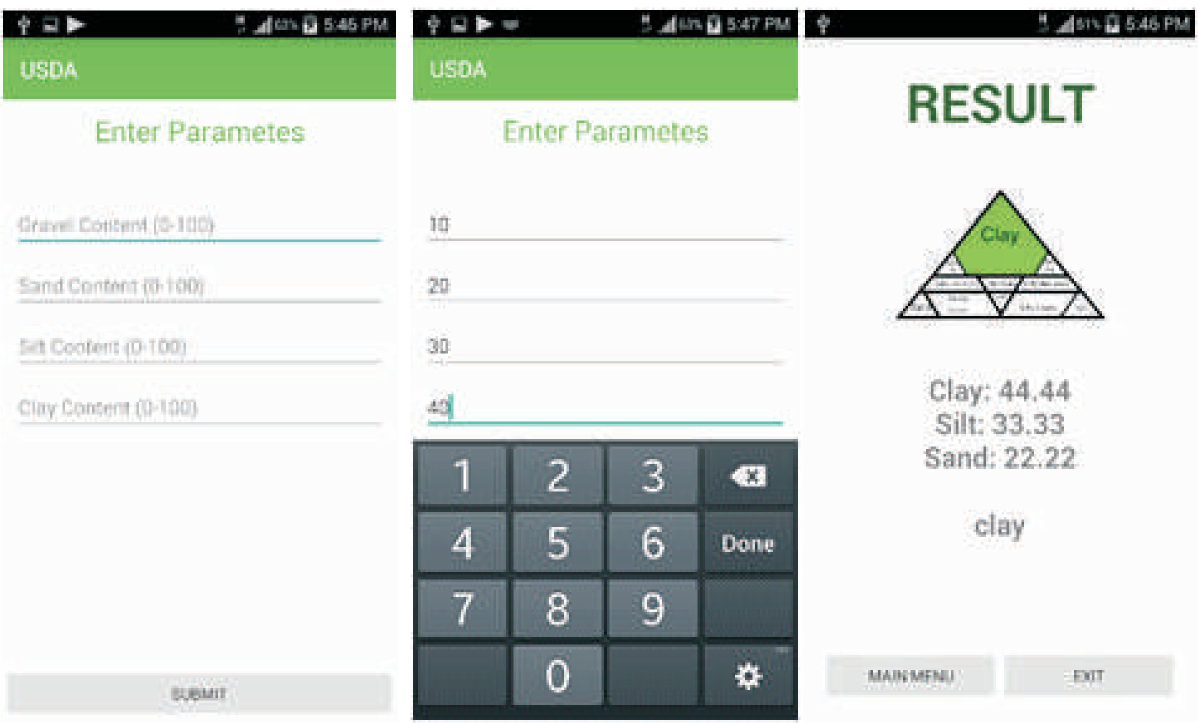

Figure 5. Soil Classification using Mobile App (USDA System)

as clay. To implement this additional application, each individual region was created by using sets of boundary lines then all the areas were merged in a bigger triangle. Each soil area in the triangular chart was linked with the classification result. The series of codes upon which the programs were based was simply conditional loop statements. These statements help in defining a particular set of properties that was assigned to each group in the classification system. Further, to develop the mobile application, open source Android Studio software was used. This software was used to design pages of mobile app, space for entering the numeric input, output, font, and color of the output. The design of the application was written in XML language. The application starts with the main screen showing all the options for different classification system, clicking on any option takes the user to the respected page for input of the different parameter, which was required to classify the soil. After analysing the input data, the software calculates and shows the result on the next page. If the entered values of the input variables were not valid or not in range or left unfilled, a warning message will pop up on the screen and the mobile app will return to the previous page. Further, if the user does not have the values of any input variable, zero can be entered for that input variable to run the mobile app.

4. Result and Discussion

The mobile application developed was user-friendly and each input-output was guided with specific comment. The results reported in literature has been discussed and compared to check the accuracy of mobile application in classifying the soils based on different classification system. Few examples from different textbooks have been taken to compare the result shown by mobile app. The results for the classification (based on the AASHTO system of classification) of soil reported by Arora (2009) is presented in Table 3.

As evident from Figure 6, the result reported in Table 3 are in agreement. Further the mobile app also shows the significant constituent material of soil, general subgrade rating, and group index value, which is also in agreement with the result reported.

In order to test the app using USDA and triangular classification, let clay=40%, sand=20%, silt=30%, and gravel=10%. As suggested by U.S. Bureau of Public Road, the gravel percentage was distributed to clay, sand and silt percentages leading to enhanced percentages of the fractions as evident from Figure 5. With these enhanced values of clay, sand and silt fractions, and the classification done by the mobile app as clay. The same results were verified using triangular chart with highlighted portion as clay as evident from the same figure. Further, the results for the classification (based on the ASTM system of classification reported by Kumar et al., 2015) of two soils (designated as soil A and soil B) as reported by Budhu (2011) is presented in Table 4.

Constituent	Values (%)
LL	45
PL	16
PI	(45-16)=29
% retained on 0.075 mm (No. 200 sieve)	60
% retained on .425 mm (No.40)	80
% retained on 2 mm (No.10)	92
% retained on No. 4	100
Classification	A-7-6, GI=13

Table 3. Properties of Soil

As evident from Table 4, soil A was classified as fine grained soil, whereas soil B was classified as coarse grained soil. Further, the classification of these soils was carried out by Kumar et al. (2015) using the mobile app and the results of the classification were shown in Figures 7 and 8, respectively for the soil A and soil B. Study of Table 4 and Figure 7 reveals that the classification of the soil A was reported as ML, sandy silt, whereas the result shown by the mobile app was CL, lean clay. This difference in classification of soil A was attributed to the human error in gathering the information from the plasticity charts and flow chart as reported in ASTMD 2487-6. The term sandy used by Budhu (2011) in classifying the soil A should not be there as the sand content was less than 15%. The liquid limit and the plasticity index as evident from Table 3, for the soil A was 26% and 8%, respectively, which indicates that the soil A was of low compressibility. Further, to decide whether the soil A was siltor clay, the point having coordinates (26%, 8%) were above the A-line in Figure 9. Hence the soil A was definitely a clay (CL) rather than silt (ML) as reported wrongly

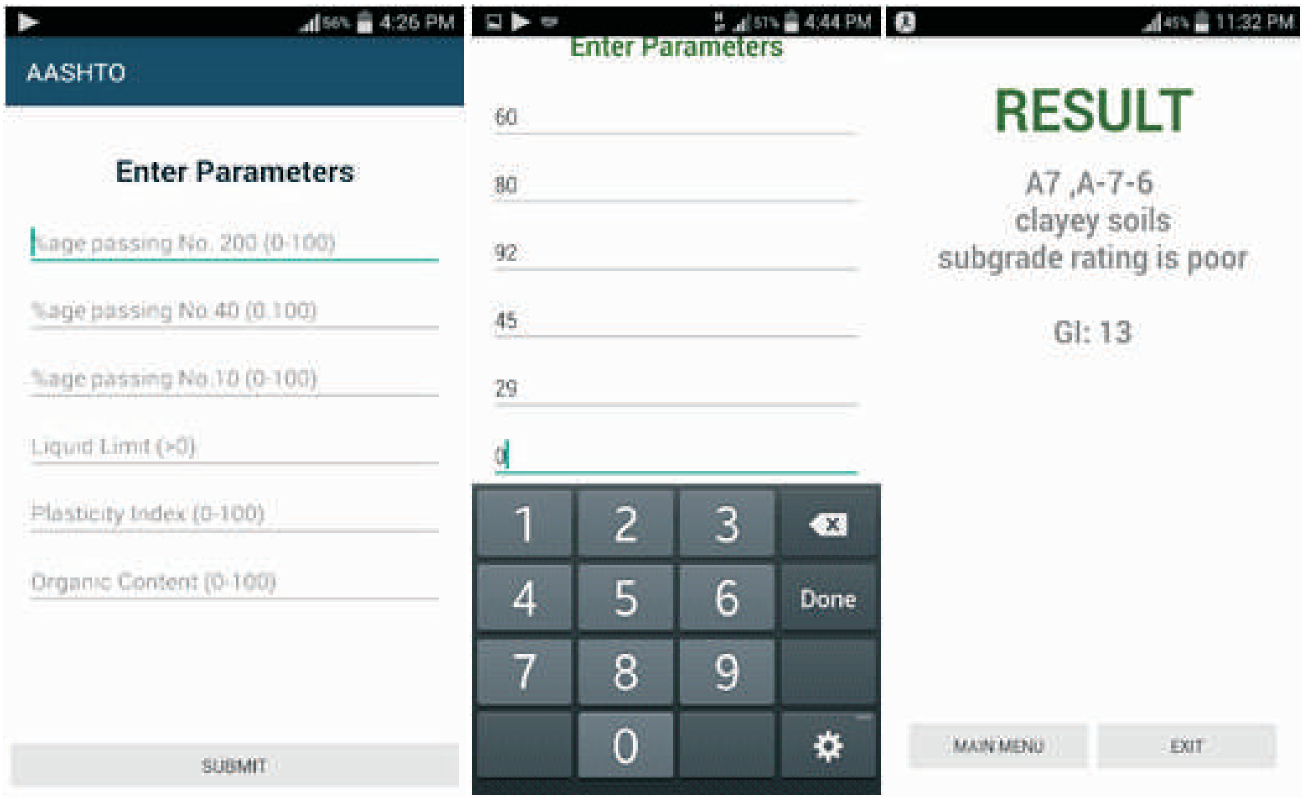

Figure 6. Soil Classification Using Mobile App (AASHTO System)

by Budhu (2011). Further study of Table 4 and Figure 8 reveals that the classification reported for soil B was in agreement with the classification reported for the soil B by Buddha (2011). The fine content as well as gravel content in soil B was greater than 12% and 15%, respectively as evident from Table 4. Soil B was also shown as non-plastic in Table 4. Hence, the classification reported in Table 3 and the one with the mobile app were in agreement. Hence, from the above discussion, it was concluded that human error may lead to the wrong classification of the soils, whereas the same could be eliminated with the use of mobile app. Further, the results for the classification (based on the ISC and USCS system of classification) of soil reported by Arora (2009) is presented in Table 5.

Constituent	Soil A	Soil B
LL	26	-
PL	18	-
PI	(26-18)=8	Non plastic
% retained on 0.075 mm (No. 200 sieve)	12	80
Fines (%) F	(100-12)=88	(100-80)=20
Gravel fraction (%) G	0	16
Sand fraction (%) S	12	64
Silt fraction (%) M	59	20
Clay fraction (%) C	29	0
Classification	ML, sandy silt	SM, Silty sand with gravel

Table 4. Properties of Soils (After Budhu et al., 2011)

As evident from Table 5, the soil was classified as CL (lean clay) and CI (clay with medium plasticity or compressibility) by USCS and ISC classification system, respectively. Further, the classification of these soils was carried out using the mobile app and the results of the classification were shown in Figures 10 and 11, respectively. These figures show the results were in agreement.

Conclusion

With the proliferation of smartphone technology, the ease of computation and communication has become readily available to end users anytime anywhere. The delay between the data collection and its interpretation can be significantly reduced with the availability of various mobile applications on smartphone platforms. The Android application developed for classifying the soils is demonstrated in this paper. The mobile application is developed for five classification systems, including improved ISC, USSC, and AASHTO system. The existing

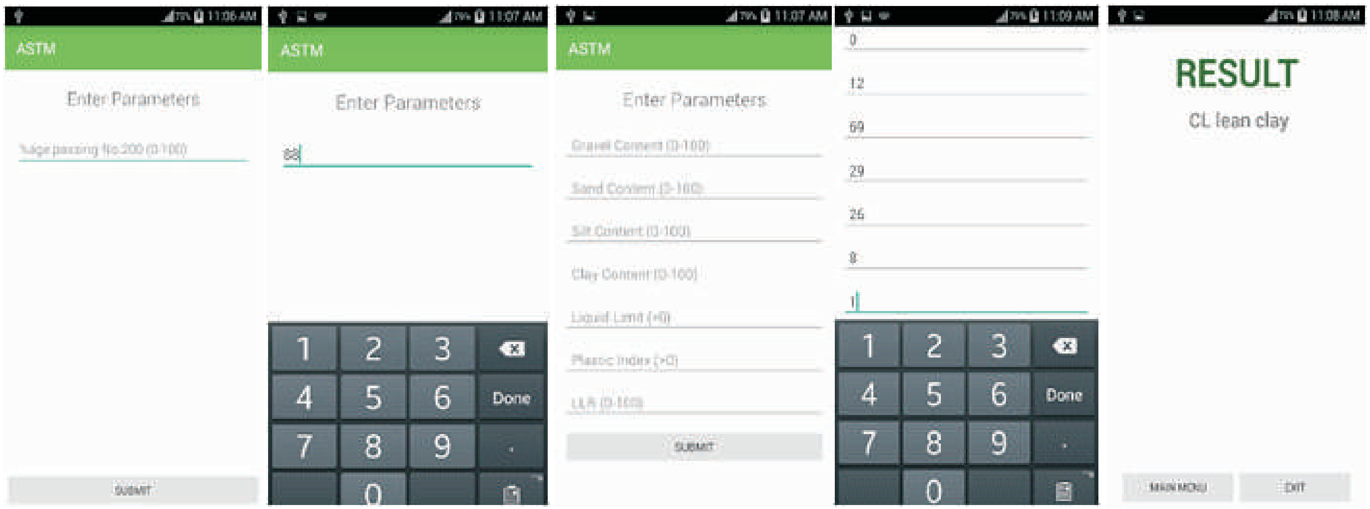

Figure 7. Soil Classification for Soil a using Mobile App and ASTM System of Soil Classification (after Kumar et al. (2015))

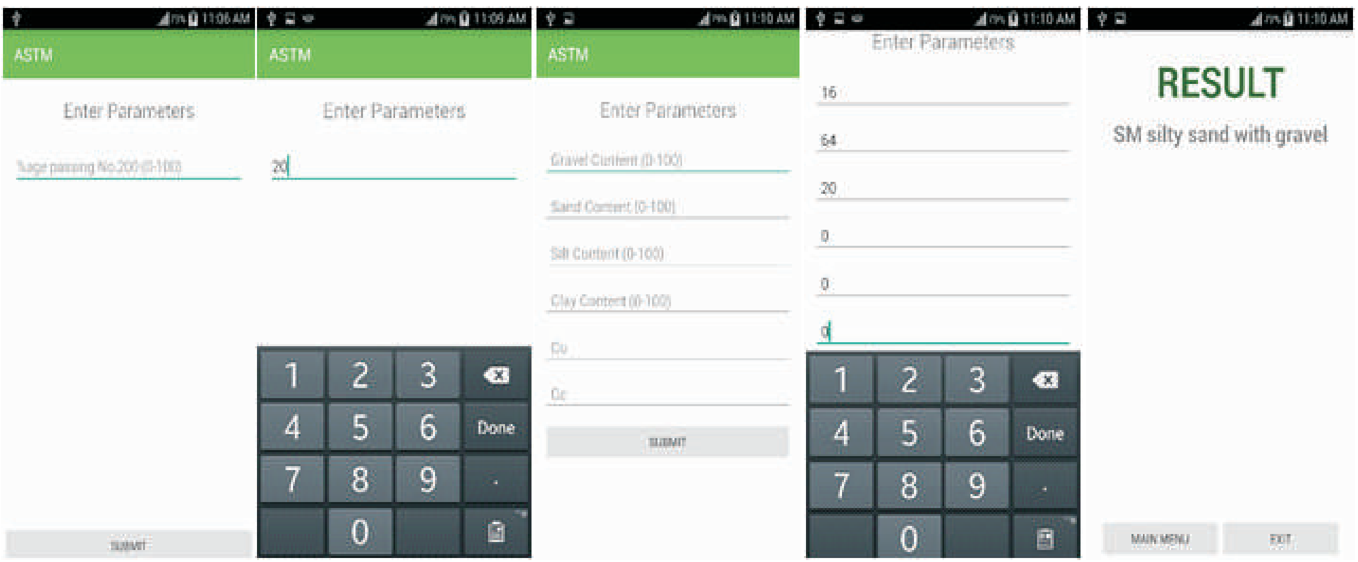

Figure 8. Soil Classification for Soil B using Mobile App and ASTM System of Soil Classification (after Kumar et al. (2015))

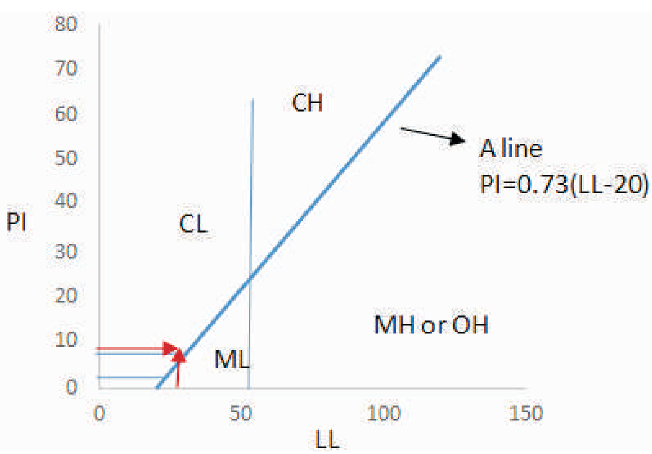

Figure 9. Plasticity Chart (after Kumar et al. (2015))

Constituent	Values (%)
LL	40
PL	25
PI	(40-25)=15
% passing on 0.075 mm (No.200 sieve)	
Classification	CL and CI

Table 5. Properties of Soil

classification systems have been analysed, and further improvement in the classification systems have also been proposed. Based on the improved classification systems, a mobile application has been developed, which can be used for wide range of domains ranging for geo technical

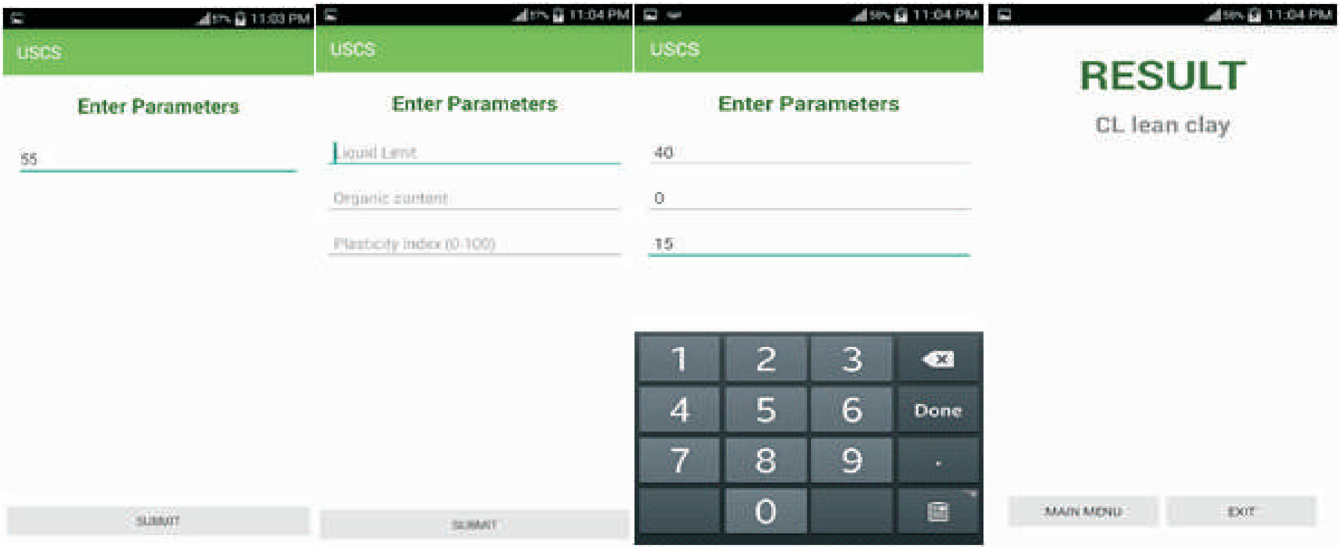

Figure 10. Soil Classification using Mobile App (USCS System)

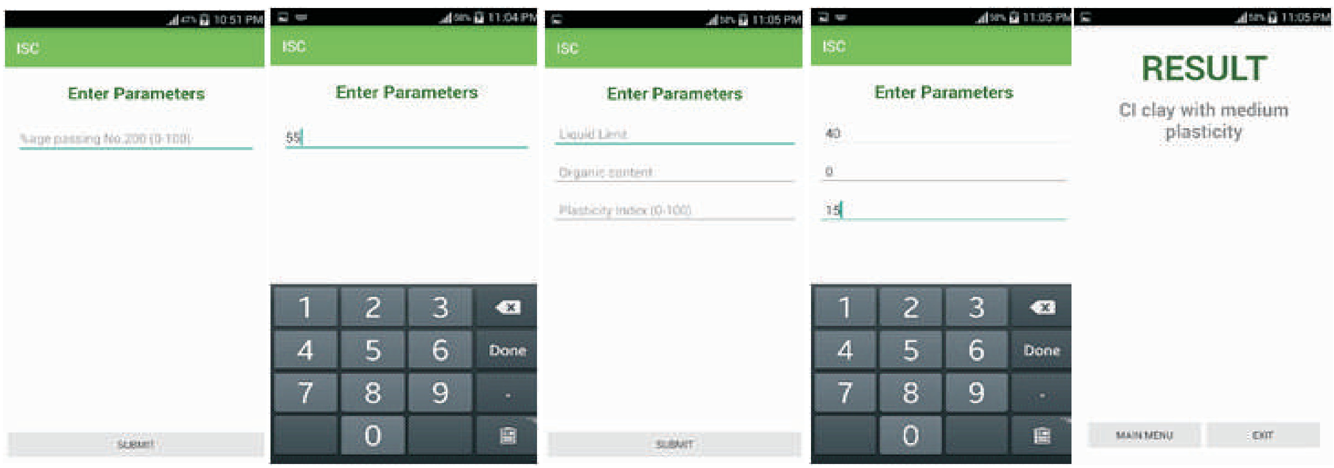

Figure 11. Soil Classification using Mobile App (ISC System)

surveys to organic soil analysis. With the help of this mobile application, dependency upon graphs, tables, and flow charts for getting the classification can be avoided. Such manual refereeing processes are not only time consuming, but also susceptible to human error, leading to incorrect classification of soils as has been shown in this paper. At present, the mobile app does not handle the cases for missing data, resulting either due to the incomplete data collection procedures or erroneous instruments, as a part of future work, predictive models that can handle missing data problem, shall be developed. The data collected through mobile app can be further stored and harvested through crowd sourcing and a soil map can be plotted, which can be useful in planning the effective utilization of land as well.

Notations

The following symbols are used in this paper:

G = gravel contents

S = sand contents

M = silt contents

C = clay contents

F = fine contents

PI = Plasticity Index

LL = Liquid Limit

Cu = coefficient of uniformity

Cc = coefficient of curvature

GI = Group Index

LLR= Liquid Limit Ratio

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