ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FACULTY OF TECHNOLOGY

DEPARTMENT OF CIVIL AND ENVIROMENTAL ENGINEERING

LAB AID SOFTWARE DEVELOPMENT FOR PERFORMING, ANALYZING AND REPORTING OF TEST DATA IN SOIL LABORATORIES FOR ROAD PROJECTS

A Project submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the Degree of Master of Engineering in Civil Engineering (GEOTECHNIQUES)

By

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LIST OF ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officals
ADO.NET	ActiveX Data Objects
CBR	California Bearing Ratio
FI	Flakiness Index
LAA	Los Angeles Abrasion Test
VB	Visual Basic for Application

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Laboratory tests are useful in providing reliable data for calculating ultimate bearing capacity of soils, stability and settlement behavior of foundation, and determining physical characteristics of soils.

The extent of soil testing required for a project varies. It depends on the type of client; the importance of the project; the funding available; the time required; and to some extent, the capability of the consultant's laboratory.

In this project, it has been attempted to develop lab aid software that helps to perform, analyze and report of laboratory tests for road projects.

1.2 STATEMENT OF THE PROBLEM

Due to the increased number of the students in civil engineering in undergraduate level in all our Universities, learning how to perform a soil laboratory test is time consuming when compared to the number of the students. So, it would be easier if there is a way that can show them what to do when they are in soil laboratory without the presence of the teacher.

Currently, in our country soil laboratories reporting is done by spreadsheet programs developed by different people. For someone to do the soil laboratory report, he/she has to develop all the spread sheet programs by himself/herself which is time consuming or he/she has to get the already developed spreadsheet programs on excel and do the report, which he/she has no guaranty whether the spreadsheet is the right one or not because these spreadsheet programs can be easily manipulated to misleading calculation by any individual.

So, the main intention of this project is to develop lab aid software that can assist students, avoid commonly used spreadsheet for perform, analyze and reporting the test for road projects.

1.3 OBJECTIVE OF THE PROJECT

This project is aimed at developing user friendly lab aided software for performing, analyzing, and reporting laboratory tests for road projects. The following detail objectives are included in this study:

1. To develop a step by step procedure to the tests according to a specific standard AASHTO.
2. To perform calculation of the evaluation based on the data collected
3. To comply a report and draw graph if necessary

1.4 SCOPE OF THE PROJECT

The scope of the study is limited to develop lab aid software program for performing, analyzing and reporting of test data in soil laboratories according to AASHTO for the common used test in our country:

- For soils and gravels
  - Natural moisture content
  - Specific gravity
  - Grain size analysis (Sieve and hydrometer analysis)
  - Atterberg limits
  - Unit weight
  - Compaction test (Proctor test)
  - California Bearing Ratio (CBR)
  - Free swell tests

- For aggregates
  - Moisture content of aggregates
  - Specific gravity and water absorption
  - Grain size analysis
  - Flakiness Index (FI)
  - Los Angeles abrasion test (LAA)
  - Soundness of Aggregates

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Testing soil samples in the laboratory plays an important role in soil mechanics research and civil engineering practice. Almost all we know about soil behavior has been learned from laboratory tests. [Atkinson]

Laboratory tests are carried out for a number of purposes, the most important being:

1. For description and classification of a particular soil.

2. To investigate the basic mechanical behavior of soils and to develop theories for soil behavior.

3. To determine design parameters (i.e. numerical values for strength, stiffness and permeability) for geotechnical analyses. [Budhu]

Samples are normally taken from the field for laboratory tests to characterize the physical and mechanical (strength and deformation) properties. These parameters are used to design foundations and to determine the use of soils as a construction material. Disturbed samples such as from a standard sampler are usually used for visual inspection and for tests to determine the physical properties such as plasticity and grain size and shape. Undisturbed samples such as from a thin-walled sampler are used for both physical and mechanical properties. Test results, especially those that relate to the mechanical properties, are strongly affected by sampling, handling, transportation, and sample preparation disturbances. [Budhu]

2.2 LABORATORY TESTS

2.2.1 For soils and gravels

2.2.1.1 Natural Moisture content

a) Definition

Moisture or water content of a soil – the ratio, expressed as a percentage, of the mass of water in a given mass of soil to the solid particles. [AASHTO]

b) Apparatus

The apparatus shall consist of the following:

- Drying Oven
- Balance
- Containers

c) Test sample

Select a representative quantity of moist soil in the amount indicated in the method of test. If no amount is indicated, the minimum mass of the sample shall be in accordance with the following table: [AASHTO]

Maximum Particle Size	Minimum Mass of Sample, g
0.425-mm (No. 40) sieve	10
4.75-mm (No. 4) sieve	100
12.5-mm (1/2 in.)	300
25.0-mm (1 in.)	500
50-mm (2 in.)	1000

Table 1 - Representative quantity of soil for moisture test

d) Procedure

Weigh a clean, dry container with its lid and place the moisture content sample in the container. Replace the lid immediately and weigh the container, including the lid and the moist sample. Remove the lid and place the container with the moist sample in the drying oven maintained at a temperature of 110 ± 5ºC and dry to a constant mass. Immediately upon removal from the oven, place the lid and allow the sample to cool to room temperature. Weigh the container including the lid and the dried sample. {AASHTO]

e) Calculation

Calculate the moisture content of the soil as follows:

$w = [(\text{mass of moisture}) / (\text{mass of oven-dry soil})] \times 100$

$w = [(W_1 - W_2) / (W_2 - W_c)] \times 100$ ..... eq. (1)

Where:

w = moisture content, percent;

W_1 = mass of container and moist soil, g;

W_2 = mass of container and oven-dried soil, g; and

W_c = mass of container, g.

Calculate the percent of moisture content to the nearest 0.1 percent.

2.2.1.2 Specific Gravity

a) Definition

Specific gravity is the ratio of the mass of a unit volume of a material at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. [AASHTO]

b) Significance and use

The specific gravity of a soil is used in almost every equation expressing the phase relationship of air, water, and solids in a given volume of material. [AASHTO]

c) Apparatus

The apparatus shall consist of the following:

- Pycnometer
- Balance
- Oven
- Thermometer

d) Calibration of pycnometer

- The pycnometer shall be cleaned, dried, weighed, and the mass recorded. The pycnometer shall be filled with distilled water essentially at room temperature. The mass of the pycnometer and water, Wa, shall be determined and recorded. A thermometer shall be inserted in the water and its temperature, Ti, determined to the nearest whole degree.

- A table of values of mass Wa shall be prepared for a series of temperatures that are likely to prevail when the mass Wb of the pycnometer, sample, and water is determined at the end of testing. These values of Wa shall be calculated as follows:

$$W_a \text{ (at } T_x) = (\text{density of water at } T_x / \text{density of water at } T_i) \times (W_a \text{ (at } T_i) - W_f) + W_f \quad \text{..... eq. (2)}$$

Where:

W_a = mass of pycnometer and water, in grams;

W_f= mass of pycnometer, in grams;

T_i = observed temperature of water, in degrees Celsius; and

T_x = any other desired temperature, in degrees Celsius

It is important that masses W_a and W_b be based on water at the same temperature. Values for the relative density of water at temperatures from 18 to 30ºC are given in Table 2.

Temperatures, °C	Relative Density of Water	Correction Factor *K*
18	0.9986244	1.0004
19	0.9984347	1.0002
20	0.9982343	1.0000
21	0.9980233	0.9998
22	0.9978019	0.9996
23	0.9975702	0.9993
24	0.9973286	0.9991
25	0.9970770	0.9989
26	0.9968156	0.9986
27	0.9965451	0.9983
28	0.9962652	0.9980
29	0.9959761	0.9977
30	0.9956780	0.9974

Table 2 – Relative Density of Water and Correction Factor K for Various Temperatures

e) Test sample

- The soil to be used in the specific gravity test may contain its natural moisture or be oven-dried. The mass of the test sample on an oven-dry basis shall be at least 25 g when the volumetric flask is to be used, and at least 10 g when the stoppered bottle is to be used. [AASHTO]

- **Samples Containing Natural Moisture** - When the sample contains its natural moisture, the mass of the soil, W_o, on an oven-dry basis shall be determined at the end of the test by evaporating the water in an oven maintained at 110º ± 5ºC.

- **Oven-Dried Samples** - When an oven-dried sample is to be used, the sample shall be dried for at least 12 hours, or to constant mass, in an oven maintained at 110º ± 5ºC, cooled to room temperature, then weighed and transferred to the pycnometer or transferred to the pycnometer and then weighed. Distilled water shall be added into the pycnometer in an amount that will provide complete sample coverage. The sample shall then soak for at least 12 hours. [AASHTO]

f) Procedure

- The sample as prepared in the above section shall have distilled water added to a level that will cover the soil to a maximum of about three-fourths full in the volumetric flask, or about one-half full in the stoppered bottle.

- Remove entrapped air by either of the following methods:
    1) Subject the contents to a partial vacuum of 13.33 kPa or less absolute pressure or

2) Boil gently for at least 10 minutes, while occasionally rolling the pycnometer to assist in the removal of the air.

- Fill the pycnometer with distilled water to its calibrated capacity and then clean the outside and dry with a clean, dry cloth. Determine the mass of the pycnometer and contents, W_b, and the temperature in degrees Celsius, T_x, of the contents.

g) Calculation

Calculate the specific gravity of the soil, based on water at a temperature T_x, as follows:

Specific Gravity, $T_x/T_x = W_o /[W_o + (W_a – W_b)]$ ……..... eq. (3)

Where:

Tx = temperature of the contents of the pycnometer when mass Wb was determined in degrees Celsius;

Wo = mass of sample of oven-dried soil in grams;

Wa = mass of pycnometer filled with water at temperature Tx, in grams; and

Wb = mass of pycnometer filled with water and soil at temperature Tx, in grams.

Unless otherwise required, specific gravity values reported shall be based on water at 20ºC. The value based on water at 20ºC shall be calculated from the value based on water at the observed temperature Tx, as follows:

Specific Gravity, Tx /20^{o}C = K x Specific Gravity, T_x /T_x ..... eq. (4)

Where:

K = a number found by dividing the relative density of water at temperature T_x by the relative density of water at 20ºC. Values for a range of temperatures are given in Table 2.

2.2.1.3 Grain Size Analysis

I) Grain-Size Analysis of Granular Soil Materials

a) Definition

A weighed sample of dry granular soil material is separated through a series of sieves with progressively smaller openings. Particle size distribution is determined by weighing the material retained on each of the sieves and dividing

these weights by the total dry weight of the sample. This method requires drying, washing, and a series of separations. [AASHTO]

b) Scope

This method covers the determination of the particle size distribution of granular soil material. This method utilizes the 6.3-mm sieve size for separation purposes. However, the sample tester may use an alternative sieve size (i.e., 4.75 mm, 2.00 mm, etc.). In this case, the alternative sieve size used must replace the 6.3-mm size throughout this procedure. [AASHTO]

Specifications for granular soil material, which reference this method, usually contain grading requirements that include both coarse and fine fractions in sizes between 100 mm and 0.075 mm. [AASHTO]

c) Significance and use

This method is used primarily to determine the gradation of granular soil material for use as fill material in sub base, pipe, or structural backfill. Granular soil material used in these applications generally necessitates a well-graded material. [AASHTO]

d) Apparatus

The apparatus shall consist of the following:

- Platform Scale
- Balance
- Sieves - The sieves shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. Suitable sieve sizes shall be selected to furnish the information required by the specifications covering the material to be tested.
- Mechanical Sieve Shaker
- Oven
- Miscellaneous—Spoons, spatulas, brushes, and containers.

e) Sampling and Preparation

- Sample the soil as specified below
- Sample Size:
  - ✓ For granular construction items, the sample(s) shall be transported to the testing facility in a clean, approved container. Assure that the sample size meets a minimum mass requirement of 20 kg.

  - ✓ For materials other than granular construction items, i.e., design testing, the sample(s) shall be transported to the testing facility in a clean,

approved container and be large enough to be representative of the material being tested. In general, the larger the nominal maximum particle size is, the larger the sample should be in order to be considered representative. The following may be considered a guide (not a requirement) for sample masses on particle size:

Nominal Maximum Particle Size	Sample Mass
50 mm	20 kg
19 mm	7 kg
6.3 mm	1 kg

Table 3 - Representative quantity of soil for sieve analysis test

f) Procedure

1. Write down the weight of each sieve as well as the bottom pan to be used in the analysis.
2. Record the weight of the given dry soil sample.
3. Make sure that all the sieves are clean, and assemble them in the ascending order of sieve numbers (#4 sieve at top and #200 sieve at bottom). Place the pan below #200 sieve. Carefully pour the soil sample into the top sieve and place the cap over it.
4. Place the sieve stack in the mechanical shaker and shake for 10 minutes.
5. Remove the stack from the shaker and carefully weigh and record the weight of each sieve with its retained soil. In addition, remember to weigh and record the weight of the bottom pan with its retained fine soil.

g) Calculation

- Obtain the mass of soil retained on each sieve by subtracting the weight of the empty sieve from the mass of the sieve + retained soil, and record this mass as the weight retained on the data sheet. The sum of these retained masses should be approximately equals the initial mass of the soil sample.

- Calculate the percent retained on each sieve by dividing the weight retained on each sieve by the original sample mass.

- Calculate the percent passing (or percent finer) by starting with 100 percent and subtracting the percent retained on each sieve as a cumulative procedure.

II) Particle Size Analysis of Soils

a) Apparatus

The apparatus shall consist of the following:

- Hydrometer - hydrometers 151 H or 152 H. Dimensions of both hydrometers are the same, the scale being the only item of difference.

- Sedimentation Cylinders - A glass cylinder approximately 460 mm in height and 60 mm in diameter and marked for a volume of 1000 ml.
- Thermometer
- Water Bath or Constant Temperature Room
- Beaker
- Timing Device
- Containers

b) Procedure

1. The approximately 100 or 50-g sample for hydrometer analysis shall be weighed, placed in a 250-ml beaker, covered with 125 mL of stock solution of the selected dispersing agent.

2. Take the fine soil from the bottom pan of the sieve set, place it into a beaker, and add 125 mL of the dispersing agent (sodium hexametaphosphate (40 g/L)) solution. Stir the mixture until the soil is thoroughly wet. Let the soil soak for at least ten minutes.

3. While the soil is soaking, add 125mL of dispersing agent into the control cylinder and fill it with distilled water to the mark. Take the reading at the top of the meniscus formed by the hydrometer stem and the control solution. A reading less than zero is recorded as a negative (-) correction and a reading between zero and sixty is recorded as a positive (+) correction. This reading is called the zero correction. The meniscus correction is the difference between the top of the meniscus and the level of the solution in the control jar (Usually about +1). Shake the control cylinder in such a way that the contents are mixed thoroughly. Insert the hydrometer and thermometer into the control cylinder and note the zero correction and temperature respectively.

4. Transfer the soil slurry into a mixer by adding more distilled water, if necessary, until mixing cup is at least half full. Then mix the solution for a period of two minutes.

5. Immediately transfer the soil slurry into the empty sedimentation cylinder. Add distilled water up to the mark.

6. Cover the open end of the cylinder with a stopper and secure it with the palm of your hand. Then turn the cylinder upside down and back upright for a period of one minute. (The cylinder should be inverted approximately 30 times during the minute.)

7. Set the cylinder down and record the time. Remove the stopper from the cylinder. After an elapsed time of one minute and forty seconds, very slowly and carefully insert the hydrometer for the first reading. (Note: It should take about ten seconds to insert or remove the hydrometer to minimize any disturbance, and the release of the hydrometer should be made as close to the reading depth as possible to avoid excessive bobbing).

8. The reading is taken by observing the top of the meniscus formed by the suspension and the hydrometer stem. The hydrometer is removed slowly and placed back into the control cylinder. Very gently spin it in control cylinder to remove any particles that may have adhered.

9. Take hydrometer readings after elapsed time of ¼, ½, 1, 2, 4, 8, 15, 30, 60 minutes and 1, 2, 4, 12 and 24 hours.

c) Calculation

- Percentage of Soil in Suspension
  - ✓ Hydrometer readings shall be corrected by applying the approximate composite correction to account for the dispersing agent used, temperature of the suspension, and height of the meniscus on the stem of the hydrometer.

  - ✓ The percentage of the dispersed soil in suspension represented by different corrected hydrometer readings depends upon both the amount and the specific gravity of the soil dispersed. The percentage of dispersed soil remaining in suspension shall be calculated as follows:

    For hydrometer 152 H

$$P = \frac{Ra}{w} \times 100$$

…… eq. (5)

    For hydrometer 151 H

$$P = \frac{1606(R-1)\,a}{w} \times 100$$

…… eq. (6)

    where:
    P = percentage of originally dispersed soil remaining in suspension,
    R = corrected hydrometer reading,
    w = mass in grams of soil originally dispersed minus the hygroscopic moisture, and
    a = constant depending on the density of the suspension.

    For an assumed value of G for the specific gravity of the soil, and a water density of 1.000 at 20.0ºC, the value of "a" may be obtained by the formula:

$$a = \frac{2.6500 - 1.000}{2.6500} \times \frac{G}{G - 1.000}$$

…… eq. (7)

- Diameter of Soil Particles in Suspension

- ✓ The maximum diameter, d, of the particles in suspension, corresponding to the percentage indicated by a given hydrometer reading, shall be calculated by

$$D = K\sqrt{\frac{L}{T}} \qquad \text{..... eq. (8)}$$

where:
K = constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of K for a range of temperatures and specific gravities are given in Table 4. The value of K may not change for a series of readings constituting a test, while values of L and T do vary.

L = effective depth, mm;

Temperature deg C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.004838	0.004759	0.004683	0.004607	0.004538	0.004471	0.004408	0.004345	0.004288
17	0.004778	0.004699	0.004623	0.004551	0.004481	0.004415	0.004351	0.004288	0.004231
18	0.004718	0.004639	0.004563	0.004494	0.004424	0.004358	0.004298	0.004234	0.004177
19	0.004661	0.004582	0.004506	0.004437	0.004370	0.004304	0.004244	0.004184	0.004127
20	0.004604	0.004525	0.004452	0.004383	0.004317	0.004250	0.004190	0.004133	0.004076
21	0.004547	0.004471	0.004399	0.004329	0.004263	0.004200	0.004139	0.004083	0.004026
22	0.004494	0.004418	0.004345	0.004279	0.004212	0.004149	0.004092	0.004035	0.003978
23	0.004440	0.004367	0.004294	0.004228	0.004165	0.004101	0.004045	0.003988	0.003931
24	0.004389	0.004317	0.004244	0.004177	0.004114	0.004054	0.003997	0.003940	0.003886
25	0.004339	0.004266	0.004196	0.004130	0.004067	0.004007	0.003950	0.003896	0.003842
26	0.004291	0.004218	0.004149	0.004083	0.004022	0.003962	0.003905	0.003852	0.003798
27	0.004244	0.004171	0.004101	0.004038	0.003978	0.003918	0.003861	0.003807	0.003757
28	0.004196	0.004124	0.004057	0.003997	0.003934	0.003875	0.003820	0.003766	0.003716
29	0.004149	0.004079	0.004013	0.003950	0.003890	0.003833	0.003779	0.003725	0.003675
30	0.004105	0.004035	0.003972	0.003909	0.003848	0.003792	0.003738	0.003684	0.003633

Table 4—Values of K for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

- Adjusted percent fines proportional of Weight Passing in No.200 to Weight of soil for sieve analysis as follows:

$$N = \frac{Wp}{W} \times N'\% \qquad \text{..... eq. (9)}$$

Where:
N'= percentage finer
Wp= Weight Passing in Sieve No.200
W= Weight of soil for sieve analysis (W)

d) Report
Plot the grain size curve D versus the adjusted percent finer on the Semi logarithmic sheet.

Hydrometer 151 H		Hydrometer 152 H			
Actual Hydrometer Reading	Effective Depth, *L*, mm	Actual Hydrometer Reading	Effective Depth, *L*, mm	Actual Hydrometer Reading	Effective Depth, *L*, mm
1.000	163	0	163	31	112
1.001	160	1	161	32	111
1.002	158	2	160	33	109
1.003	155	3	158	34	107
1.004	152	4	156	35	106
1.005	150	5	155		
1.006	147	6	153	36	104
1.007	144	7	152	37	102
1.008	142	8	150	38	101
1.009	139	9	148	39	99
1.010	137	10	147	40	97
1.011	134	11	145	41	96
1.012	131	12	143	42	94
1.013	129	13	142	43	92
1.014	126	14	140	44	91
1.015	123	15	138	45	89
1.016	121	16	137	46	88
1.017	118	17	135	47	86
1.018	115	18	133	48	84
1.019	113	19	132	49	83
1.020	110	20	130	50	81
1.021	107	21	129	51	79
1.022	105	22	127	52	78
1.023	102	23	125	53	76
1.024	100	24	124	54	74
1.025	97	25	122	55	73
1.026	94	26	120	56	71
1.027	92	27	119	57	70
1.028	89	28	117	58	68
1.029	86	29	115	59	66
1.030	84	30	114	60	65
1.031	81				
1.032	78				
1.033	76				
1.034	73				
1.035	70				
1.036	68				
1.037	65				
1.038	62				

Table 5 - Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specified Sizes

2.2.1.4 Atterberg Limits

I) Determining the liquid limit of soils

a) Definition

Liquid limit (LL) is the water content at which a soil changes from a plastic state to a liquid state.

b) Significance and use

The liquid limit provides a means of identifying and classifying fine-grained cohesive soils especially when also the plastic limit is known.

c) Apparatus

The apparatus shall consist of the following:

- Dish - A porcelain dish, preferably unglazed, or similar mixing dish, about 115 mm in diameter.
- Spatula
- Liquid limit device (Manually operated and mechanically operated)
- Grooving tool
- Gauge
- Containers
- Balance
- Oven

d) Test sample

A sample with a mass of about 100 g shall be taken from the thoroughly mixed portion of the material passing the 0.425mm sieve.

e) Procedure

- The soil sample shall be placed in the mixing dish and thoroughly mixed with 15 to 20 mL of distilled or demineralized water by alternately and repeatedly stirring, kneading, and chopping with a spatula. Further additions of water shall be made in increments of 1 to 3 ml. Each increment of water shall be thoroughly mixed with the soil before another increment of water is added. Once testing has begun, no additional dry soil should be added to the moistened soil. The cup of the Liquid Limit Device shall not be used for mixing soil and water. If too much moisture has been added to the sample, the sample shall either be discarded, or mixed and kneaded until natural evaporation lowers the closure point into an acceptable range.

- When sufficient water has been thoroughly mixed with the soil to form a uniform mass of stiff consistency, a sufficient quantity of this mixture shall be placed in the cup above the spot where the cup rests on the base and shall be squeezed and spread with the spatula to level and at the same time trimmed to a depth of 10 mm at the point of maximum thickness. As few strokes of the spatula as possible shall be used, care being taken to prevent the entrapment of air bubbles within the mass. The excess soil shall be returned to the mixing dish and covered to retain the moisture in the sample. The soil in the cup of the device shall be divided by a firm stroke of the grooving tool along the diameter through the centerline of the cam follower so that a clean sharp

groove of the proper dimensions will be formed as shown in Figure 1. To avoid tearing of the sides of the groove or slipping of the soil cake on the cup, up to six strokes from front to back or from back to front counting as one stroke, shall be permitted. The depth of the groove should be increased with each stroke and only the last stroke should scrape the bottom of the cup.

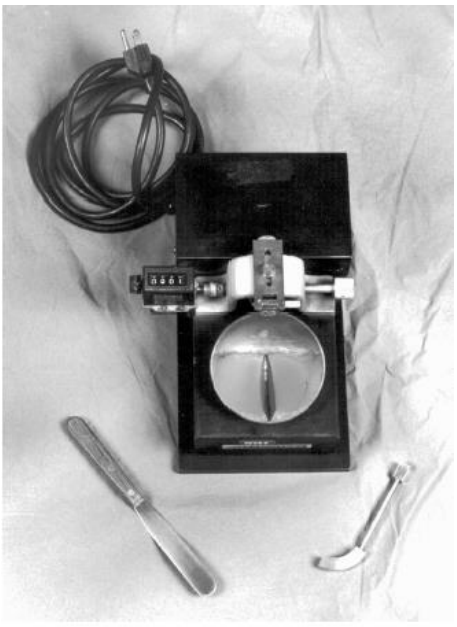

Figure 1—Liquid Limit Device with Soil Sample in Place

- The cup containing the sample prepared as described in the above section shall be lifted and dropped by turning the crank at the rate of approximately two revolutions per second until the two sides of the sample come in contact at the bottom of the groove along a distance of about 13 mm. The number of shocks required to close the groove this distance shall be recorded. The base of the machine shall not be held with the free hand while the crank is turned.

- A slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, shall be removed and placed in a suitable container. The soil in the container shall be dried in the drying oven maintained at a temperature of 110 ± 5ºC to determine the moisture content, and the results recorded.

- The soil remaining in the cup shall be transferred to the mixing dish. The cup and grooving tool shall then be washed and dried in preparation for the next trial.

- Repeat the foregoing operations, adding sufficient water to bring the soil to a more fluid condition. Obtain the first sample in the range of 25 to 35 shocks, the second sample in the range of 20 to 30 shocks, and the third sample in the range of 15 to 25 shocks. The range of the three determinations shall be at least 10 shocks.

f) Calculation

- The water content of the soil shall be expressed as the moisture content in percentage of the mass of the oven-dried soil and shall be calculated as follows:

$$\text{Percentage moisture} = \frac{\text{mass of water}}{\text{mass of oven-dried soil}} \times 100 \quad \text{..... eq. (10)}$$

Calculate the percentage of moisture to the nearest whole percent.

g) Report

- The moisture content corresponding to the intersection of the flow curve with the 25 shock ordinate shall be taken as the liquid limit of the soil. Report this value to the nearest whole number.

II) Determining the plastic limit and plasticity index of soils

a) Definition

The plastic limit (PL) of a soil is the lowest water content determined at which the soil remains plastic.

The plasticity index (PI) of a soil is the range in water content, expressed as a percentage of the mass of the oven-dried soil, within which the material is in a plastic state. It is the numerical difference between the liquid limit and plastic limit of the soil.

b) Significance and use

The plastic limit is used together with the liquid limit to determine the plasticity index which when plotted against the liquid limit on the plasticity chart provides a means of classifying cohesive soils.

c) Apparatus

The apparatus shall consist of the following:

- Dish
- Spatula
- Surface for Rolling
- Plastic Limit Rolling Device (optional)
- Paper for Rolling Device
- Containers
- Balance
- Oven

d) Test sample

- If the plastic limit only is required, take a quantity of soil with a mass of about 20 g from the thoroughly mixed portion of the material passing the 0.425-mm sieve. Place the air-dried soil in a mixing dish and thoroughly mix with distilled or demineralized water until the mass becomes plastic enough to be easily shaped into a ball. Take a portion of this ball with a mass of about 8 g for the test sample.

- Take the sample at any stage of the mixing process at which the mass becomes plastic enough to be easily shaped into a ball without sticking to the fingers excessively when squeezed. If the sample is taken before completion of the liquid limit test, set it aside and allow to season in air until the liquid limit test has been completed. If the sample taken during the liquid limit test is too dry to permit rolling to a 3-mm thread, add more water and remix.

e) Procedure

- Select a 1.5 to 2.0g portion from the mass of soil taken in accordance with in the above test sample procedure. Form the selected portion into an ellipsoidal mass.

- Use one of the following methods to roll the soil mass into a 3-mm diameter thread at a rate of 80 to 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position again.

  ✓ Hand Rolling Method - Roll the mass between the palm or fingers and the ground-glass plate (or a piece of paper laying on a smooth horizontal surface) with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The thread shall be further deformed on each stroke so that its diameter reaches 3 mm, taking no more than 2 minutes. The amount of hand or finger pressure required will vary greatly, according to the soil. Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb.

  ✓ Alternate Procedure, Plastic Limit Device Method—Place the soil mass on the bottom plate. Place the top plate in contact with the soil mass. Simultaneously apply a slight downward force and back and forth motion to the top plate so the plate comes in contact with the side rails within 2 minutes. During this rolling process, do not allow the soil thread to contact the side rails.

- When the diameter of the thread becomes 3 mm, break the thread into six or eight pieces. Squeeze the pieces together between the thumbs and fingers of both hands into a uniform mass roughly ellipsoidal in shape and then reroll. Continue this alternate rolling to a thread 3 mm in diameter, gathering together, kneading, and rerolling, until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread.

- Gather the portions of the crumbled soil together and place in a weighed container. Immediately cover the container.

- Repeat the operations described in the above procedure until the 8-g specimen is completely tested. Determine the moisture content of the soil in the containers and record the results.

f) Calculation

- Calculate the plastic limit, expressed as the water content in percentage of the mass of the oven dry soil, as follows:

$$\text{Plastic Limit} = \frac{\text{mass of water}}{\text{mass of oven-dry soil}} \times 100 \quad \text{..... eq. (11)}$$

Report the plastic limit to the nearest whole number.

- Calculate the plasticity index of a soil as the difference between its liquid limit and its plastic limit, as follows:

$$\text{Plasticity Index} = \text{liquid limit} - \text{plastic limit} \quad \text{..... eq. (12)}$$

- Report the difference calculated between liquid limit and plastic limit as the plasticity index, except under the following conditions:

  ✓ When the liquid limit or plastic limit cannot be determined, report the plasticity index as NP (non-plastic).

  ✓ When the plastic limit is equal to, or greater than, the liquid limit, report the plasticity index as NP.

g) Report

The test report shall include the following:

- ✓ Type of material and sample identification
- ✓ The Plastic Limit result of the soil sample
- ✓ The Plastic Index result of the soil sample

2.2.1.5 Unit Weight

a) Definition

Unit Weight of Soil – is defined as the weight per unit volume of soil mass. [A. Tefera]

b) Significance and use

This test is used to determine the in-place density of soils. This test can also be used to determine density of compacted soils used in the construction of structural fills, highway embankments, or earth dams.

c) Apparatus

The apparatus shall consist of the following:

- Straightedge
- Balance
- Moisture can
- Drying oven
- Caliper

d) Procedure

- Extrude the soil sample from the cylinder or block using the extruder.
- Cut a representative soil specimen from the extruded sample.
- Determine and record for the cylinder sample the length (L), diameter (D) and mass, and for the block sample the length (L), height (H), width (W) and mass of the soil specimen.
- Determine and record the moisture content of the soil (w).

e) Calculation

- Determine the moisture content
- Determine the volume of the soil sample
  - ✓ For the cylinder sample

$$V = \frac{\pi D^2 L}{4} \qquad \text{..... eq. (13)}$$

  - ✓ For the block sample

$$V = L \times H \times W \qquad \text{..... eq. (14)}$$

Where
V - Volume of the sample
L – Length of the sample
D - Diameter of the sample (cylinder sample)
H – Height of the sample(block sample)
W – Width of the sample(block sample)

- Calculate bulk density (ρt) of soil

$$\rho_t = \frac{M_t}{V} \qquad \text{..... eq. (15)}$$

- Calculate dry density (ρd) of soil

$$\rho_d = \frac{\rho_t}{1+w}$$ ..... eq. (16)

Where
ρd = Dry density
ρt = Bulk density
Mt = Mass of the sample

2.2.1.6 Compaction test

a) Definition

Compaction - is the densification of soils by the application of mechanical energy. It may also involve a modification of the water content as well as the gradation of the soil. [Robert]

Maximum dry unit weight - is the maximum unit weight that a soil can attain using a specified means of compaction.

Optimum water content - is the water content required to allow a soil to attain its maximum dry unit weight following a specified means of compaction.

b) Significance and use

The objective of compaction is the improvement of the engineering properties of the soil mass. There are several advantages which occur through compaction:

- Detrimental settlements can be reduced or prevented.
- Soil strength increases and slope stability can be improved
- Bearing capacity of pavement sub grades can be improved.
- Undesirable volume changes, for example, caused by frost action, swelling, and shrinkage may be controlled. [Robert]

I) Compaction (Moisture-Density Relations of Soils Using a 2.5Kg Rammer and a 305mm Drop

c) Apparatus

- Molds - The molds shall be solid-wall, metal cylinders.
- Rammer - Metal rammer with a mass of 2.495 ± 0.009 kg
- Sample Extruder (for Solid-Walled Molds Only)
- Balance and Scales
- Drying oven
- Straightedge
- Sieves
- Mixing tools – Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc.
- Containers

II) Compaction (Moisture-Density Relations of Soils Using a 4.54Kg Rammer and a 457mm Drop

c) Apparatus

- Molds - The molds shall be solid-wall, metal cylinders.
- Rammer - Metal rammer with a mass of 4.536 ± 0.009 kg
- Sample Extruder (for Solid-Walled Molds Only)
- Balance and Scales
- Drying oven
- Straightedge
- Sieves
- Mixing tools – Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.
- Containers

d) Test sample

- If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus that is maintained at a temperature not exceeding 60ºC. Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

- Sieve an adequate quantity of the representative pulverized soil over the 4.75-mm (No. 4) sieve. Discard the coarse material, if any, retained on the 4.75-mm (No. 4) sieve.

- Select a representative sample, with a mass of approximately 3 kg or more, of the soil prepared as described in the above steps.

e) Procedure

- Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four percentage points below optimum moisture content.

- Form a specimen by compacting the prepared soil in the 101.60-mm mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 125 mm. Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or a similar device having a face diameter of approximately 50 mm. Following compaction of each of the first two layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed using a knife or other suitable device and evenly distributed on top of the layer. Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 305 mm above the elevation of the soil when a sleeve-type rammer is used, or from 305 mm above the approximate elevation of compacted soil when a

stationary mounted type of rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process.

- Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge, and determine the mass of the mold and moist soil in kilograms to the nearest five grams. Calculate the wet density, W1.

- Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces and weigh immediately. Determine the moisture content and record the results.

- Thoroughly break up the remaining portion of the molded specimen until it will pass through a 4.75-mm (No. 4) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amount to increase the moisture content of the soil 1 to 2 percentage points (water content increments should not exceed 2.5 percent except when heavy clay soils or organic soils exhibiting flat elongated curves are encountered; the water content increments may be increased to a maximum of 4 percent) and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet unit mass, W1, per cubic meter of the compacted soil.

f) Calculation

- The wet density can be determined using

$$W1 = (A - B) / V \qquad \text{…….. eq. (17)}$$

Where:
A = mass of compacted specimen and mold;
B = mass of mold;
V = volume of mold; and
W1 = wet density.

- The dry density is related to the wet density as follows:

$$W = \frac{W_1}{w + 100} \times 100 \qquad \text{……. eq. (18)}$$

where:
w = moisture content (percent) of the specimen
W = dry density, in kilograms per cubic meter of compacted soil of compacted soil.

g) Report
- The report shall include the following:
  - ✓ The optimum moisture content, as a percentage, to the nearest whole number.
  - ✓ The maximum density in kilograms per cubic meter to the nearest 10 kg/m3 to the nearest whole number.

2.2.1.7 Free Swell Tests

a) Definition

Free swell - is the increase in volume of soil without any external constraint when subjected to submergence in water.

b) Significance and use

This test gives a fair approximation of the degree of expansiveness of a given soil sample.

c) Apparatus

The apparatus used:
- Sieve of size 425µm
- Oven
- Balance
- Graduated glass cylinder - 100ml capacity

d) Procedure
- Take a specimen of 10g each of pulverized soil passing through 425µm Sieve and oven-dry.
- Pour the soil specimen into a graduated glass cylinder of 100ml capacity.
- Measure the initial volume of the sample
- Remove entrapped air by gently shaking or stirring with a glass rod.
- Allow the suspension to attain the state of equilibrium (for not less than 24hours).
- Measure the final volume of the soil sample.

e) Calculation

$$\text{Free swell (\%)} = [(Vf - Vi) / Vi] * 100 \quad \text{…….. eq. (19)}$$

Where
Vi = Initial Volume of the soil sample
Vf = Final Volume of the soil sample

When the Value of Free swell is
- Free swell < 50%, Not Expansive
- Free swell between 50-100%, Marginal

- Free swell >100, Expansive

2.2.1.8 California Bearing Ratio (CBR)

a) Significance and use

- This test method is used to evaluate the potential strength of subgrade, sub base, and base course material, including recycled materials, for use in road and airfield pavements. The CBR value obtained in this test forms an integral part of several flexible pavement design methods.

b) Apparatus

- Molds - The molds shall be cylindrical in shape, made of metal, with an internal diameter of 152.40 ± 0.66 mm and a height of 177.80 ± 0.46 mm.
- Spacer Disk
- Rammer
- Apparatus for Measuring Expansion
- Indicators - Two dial indicators: each indicator shall have a 25-mm throw and read to 0.02mm.
- Surcharge Weights - One annular metal weight with a center hole approximately 54.0 mm in diameter and several slotted or split metal weights, all 149.2 ± 1.6 mm in diameter and each having a mass of 2.27 ± 0.04kg.
- Penetration Piston - A metal piston of circular cross-section having diameter of 49.63 ± 0.13 mm, area = 1935 mm2 and not less than 102 mm long.
- Loading Device - A compression-type apparatus capable of applying a uniformly increasing load up to a capacity sufficient for the material being tested at a rate of 1.3 mm/min., used to force the penetration piston into the specimen.
- Soaking Tank
- Drying Oven
- Moisture Content Containers
- Miscellaneous – Miscellaneous tools such as mixing pans, spoons, straightedge, filter paper, balances, etc.

c) Test sample

- The sample shall be handled and specimen(s) for compaction shall be prepared in accordance with the procedures given in compaction for compaction in a 152.4-mm mold except as follows:

  ✓ If all material passes a 19.0-mm sieve, the entire gradation shall be used for preparing specimens for compaction without modification. If there is material retained on the 19.0-mm sieve, the material retained on the 19.0-mm sieve shall be removed and replaced by an equal amount of material passing the 19.0-mm sieve and retained on the 4.75-mm (No. 4) sieve

obtained by separation from portions of the sample not otherwise used for testing.

- ✓ Bearing Ratio at Optimum Water Content - From a sample having a mass of 35 kg or more, select a representative portion having a mass of approximately 11 kg for a moisture density test and divide the remainder of the sample to obtain three representative portions having a mass of approximately 6.8 kg each.

- ✓ Bearing Ratio for a Range of Water Content - From a sample having a mass of 113 kg or more, select at least five representative portions having a mass of approximately 6.8 kg each for use in developing each compaction curve.

d) Procedure

- Bearing Ratio at Optimum Water Content:
  - ✓ Normally, three specimens must be compacted so that their compacted densities range from 95 percent (or lower) to 100 percent (or higher) of the maximum dry density determined as above.

  - ✓ Clamp the mold to the base plate, attach the extension collar and weigh to the nearest 5 g. Insert the spacer disk into the mold and place a coarse filter paper on top of the disk.

  - ✓ Mix each of the three 6.8-kg portions prepared as in the test sample procedure with sufficient water to obtain the optimum moisture content determined in above.

  - ✓ Compact the first of the three portions of soil-water mixture into the mold, using three equal layers and appropriate rammer, if maximum density was determined by proctor test, or five equal layers if maximum density was determined by modified proctor test, to give a total compacted depth of about 125 mm, compacting each layer with the lowest selected number of blows in order to give a compacted density of 95 percent or less of the maximum density.

  - ✓ Determine the moisture content of the material being compacted at the beginning and end of the compaction procedure (two samples). Each moisture sample shall have a mass of at least 100 g for fine-grained soils and 500 g for coarse-grained soils.

  - ✓ Remove the extension collar, and using a straightedge, trim the compacted soil even with the top of the mold. Surface

irregularities should be patched with small-sized material. Remove the spacer disk, place a coarse filter paper on the perforated base plate, invert the mold and compacted soil, and place on the filter paper so the compacted soil is in contact with the filter paper. Clamp the perforated base plate to the mold and attach the collar. Determine the mass of the mold and specimen to the nearest 5 g.

- ✓ Compact the other two 6.8-kg portions in accordance with the procedure in the above, except that an intermediate number of blows per layer should be used to compact the second specimen and the highest number of blows per layer shall be used to compact the third specimen.

- Bearing Ratio for a Range of Water Content:
  - ✓ Prepare specimens in accordance with bearing ratio for a range of water content specified as above. Perform all compaction in the CBR molds. Each specimen used to develop the compaction curves for the 10-blow, 25-blow, and 56-blow per layer compactive efforts shall be penetrated. In cases where the specified unit mass is at or near 100 percent maximum dry unit mass, it will be necessary to include a compactive effort greater than 56 blows per layer.

e) Soaking

- Place the swell plate with adjustable stem on the soil sample in the mold and apply sufficient annular weights to produce an intensity of loading equal to the mass of the sub base and base courses and surfacing above the tested material. The total mass shall be a minimum of 4.54 kg. Additional mass shall be added in increments of 2.26 kg.
- Place the tripod with dial indicator on top of the mold and make an initial dial reading.
- Immerse the mold in water to allow free access of water to top and bottom of the specimen. During soaking, maintain the water level in the mold and the soaking tank approximately 25 mm above the top of the specimen. Soak the specimen 96 hours (4 days).
- At the end of 96 hours, make a final dial reading on the soaked specimens and calculate the swell as a percentage of the initial sample length:

$$\text{Percent swell} = \frac{\text{Change in length in mm during soaking}}{116.43\ \text{mm}} \times 100 \qquad \text{…….. eq. (20)}$$

- Remove the specimens from the soaking tank, pour the water off the top and allow to drain downward for 15 minutes. Care shall be taken not to disturb the surface of the specimens during removal of the water. After draining, remove the surcharge weights, perforated plates, and top filter paper.

f) Penetration Test

- Application of Surcharge - Place a surcharge of annular and slotted weights on the specimens equal to that used during soaking. To prevent displacement of soft materials into the hole of the surcharge weights, seat the penetration piston with a 44 N load after one surcharge weight has been placed on the specimen. After seating the penetration piston the remainder of the surcharge weights shall then be placed around the piston.
- Seating Piston - Seat the penetration piston with a 44 N load, then set both the penetration dial indicator and the load indicator to zero.
- Application of Load - Apply the loads to the penetration piston so the rate of penetration is uniform at 1.3 mm/min. Record the load when the penetration is 0.64, 1.27, 1.91, 2.54, 3.81, 5.08, and 7.62 mm. Load readings at penetrations of 10.16 and 12.70 mm may be obtained if desired.

g) Calculation

- California Bearing Ratio - The corrected load values shall be determined for each specimen at 2.54 and 5.08 mm penetration. California Bearing Ratio values are obtained in percent by dividing the corrected load values at 2.54 and 5.08 mm by the standard loads of 6.9 and 10.3 MPa respectively, and multiplying these ratios by 100.

$$CBR = \frac{\text{Corrected load value}}{\text{Standard load}} \times 100 \qquad \text{..... eq. (21)}$$

- The CBR is generally selected at 2.54 mm penetration. If the ratio at 5.08 mm penetration is greater, the test shall be rerun. If the check test gives a similar result, the ratio at 5.08 mm penetration shall be used.

h) Report

- The report shall include the following information for each specimen:
  - ✓ Compaction effort (number of blows per layer).
  - ✓ Dry density as molded, percent.
  - ✓ Moisture content as molded, percent.
  - ✓ Swell (percent of original length), percent.
  - ✓ California Bearing Ratio, percent.

2.2.2 For Aggregates

2.2.2.1 Moisture Content of Aggregates

a) Definition

Moisture or water content of aggregate – the ratio, expressed as a percentage, of the mass of water in a given mass of aggregate to the solid particles. [AASHTO]

b) Apparatus

The apparatus shall consist of the following:

- Drying Oven
- Balance
- Containers

c) Test sample

Select a representative quantity of aggregate in the amount indicated in the method of test.

d) Procedure

Weigh a clean, dry container with its lid and place the moisture content sample in the container. Replace the lid immediately and weigh the container, including the lid and the moist sample. Remove the lid and place the container with the moist sample in the drying oven maintained at a temperature of 110 ± 5ºC and dry to a constant mass. Immediately upon removal from the oven, place the lid and allow the sample to cool to room temperature. Weigh the container including the lid and the dried sample. {AASHTO]

e) Calculation

Calculate the moisture content of aggregate as follows:

$w = [(\text{mass of moisture}) / (\text{mass of oven-dry aggregate})] \times 100$

$w = [(W_1 - W_2) / (W_2 - W_c)] \times 100$ ……. eq. (22)

Where:

w = moisture content, percent;

W_1 = mass of container and moist aggregate, g;

W_2 = mass of container and oven-dried aggregate, g; and

W_c = mass of container, g.

Calculate the percent of moisture content to the nearest 0.1 percent.

2.2.2.2 Specific Gravity and Water Absorption

a) Definition

Absorption - the increase in the mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass. The aggregate is considered "dry" when it has been maintained at a temperature of 110 ± 5ºC for sufficient time to remove all uncombined water by reaching a constant mass.

Specific gravity - the ratio of the mass (or weight in air) of a unit volume of a material to the mass of the same volume of gas-free distilled water at stated temperatures. Values are dimensionless.

b) Significance and use
- Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential.

c) Apparatus
- Balance
- Pycnometer
- Mold
- Tamper

d) Test sample
- Obtain approximately one kilogram of the fine aggregate from the sample.
- Dry it in a suitable pan or vessel to constant mass at a temperature of 110 ± 5ºC. Allow it to cool to comfortable handling temperature, cover with water, either by immersion or by the addition of at least 6 percent moisture to the fine aggregate and permit to stand for 15 to 19 hours.
- Decant excess water with care to avoid loss of fines, spread the sample on a flat, nonabsorbent surface exposed to a gently moving current of warm air, and stir frequently to secure homogeneous drying. If desired, mechanical aids such as tumbling or stirring may be employed to assist in achieving the saturated surface-dry condition.

e) Procedure
- Make and record all mass determinations to 0.1 g.
- Partially fill the pycnometer with water. Immediately introduce into the pycnometer 500 ± 10 g of saturated surface-dry fine aggregate prepared as described in the above section, and fill with additional water to approximately 90 percent of capacity. Manually roll, invert, and agitate or use a combination of these actions to eliminate all air bubbles in the pycnometer.
- Remove the fine aggregate from the pycnometer, dry to constant mass at a temperature of 110 ± 5ºC, cool in air at room temperature for 1.0 ± 0.5 hours and determine the mass.
- Determine the mass of the pycnometer filled to its calibration capacity with water at 23.0 ± 1.7ºC.

f) Calculation

- Calculate the percentage of absorption as follows:

$$\text{Absorption, \%} = [(A - D)/D] \times 100 \quad \text{…….. eq. (23)}$$

- Calculate the apparent specific gravity, 23/23ºC as follows:

$$\text{Apparent sp gr} = D/(C + D - B) \quad \text{…….. eq. (24)}$$

where:
A= mass of saturated surface-dry specimen, g; and
B = mass of pycnometer with specimen and water to calibration mark, g.
C = mass of pycnometer filled with water, g;
D = mass of oven-dry specimen in air, g;

g) Report

- Report specific gravity results to the nearest 0.001 and absorption to the nearest 0.1 percent.

2.2.2.3 Sieve Analysis of Fine and Coarse Aggregate Grain Size Analysis

a) Significance and use

This method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

b) Apparatus

- Balance
- Sieves
- Mechanical Sieve Shaker
- Oven

c) Test sample

- Sample the aggregate in accordance with sampling of aggregates. The mass of the field sample shall be the mass shown in sampling of aggregates or four times the mass required in the table 6, whichever is greater.
- Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in T 248. The sample for test shall be the approximate mass desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted.

- Fine Aggregate - The size of the test sample of aggregate, after drying, shall be 300 g minimum.
- Coarse Aggregate—The mass of the test sample of coarse aggregate shall conform with the following:

Nominal Maximum Size Square Openings, mm (in.)	Minimum Mass of Test Sample, kg (lb)
9.5 (3/8)	1 (2)
12.5 (1/2)	2 (4)
19.0 (3/4)	5 (11)
25.0 (1)	10 (22)
37.5 (1 1/2)	15 (33)
50 (2)	20 (44)
63 (2 1/2)	35 (77)
75 (3)	60 (130)
90 (3 1/2)	100 (220)
100 (4)	150 (330)
125 (5)	300 (660)

Table 6 - Representative quantity of aggregate for sieve analysis test

- Coarse and Fine Aggregates Mixtures—The mass of the test sample of coarse and fine aggregate mixtures shall be the same as for coarse aggregate in the above table.

d) Procedure

- Dry the test sample to constant mass at a temperature of 110 ± 5ºC and determine the mass of it to the nearest 0.1 percent of the total original dry sample mass.
- Select sieves with suitable openings to furnish the information required by the specifications covering the material to be tested. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample, or portion of the sample if it is to be sieved in more than one increment, on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period.
- Limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation.
- Continue sieving for a sufficient period
- Unless a mechanical sieve shaker is used, hand sieve particles obtained on the 75 mm by determining the smallest sieve opening through which each particle will pass by rotating the particles, if necessary, in order to determine

whether they will pass through a particular opening; however, do not force particles to pass through an opening.

- Determine the mass of each size increment on a scale or balance conforming to the requirements to the nearest 0.1 percent of the total original dry sample mass. The total mass of the material after sieving should check closely with the original mass of sample placed on the sieves. If the amounts differ by more than 0.3 percent, based on the original dry sample mass, the results should not be used for acceptance purposes.

e) Calculation

- Calculate percentages passing, total percentages retained, or percentages in various size fractions to the nearest 0.1 percent on the basis of the total mass of the initial dry sample.

f) Report

- Depending upon the form of the specifications for use of the material under test, the report shall include one of the following:
  - ✓ Total percentage of material passing each sieve, or
  - ✓ Total percentage of material retained on each sieve, or
  - ✓ Percentage of material retained between consecutive sieves.

- Report percentages to the nearest whole number, except if the percentage passing the 75-μm (No. 200) sieve is less than 10 percent, it shall be reported to the nearest 0.1 percent.

2.2.2.4 Flakiness Index (FI)

a) Main Principles

The Flakiness Index of an aggregate sample is found by separating the flaky particles and expressing their mass as a percentage of the mass of the sample. The test is applicable to material passing a 63mm sieve and retained on a 6.3mm sieve.

b) Significance and use

Flakiness Index – is one of the tests used to classify aggregates and stones. For base course and wearing course aggregates the presence of flaky particles are considered undesirable as they may cause inherent weakness with possibilities of breaking down under heavy loads. Aggregates are classified as flaky when they have a thickness of less than 60% of their mean sieve size.

c) Apparatus

- A sample divider
- Drying oven

- Balance
- Test sieves
- Metal trays
- A Metal thickness gauge

d) Test sampling and Procedure
- Carry out a sieve analysis
- Discard all aggregates retained on the 63mm sieve and all aggregate passing the 6.3mm sieve.
- Weigh each of the individual size-fractions retained on the sieves, and store them in trays with their size marked on the trays.
- From the sums of masses of the fractions in the trays (M1), calculate the individual percentage retained on each of the various sieves. Discard any fraction whose mass is 5% or less of mass M1, Record the mass remaining (M2).
- Gauge each fraction using the thickness gauge. Select the gauge appropriate to the size-fraction under test and gauge each particle of that size-fraction separately by hand.
- Combine and weigh all the particles passing each of the gauges, (M3).

e) Calculation
The value of the Flakiness Index is calculated as

$$\text{Flakiness Index, } FI = \frac{M_3}{M_2} \times 100 \quad \text{..... eq. (25)}$$

where:
FI = Flakiness Index
M2 = mass remaining from discarded fraction whose mass is 5% or less of mass M1

M3 = Combine and weigh all the particles passing each of the gauges

f) Report
The test report shall include the following:
- The Flakiness Index of the test sample. The Flakiness Index shall be expressed to the nearest whole number.

2.2.2.5 Los Angeles Abrasion Test (LAA)

a) Definition
The Los Angeles Abrasion Test – is a measure of degradation of mineral aggregates of standard grading resulting from a combination of actions including

abrasion, impact and grinding in a rotating steel drum containing a specified number of steel spheres.

b) Significance and use

The Los Angeles test has been widely used as an indicator of the relative quality of various sources of aggregate having similar mineral compositions.

c) Apparatus

- Los Angeles Testing Machine
- Drying oven
- Balance
- Charge

d) Test sample

- The test sample shall be washed and oven dried at 105^{O}C to 110 ^{O}C to substantially constant mass.
- The sample shall be separated into individual size fractions and recombined to the grading of Table 7 nearly corresponding to the range of sizes in the aggregates.
- The mass of the sample shall prior to test shall be recorded to the nearest 1g.

Sieve Size		Mass of indicated Sizes (g)			
Passing	Retained on	Grading			
		A	B	C	D
37.5 mm	25.0 mm	1250 ± 25			
25.0 mm	19.0 mm	1250 ± 25			
19.0 mm	12.5 mm	1250 ± 10	2500 ± 10		
12.5 mm	9.5 mm	1250 ± 10	2500 ± 10		
9.5 mm	6.3 mm			2500 ± 10	
6.3 mm	4.75 mm			2500 ± 10	
4.75 mm	2.36 mm				5000 ± 10
Total		5000 ± 10	5000 ± 10	5000 ± 10	5000 ± 10

Grading A: Suitable for Graded Crushed Stone and Natural Gravel for Base Course.
Grading B: Suitable for chippings for Surface Dressing, nominal sizes 20 mm and 14 mm.
Grading B: Suitable for chippings for Surface Dressing, nominal size 10 mm.
Grading B: Suitable for chippings for Surface Dressing, nominal size 7 mm.

Table 7 Grading of the test samples

e) Procedure

- Place the test sample and the charge in the Los Angeles testing machine and rotate the machine at a speed of 30 to 33 rpm for 500 revolutions.
- After the 500 revolutions, discharge the material from the machine and make ta preliminary separation of the sample in a sieve coarser than the 1.70mm sieve. Sieve the finer portion on a 1.70mm sieve.

- Wash the material coarser than 1.70mm sieve.
- Oven-dry at 105^{0}C to 110 ^{0}C to substantially constant mass, and weight to the nearest 1g.

f) Calculation

- Express the loss (difference between the original mass and the final mas of the test sample as a percentage of the original mass of the test sample:

$$\text{LAA value} = \left(\frac{m_1 - m_2}{m_1}\right) \times 100\ (\%) \quad \text{..... eq. (26)}$$

where:
LAA = Los Angeles Abrasion value
m1 = original mass of the test sample
m2 = final mass of the test sample

g) Report

The test report shall include the following

- Type of material and sample identification
- LAA value of the test sample. Report the value as the percentage loss.

2.2.2.6 Soundness of Aggregate by Use of Sodium Sulfate

a) Definition

This method covers the procedure to be followed in testing aggregates to determine their resistance to disintegration by saturated solutions of sodium sulfate. This is accomplished by repeated immersion in saturated solutions of sodium or magnesium sulfate followed by oven drying to partially or completely dehydrate the salt precipitated in permeable pore spaces. The internal expansive force, derived from the rehydration of the salt upon re-immersion, simulates the expansion of water on freezing.

b) Significance and use

- This test method furnishes information helpful in judging the soundness of aggregates subject to weathering action, particularly when adequate information is not available from service records of the material exposed to actual weathering conditions.

c) Apparatus

- Sieves - with square openings of the following sizes, for sieving the samples in accordance

4.75 mm	(No. 4)	63 mm
4.00 mm	(No. 5)	50 mm
2.36 mm	(No. 8)	37.5 mm
1.18 mm	(No. 16)	31.5 mm
600 µm	(No. 30)	25.0 mm
300 µm	(No. 50)	19.0 mm
150 µm	(No. 100)	16.0 mm
		12.5 mm
		9.5 mm
		8.0 mm

Table 8 – Sieve size opening

- Containers for Samples
- Coarse Aggregate—2.36-mm (No. 8) Size
- Fine Aggregate—250-µm (No. 60) Size
- Apparatus for Immersing Samples in Solution (optional)
- Temperature Regulation
- Thermometer
- Temperature Recorder
- Balance
- Drying Oven
- Specific Gravity Measurement

d) Test sample

- Fine Aggregate—Fine aggregate for the test shall be passed through a 9.5-mm sieve. The sample shall be of such size that it will yield not less than 100 g of each of the following sizes, expressed in terms of the following sieves:

Passing Sieve	Retained on Sieve
9.5 mm ($^3/_8$ in.)	4.75 mm (No. 4)
4.75 mm (No. 4)	2.36 mm (No. 8)
2.36 mm (No. 8)	1.18 mm (No. 16)
1.18 mm (No. 16)	600 µm (No. 30)
600 µm (No. 30)	300 µm (No. 50)

Table 9 – Fine Aggregate Sample

- Coarse Aggregate—Coarse aggregate for the test shall consist of material from which the sizes finer than the 4.75-mm (No. 4) sieve have been removed. The sample shall be of such a size that it will yield the amounts indicated in Table 10.

Sieve Size	Mass, g
63 mm to 37.5 mm ($2^1/_2$ in. to $1^1/_2$ in.)	5000 ± 300
Consisting of:	
50-mm to 37.5-mm (2-in. to $1^1/_2$-in.) material	2000 ± 200
63-mm to 50-mm ($2^1/_2$-in. to 2-in.) material	3000 ± 300
37.5 mm to 19.0 mm ($1^1/_2$ in. to $^3/_4$ in.)	1500 ± 50
Consisting of:	
25.0-mm to 19.0-mm (1-in. to $^3/_4$ -in.) material	500 ± 30
37.5-mm to 25.0-mm ($1^1/_2$-in. to 1-in.) material	1000 ± 50
19.0 mm to 9.5 mm ($^3/_4$ in. to $^3/_8$ in.)	1000 ± 10
Consisting of:	
12.5-mm to 9.5-mm ($^1/_2$-in. to $^3/_8$-in.) material	330 ± 5
19.0-mm to 12.5-mm ($^3/_4$-in. to $^1/_2$-in.) material	670 ± 10
9.5 mm to 4.75 mm ($^3/_8$ in. to No. 4)	300 ± 5

Table 10 - Coarse Aggregate Sample

- Fine Aggregate - Thoroughly wash the sample of fine aggregate on a 300µm (No. 50) sieve, dry to constant mass at 110º ± 5ºC and separate into the different sizes by sieving, as follows: Make a rough separation of the graded sample by means of a nest of the standard sieves specified above. From the fractions obtained in this manner, select samples of sufficient size to yield 100 g after sieving to refusal. Weigh samples consisting of 100 ± 0.1 g out of each of the separated fractions after final sieving, record the masses of the test samples, and place in separate containers for the test.

- Coarse Aggregate - Thoroughly wash and dry the sample of coarse aggregate to constant mass at 110º ± 5ºC and separate it into the different sizes shown in above section by sieving to refusal. Weigh out quantities of the different sizes within the tolerances of specified above and combine them to the designated total mass. Record the masses of the test samples and their fractional components. In the case of sizes larger than 19.0 mm, record the number of particles in the test samples.

e) Procedure

- Storage of Samples in Solution - Immerse the samples in the prepared solution of sodium sulfate for not less than 16 hours nor more than 18 hours in such a manner that the solution covers them to a depth of at least 12.5 mm. Cover the containers to reduce evaporation and prevent the accidental addition of extraneous substances.

- Drying Samples after Immersion - After the immersion period, remove the aggregate sample from the solution, permit it to drain for 15 ± 5 minutes, and place in the drying oven.

- After constant mass has been achieved, allow the samples to cool to room temperature, when they shall again be immersed in the prepared solution.
- Repeat the process of alternative immersion and drying until the required number of cycles is obtained.

f) Calculation

- Calculate Individual Percent Loss of each size fraction (ci):

$$ci = [(ai \times bi) / ai]/100 \quad \text{..... eq. (27)}$$

Where:
ai = initial mass of each size fraction
bi = final mass of each size fraction
ci= Individual Percent Loss of each size fraction

- Calculate Normalized Percent Loss of each size fraction (di)

$$di = ci \times ei \quad \text{..... eq. (28)}$$

Where:
ci= Individual Percent Loss of each size fraction
di = Normalized Percent Loss of each size fraction
ei = Normalized Gradation Percent / Grading of original sample

- Calculate Total Percent Loss

$$f = \sum(di) \quad \text{..... eq. (29)}$$

Where:
f= Total Percent Loss

g) Report

- Mass of each fraction of each sample before test.
- Material from each fraction of the sample finer than the sieve designated for sieving after test, expressed as a percentage of the original mass of the fraction.
- Weighted average calculated from the percentage of loss for each fraction, based on the grading of the sample as received for examination.

3. SOFTWARE DEVELOPMENT

3.1 GENERAL

The Software developed in this project is used for performing, analyzing, and reporting of laboratory tests for road projects. This software is user friendly and developed using Visual Basic 2010.

3.2 ENTERING THE CODES AND DEVELOPING THE APPLICATION

In the development of the Software, programing codes are written to the corresponding tests. A **Text Box** Control is used to enter the data of Project information (Project name, Station, Depth, Material description, lab number, Date sampled, Date tested) and the input data that are collected while performing the test.

- After completing filling the necessary Project information and input data on the white **Text Box**, by clicking the **Calc.** button we can calculate the output of the test based on the input data.

- In addition there is a **Test Procedure** button that will help someone to refer Definition of the test, Use of the test, Apparatus needed, Test Sample and Test Procedure to perform the test.

- The output results will be displayed on the light grey **Label** respectively to the sample number and the test and also the necessary plot if there is any, when we click the **Calc.** button.

Logical conditions are included to avoid miss calculation of the output based on the incorrect input by the user. These incorrect inputs may be negative values of mass, volume, length, width or height of the sample and also values that are none logical like the weight of the container can't be greater than from the weight of the container and the sample. So, when the user enter these negative values or none logical values in the input box, the software automatically will not calculate the output based on the input data and a message box will appear and let the user where these values are inputted and let the user correct the values before proceeding.

3.3 INTERFACE OF THE SOFTWARE FOR THE TESTS

3.3.1 WHEN THE USER START THE SOFTWARE PROGRAM

I) When the user select **File** from the main task bar

Fig 2 – Front interface of the software

II) When the user select **Soil Mechanics Lab**. From the main task bar

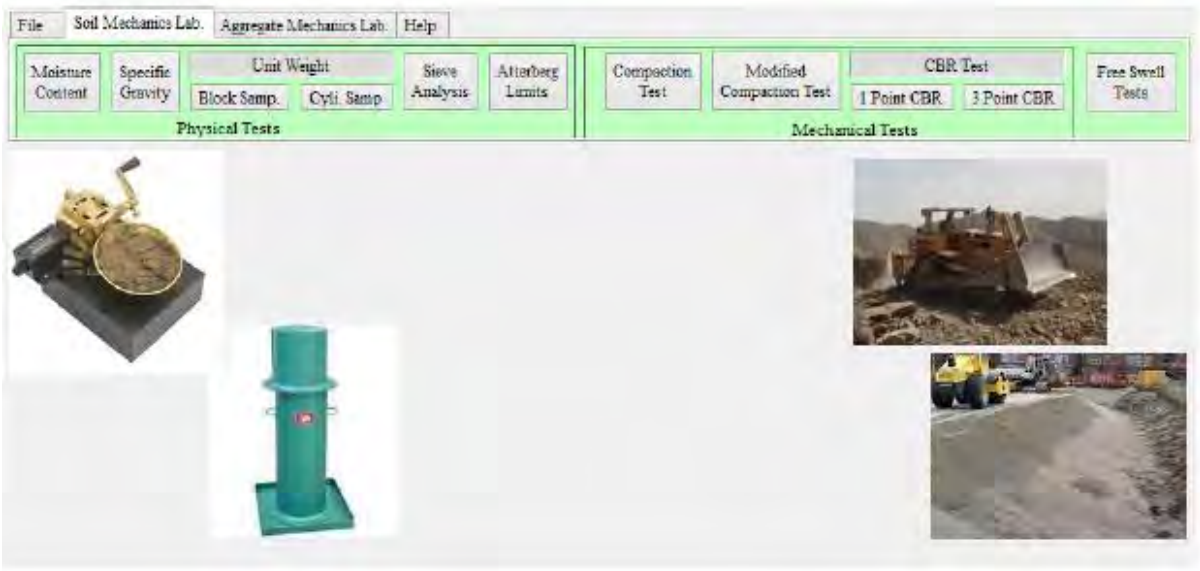

Fig 3 – Soil Mechanics Lab. interface of the software

III) When the user select **Aggregate Mechanics Lab.** From the main task bar

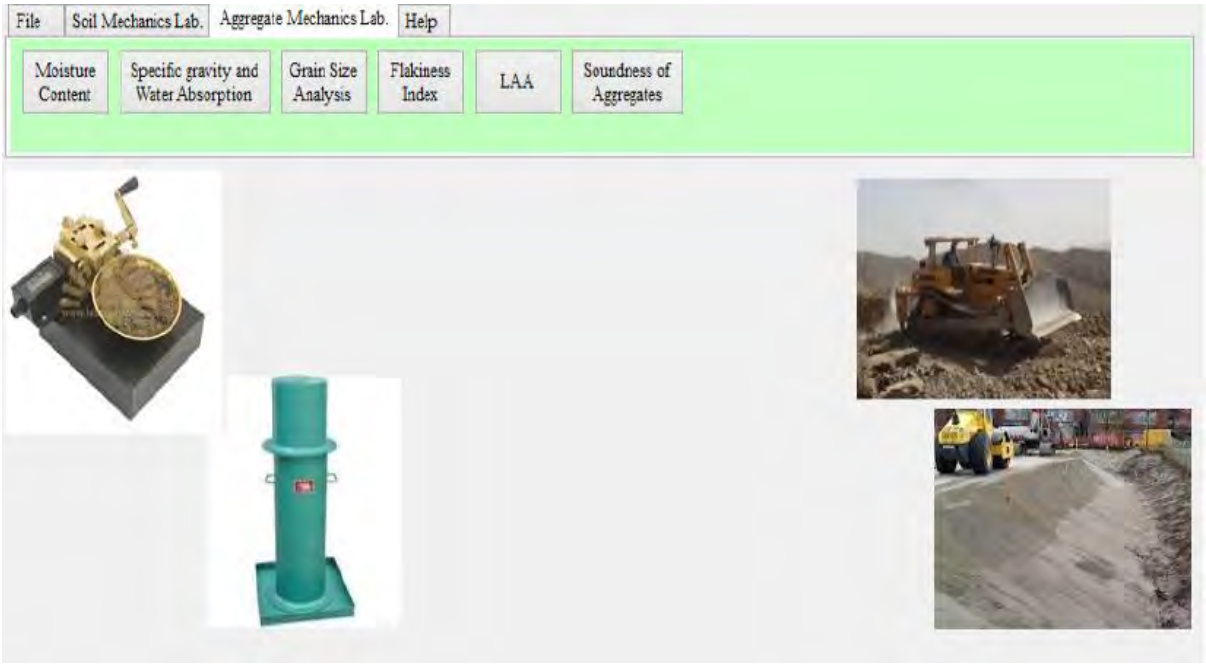

Fig 4 – Aggregate Mechanics Lab. interface of the software

IV) When the user select **Help** from the main task bar

Fig 5 – Help interface of the software

3.3.2 SOIL MECHANICS LABORATORY TEST

I) When the user select Moisture Content Test

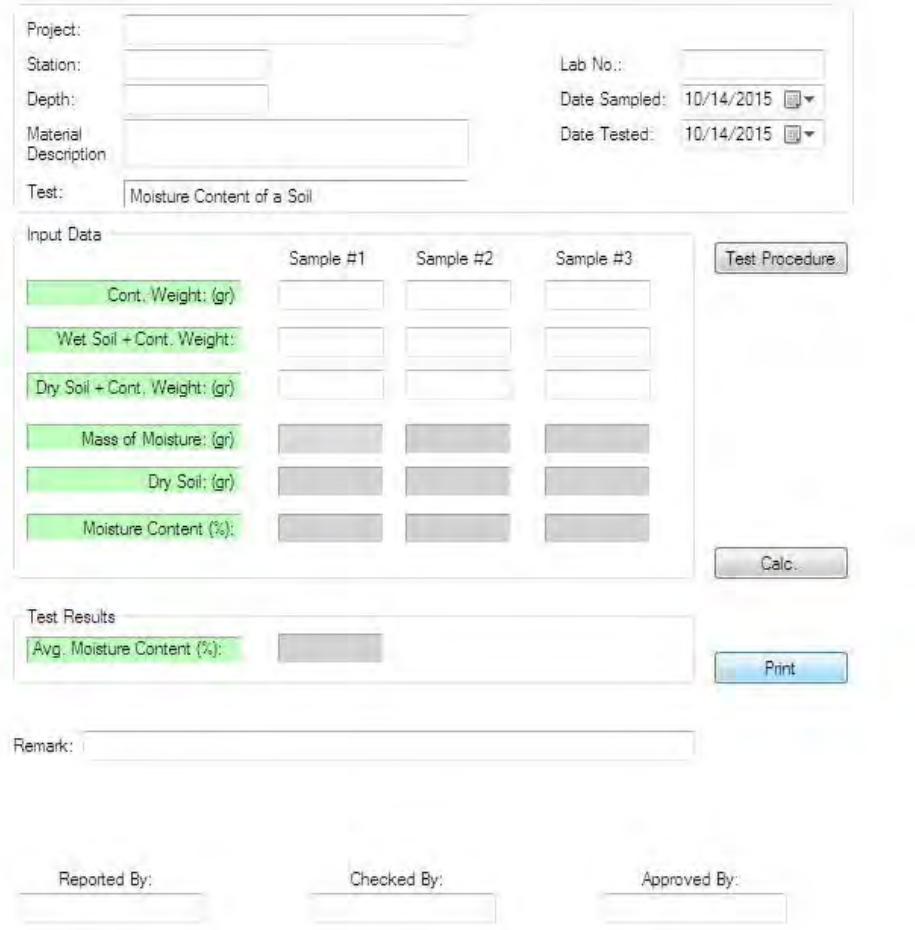

Fig 6 – Moisture Content Test interface of the software

II) When the user select Specific Gravity Test

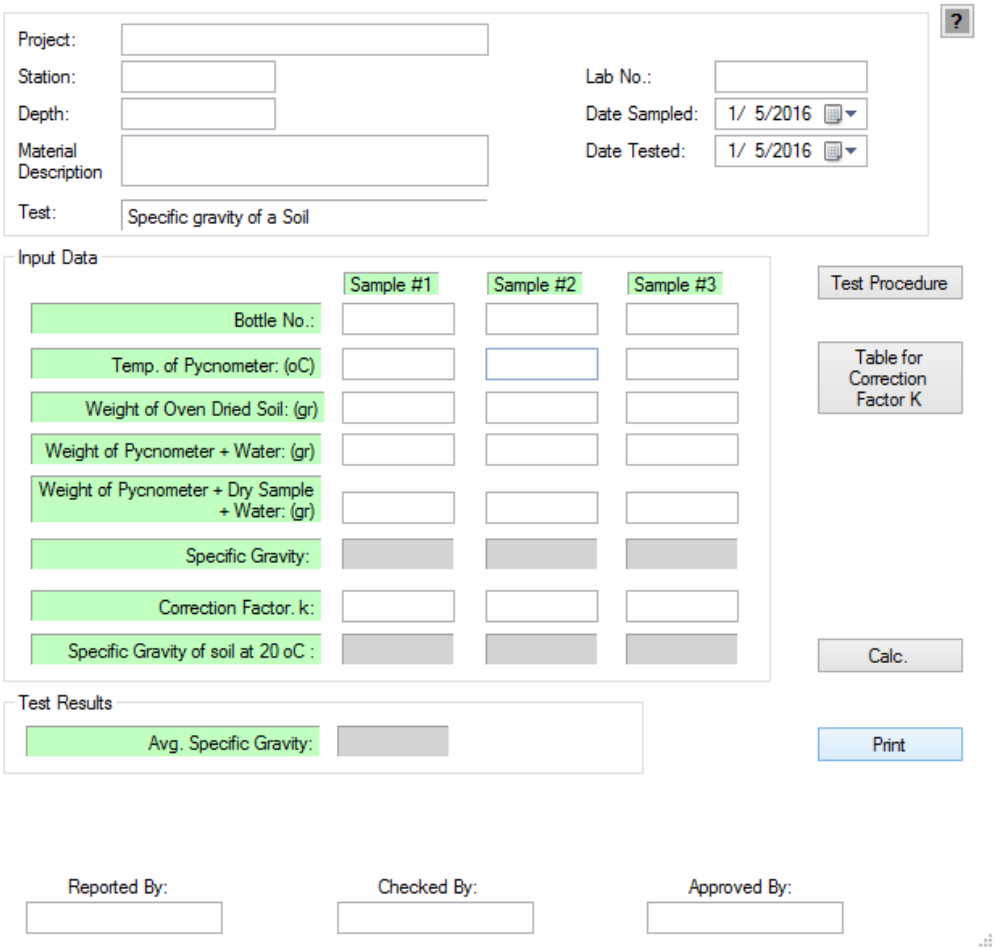

Fig 7 – Specific Gravity Test interface of the software

III) When the user select Unit Weight Test

- When the user select Unit Weight using Block sample Test

Fig 8 – Unit Weight Test (using Block sample) interface of the software

- When the user select Unit Weight using Cylindrical sample Test

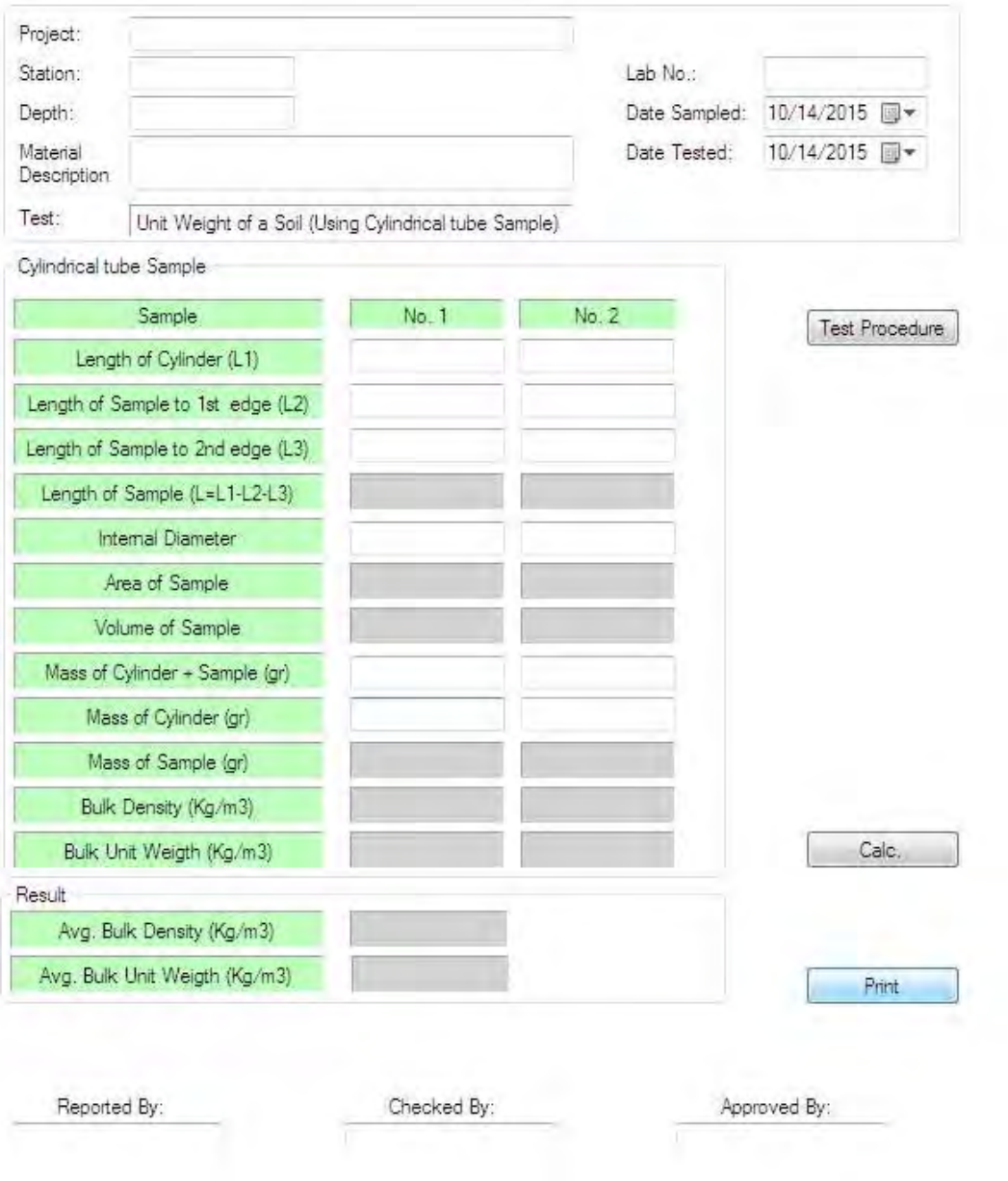

Fig 9 – Unit Weight Test (using cylindrical sample) interface of the software

IV) When the user select Sieve Analysis Test

Fig 10 – Sieve Analysis Test interface of the software

V) When the user select Atterberg Limits Test

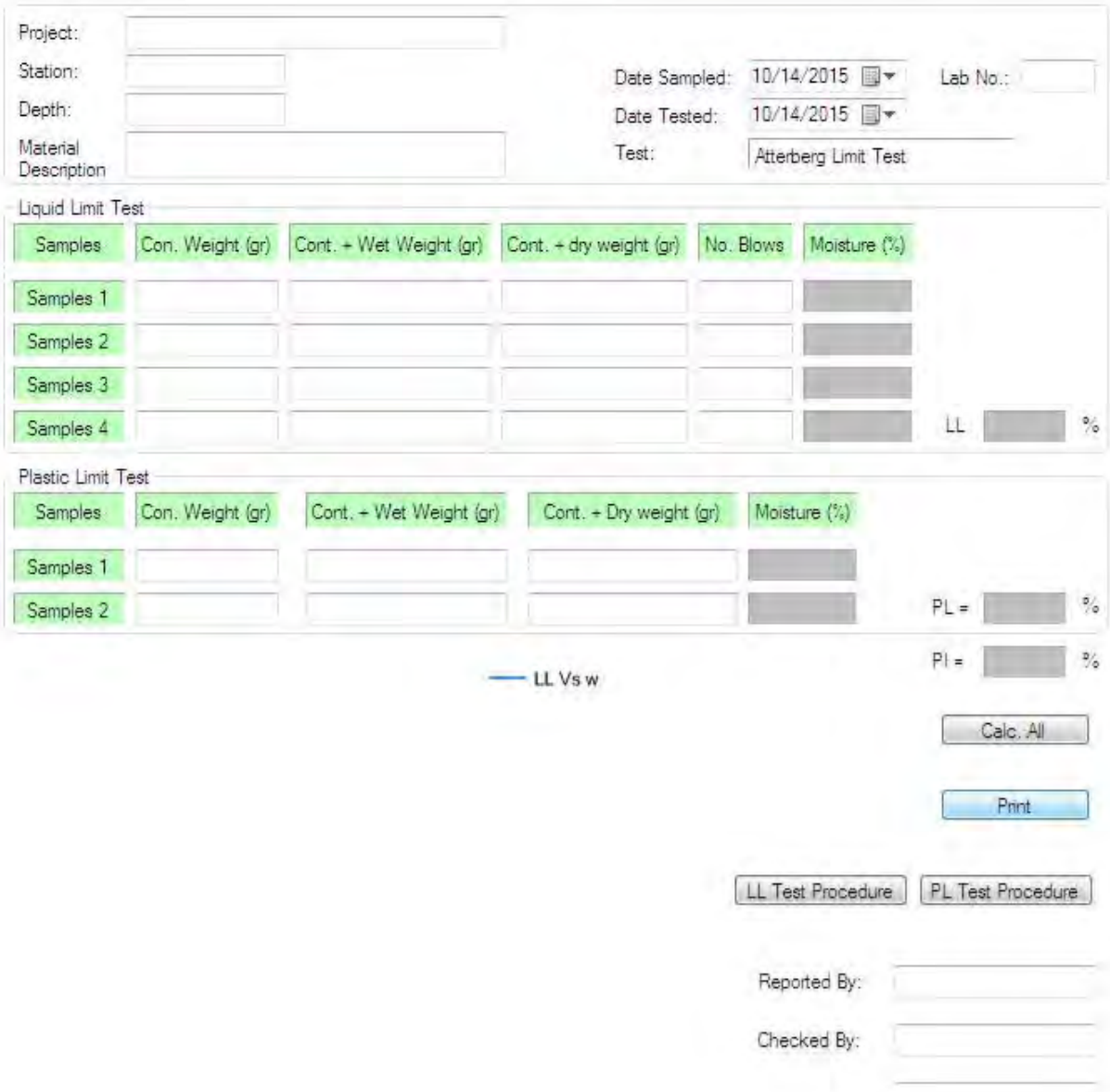

Fig 11 – Atterberg Limits Test interface of the software

I) When the user select Compaction Test

- When the user select Compaction Test

Fig 12 – Compaction Test interface of the software

- When the user select Modified Compaction Test

Fig 13 – Modified Compaction Test interface of the software

II) When the user select CBR Test

- When the user select CBR Test Using 1 Point Method

Fig 14 – CBR Test Using 1 Point Method interface of the software

- When the user select CBR Test Using 3 Point Method

Fig 15 – CBR Test Using 3 Point Method interface of the software

III) When the user select Free Swell Test

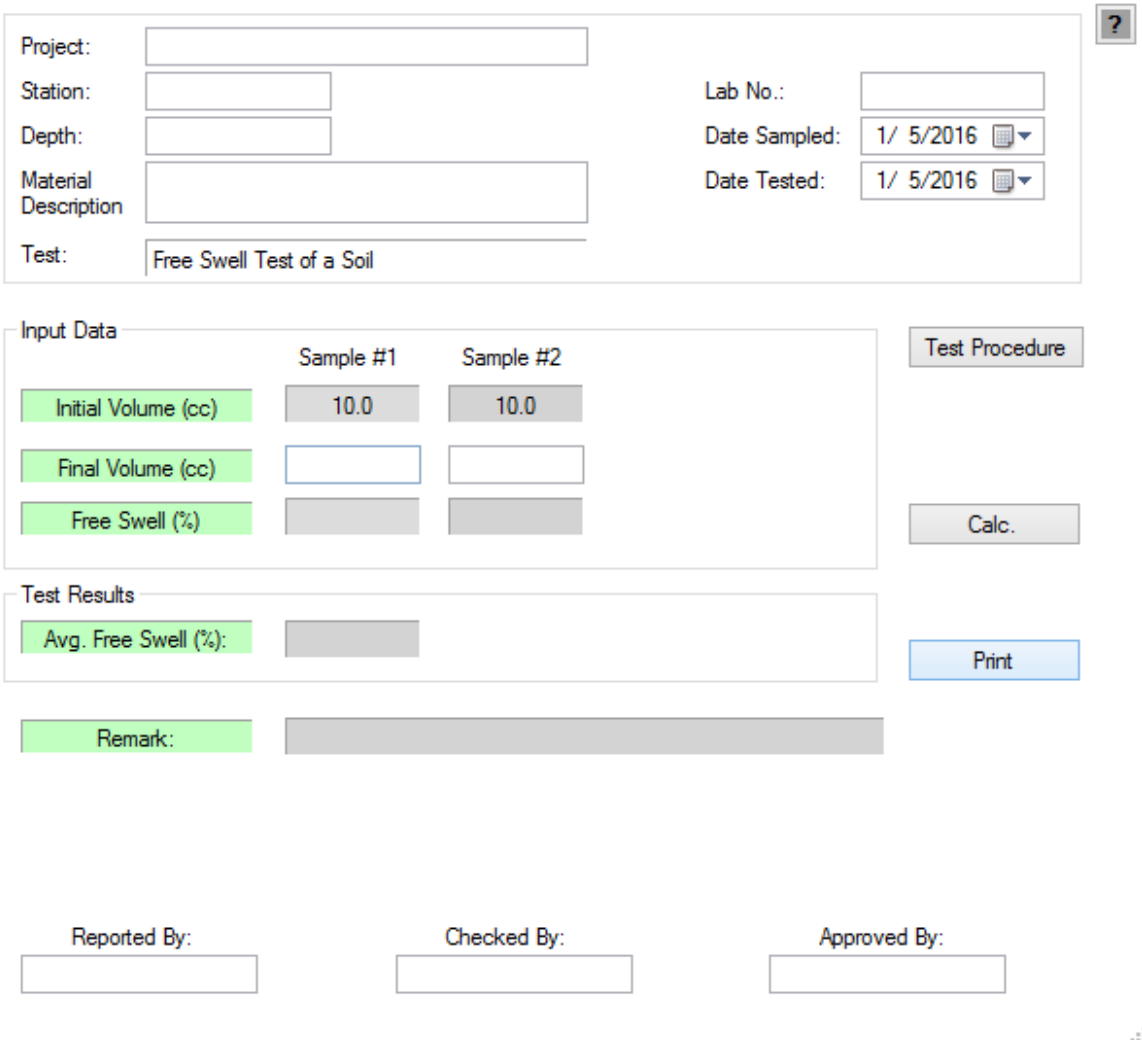

Fig 16 – Free Swell Test interface of the software

3.3.3 AGGREGATE MECHANICS LABORATORY TEST

- When the user select Moisture Content Test

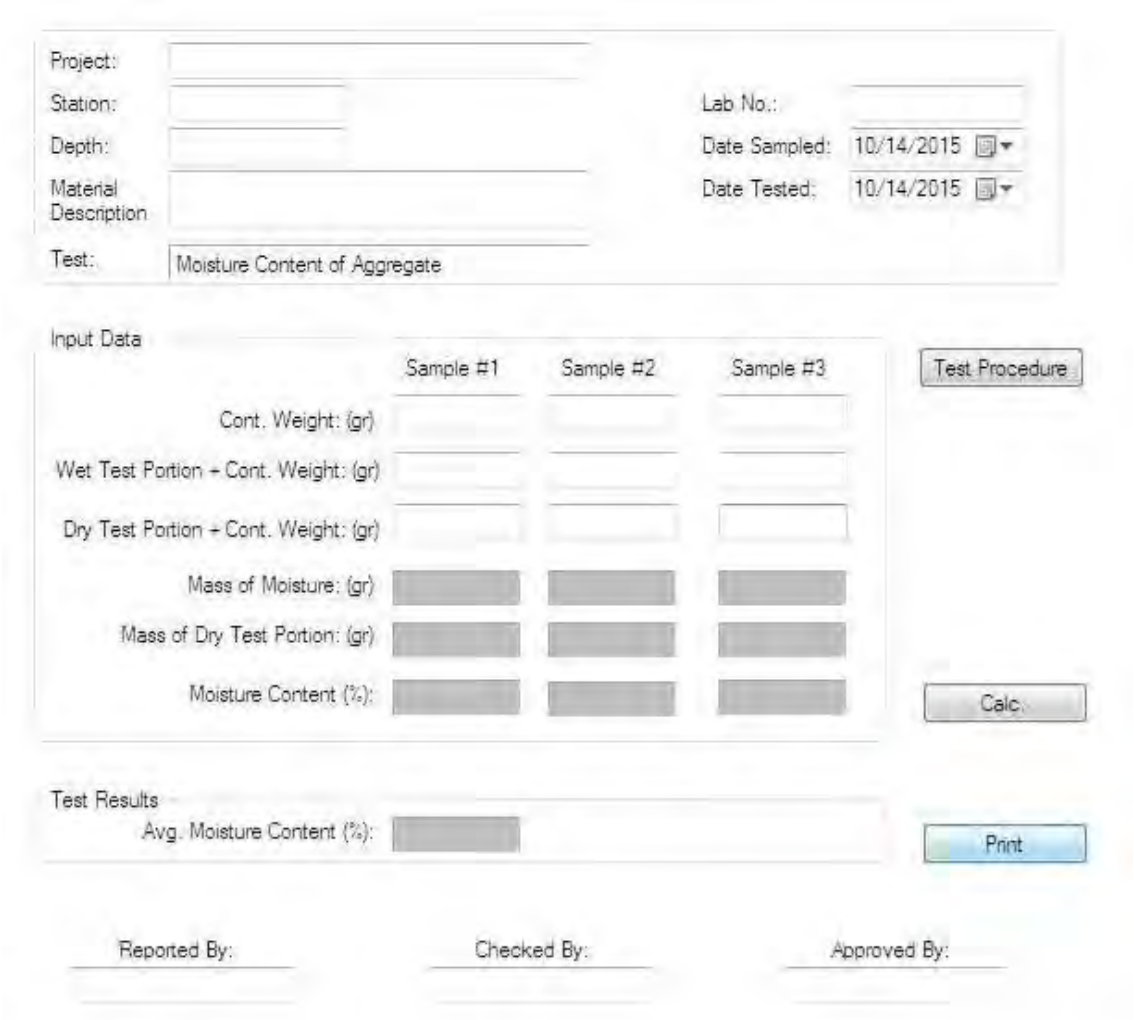

Fig 17 – Moisture Content Test of aggregate interface of the software

- When the user select Specific Gravity and Water Absorption Test

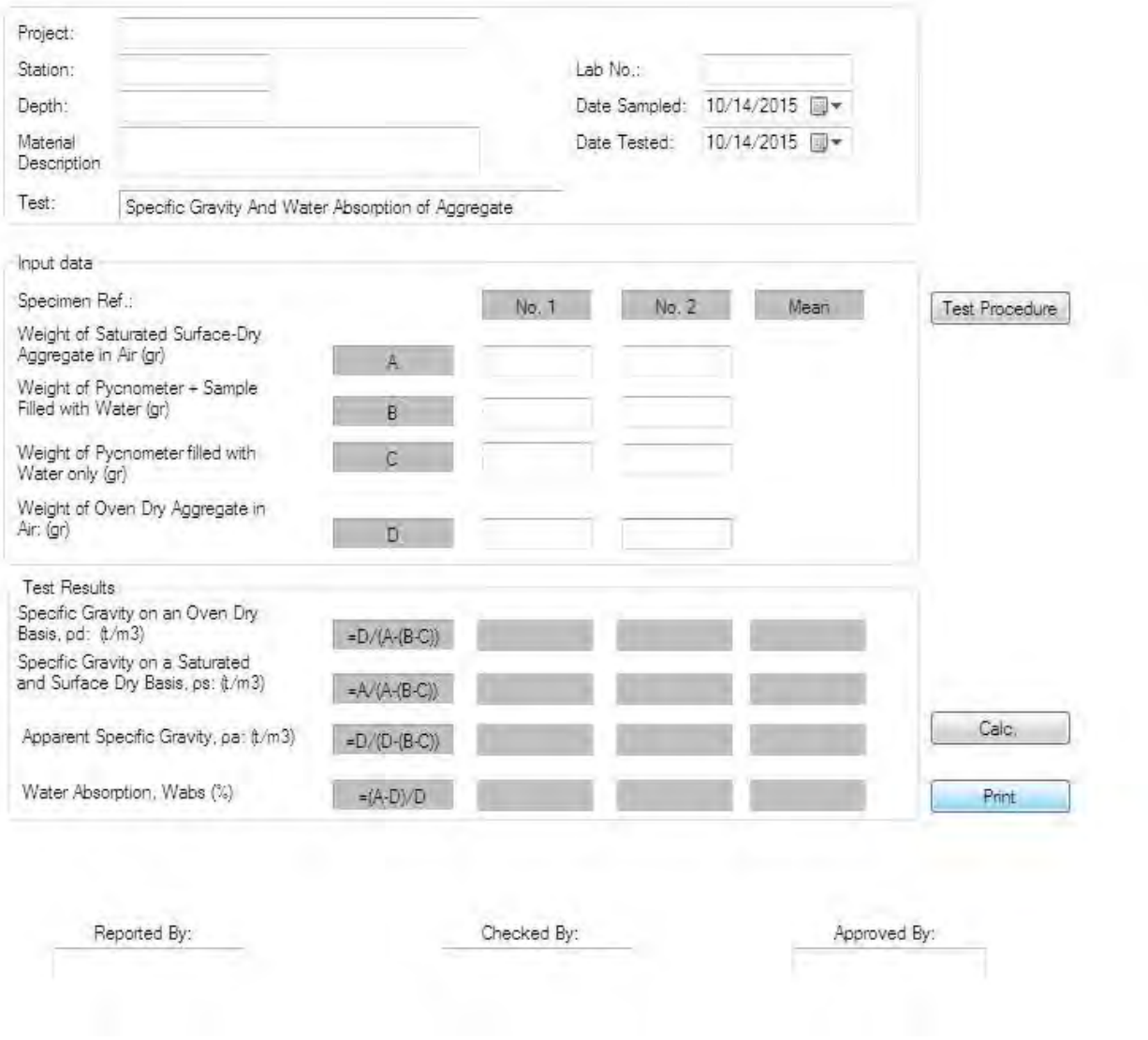

Fig 18 – Specific Gravity and Water Absorption Test of aggregate interface of the software

- When the user select Grain Size Analysis Test

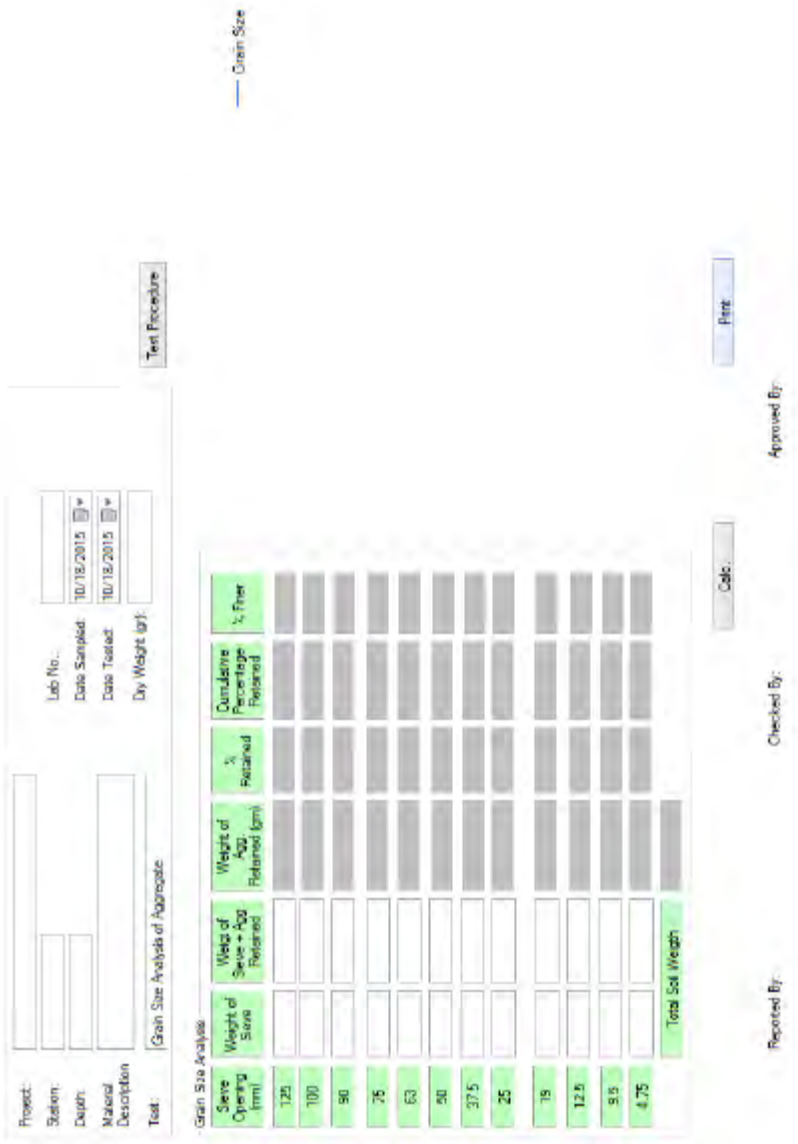

Fig 19 – Grain Size Analysis Test of aggregate interface of the software

- When the user select Flakiness Index Test

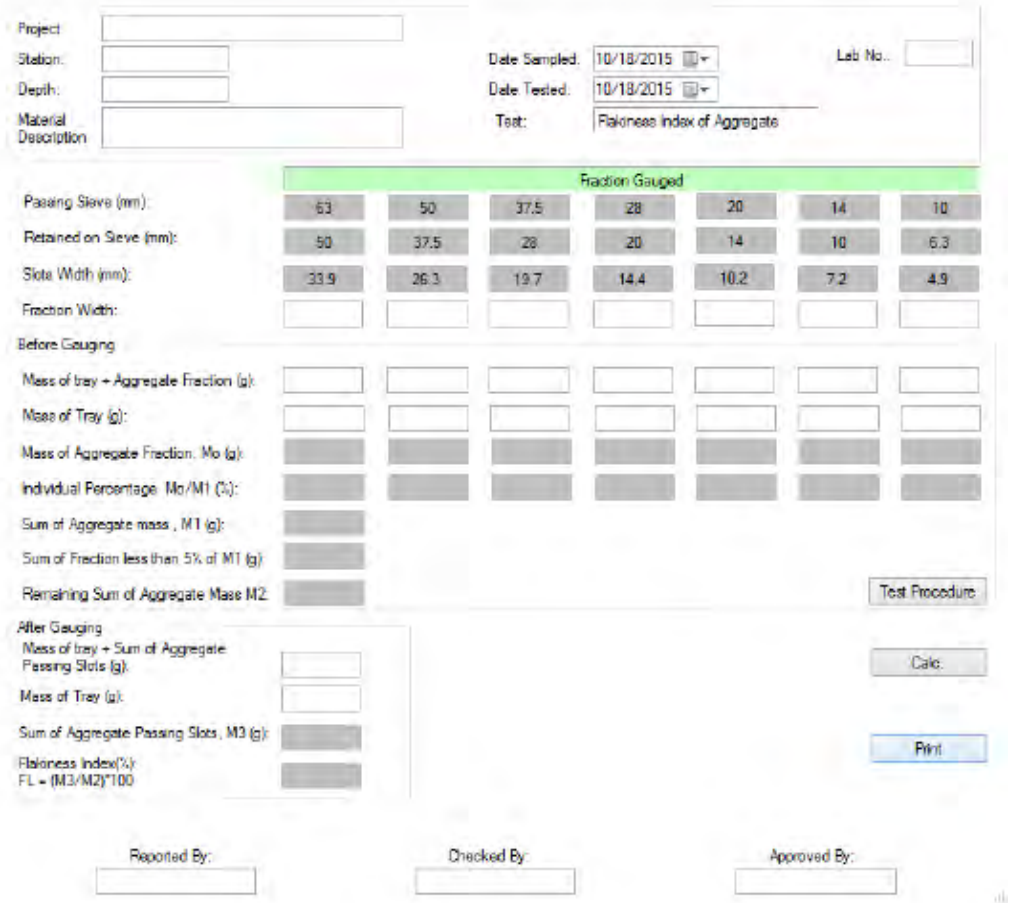

Fig 20 – Flakiness Index Test of aggregate interface of the software

- When the user select LAA Test

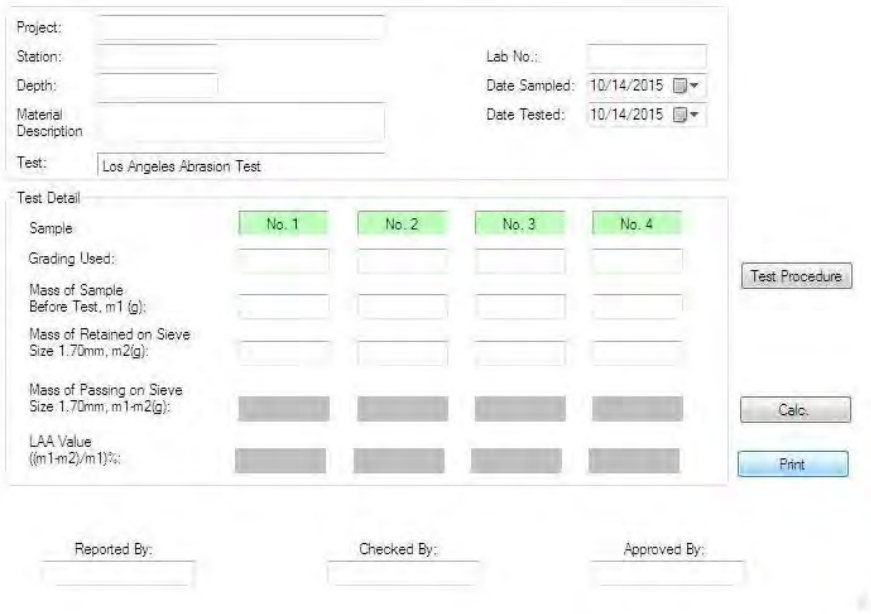

Fig 21 – LAA Test of aggregate interface of the software

- Soundness of Aggregate Test

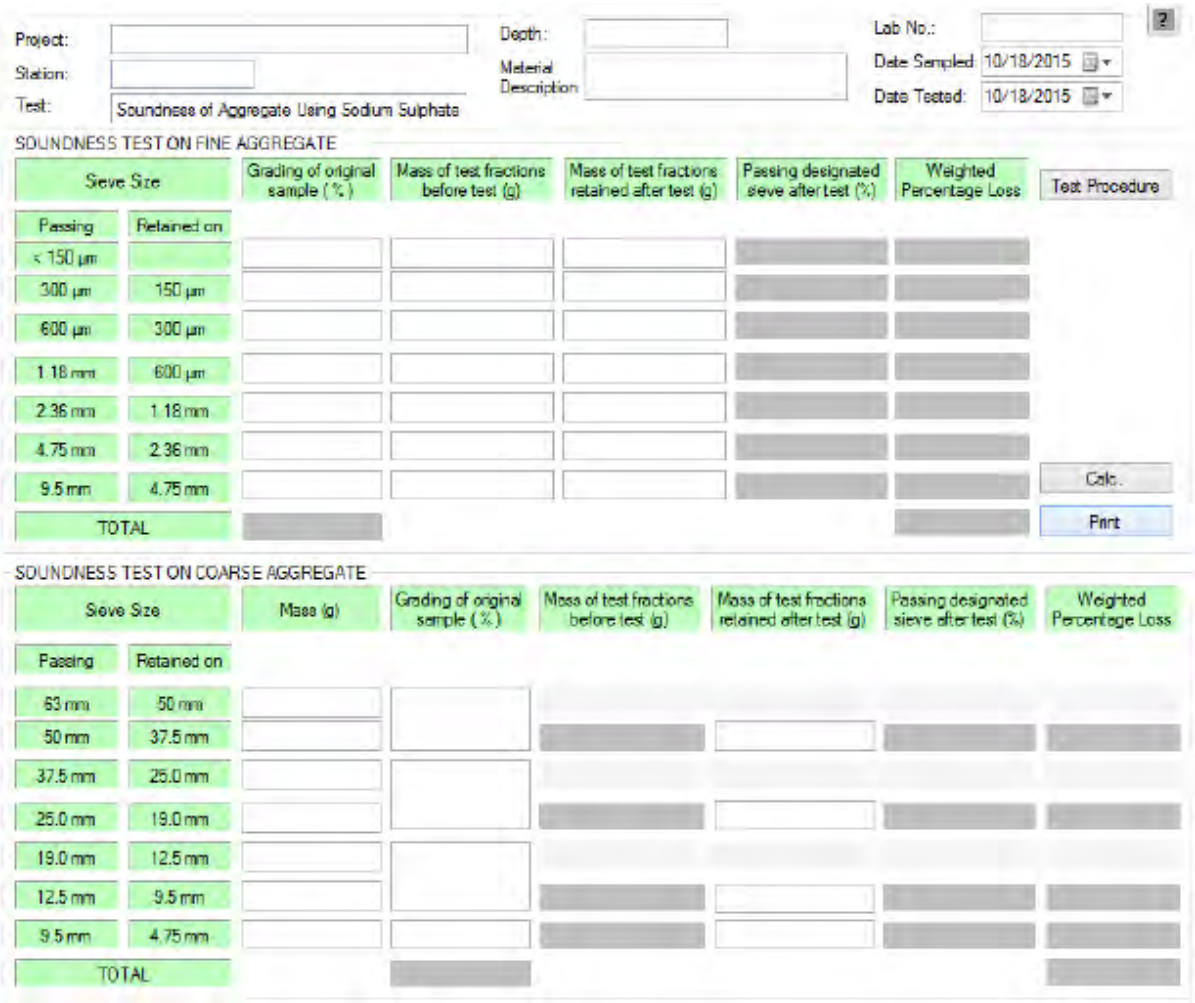

Fig 22 – Soundness of Aggregate Test interface of the software

4) CONCLUSION AND RECOMMENDATIONS:

4.1) LIMITATIONS

The limitations in this software are:

- Due to the need of advanced knowledge in software development to include the data base, the data base is not developed in this software. However, this problem is tried to be solved though converting the software output directly .pdf file format.

- The logarithm graph for Sieve analysis test for soil is not in the format that is needed in the practice of civil engineering due to the need of advanced knowledge in software development.

4.2) CONCLUSION

Based on the observations made in of this project, the following conclusions are made:

- A user friendly lab aided software for performing, analyzing and reporting laboratory tests for road projects are developed. The software also allow us to see or refer the test procedures, apparatus needed to perform the tests, how to prepare the sample and use of the test.

- This software has an advantage of avoiding miss calculation of the output based on the incorrect or none logical inputs by the user over spreadsheet programs

which are currently in practices, by sending message and let the user to correct the incorrect or none logical inputs.

- This developed software is a sparking proof that we can develop similar and related software for civil engineering locally by collaboration of civil engineers with software developers. Since purchasing of similar type of software from aboard is expensive.

4.3) RECOMMENDATIONS

Based on the observations made in of this project, the following recommendations are made:

- By including the database and other necessary additional test, this software can be developed and will be helpful for students, researchers and consulting office.

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APPENDIX

APPENDIX I - SAMPLE CALCULATION OF TESTS

1. SOIL MECHANICS LABORATORY TEST
   A. Moisture Content Test

      Data taken from the laboratory after conducting the **Moisture Content tests** for three samples of [Container Weight (g), Wet Soil + Container Weight (g), and Dry Soil + Container Weight (g)] respectively are:

      For Sample 1 – [15.4, 105, 89.9]
      For Sample 2 – [15.5, 101, 85.4]
      For Sample 3 – [15.3, 108, 92.0]

      - Using hand calculation

      Calculate the moisture content of the soil as follows:
      w = [(mass of moisture) / (mass of oven-dry soil)] x 100
      $w = [(W_1 - W_2) / (W_2 - W_c)] \times 100$

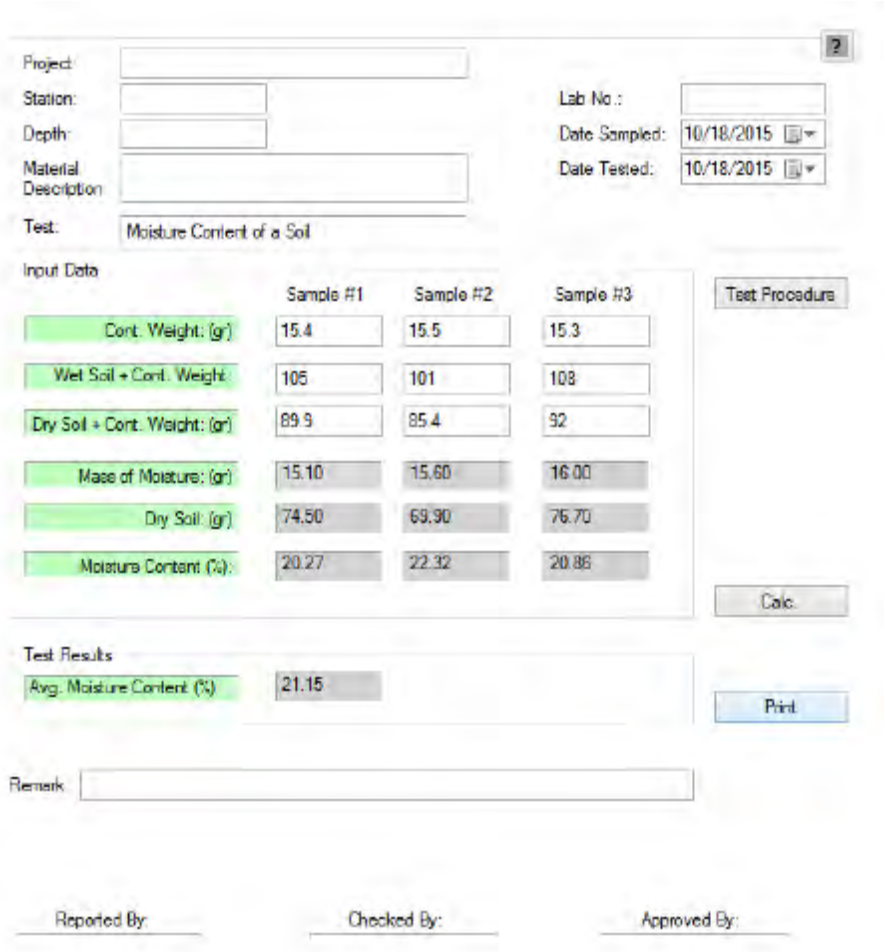
      Where:
      w = moisture content, percent;
      W_1 = mass of container and moist soil, g;
      W_2 = mass of container and oven-dried soil, g; and
      W_c = mass of container, g.

      For Sample 1, w1 = [(105-89.9)/(89.9-15.4)]*100 = <u>20.27%</u>

For Sample 2, w2 = [(101-85.4)/(85.4-15.5)]*100 = 22.32%
For Sample 3, w3 = [(108-92)/(92-15.3)]*100 = 20.86%

Average Moisture Content (%) = (w1+w2+w3)/3
Average Moisture Content (%) = (20.27+22.32+20.86)/3 = 21.15

- Using the software



Note - As you can see the value we get from hand calculation and using software is equal.

B. Specific Gravity Test

Data taken from the laboratory after conducting the **Specific Gravity tests** for two samples of at Temperature of Pycnometer 20^{o}C [Weight of Oven Dried Soil (g), Weight of Pycnometer + Water (g), and Weight of Pycnometer + Dry Sample + Water (g)] respectively are:

For Sample 1 – [26.1, 137.4, 153.6]
For Sample 2 – [19.6, 153.7, 165.8]

- Using hand calculation

Calculate the specific gravity of the soil, based on water at a temperature T_x, as follows:

Specific Gravity, $T_x/20^{o}C = K * W_o /[W_o + (Wa – W_b)]$

Where:
T_x = temperature of the contents of the pycnometer when mass Wbwas determined, in degrees Celsius;
W_o = mass of sample of oven-dried soil in grams;
W_a = mass of pycnometer filled with water at temperature Tx, in grams; and
W_b = mass of pycnometer filled with water and soil at temperature Tx, in grams.
K = a number found by dividing the relative density of water at temperature T_x by the relative density of water at 20ºC. Values for a range of temperatures are given in Table. (From the table, for Temperature of 20^{o}C – K=1.0)

For Sample 1 –

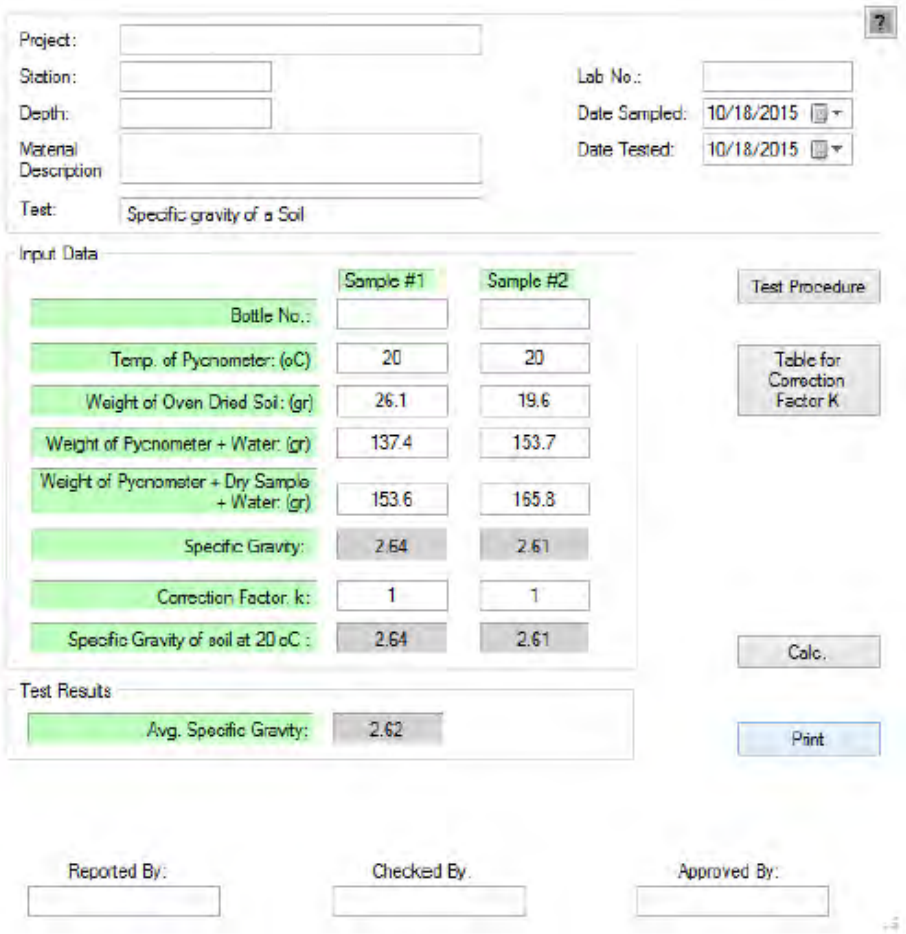
Specific Gravity1 = 1 * 26.1 /[26.1 + (137.4 – 153.6)] = 2.64

For Sample 2 –

Specific Gravity2 = 1 * 19.6 /[19.6 + (153.7 – 165.8)] = 2.61

Average Specific Gravity = (Specific Gravity1 + Specific Gravity2)/2
Average Specific Gravity = (2.64 + 2.61)/2 = 2.625

- Using the software



Note - As you can see the value we get from hand calculation and using software is equal.

C. Compaction Test

Data taken from the laboratory after conducting the **Compaction/proctor test** for five samples of [Mold + Wet Soil Weight (g)] and from moisture test [Container Weight (g), Wet Soil + Container Weight (g), and Dry Soil + Container Weight (g)] respectively are:

For Sample 1 – [5920] and [35.6, 204.6, 184.4] (g)
For Sample 2 – [6042] and [23.9, 232.5, 203.9] (g)
For Sample 3 – [6160] and [23.5, 222.2, 191.4] (g)
For Sample 4 – [6240] and [33.5, 263.6, 224.2] (g)
For Sample 5 – [6235] and [35.4, 317.3, 264.4] (g)
And, Mold volume is 929cm3 and weight of mold is 4200g,

- Using hand calculation

* The wet density can be determined using

$W1 = (A - B) / V$

Where:
A = mass of compacted specimen and mold;
B = mass of mold;
V = volume of mold; and
W1 = wet density.

For Sample 1, W1,1 = (5920-4200) / 929= 1.85
For Sample 2, W1,2 = (6042-4200) / 929= 1.98
For Sample 3, W1,3= (6160-4200) / 929= 2.11
For Sample 4, W1,4 = (6240-4200) / 929= 2.20
For Sample 5, W1,5 = (6235-4200) / 929= 2.19

* Calculate the moisture content of the soil as follows:

$w = [(W_1 - W_2) / (W_2 - W_c)] \times 100$

Where:
w = moisture content, percent;
W_1 = mass of container and moist soil, g;
W_2 = mass of container and oven-dried soil, g; and
W_c = mass of container, g.

For Sample 1, w1 = [(204.6 - 184.4) / (184.4 – 35.6)]*100 = 13.58%

For Sample 2, w2 = [(232.5 – 203.9) / (203.9 – 23.9)]*100 = 15.89%
For Sample 3, w3 = [(222.2 – 191.4) / (191.4 – 23.5)]*100 = 18.34%
For Sample 4, w4 = [(263.6 – 224.2) / (224.2 – 33.5)]*100 = 20.66%
For Sample 5, w5 = [(317.3 – 264.4) / (264.4 – 35.4)]*100 = 23.10%

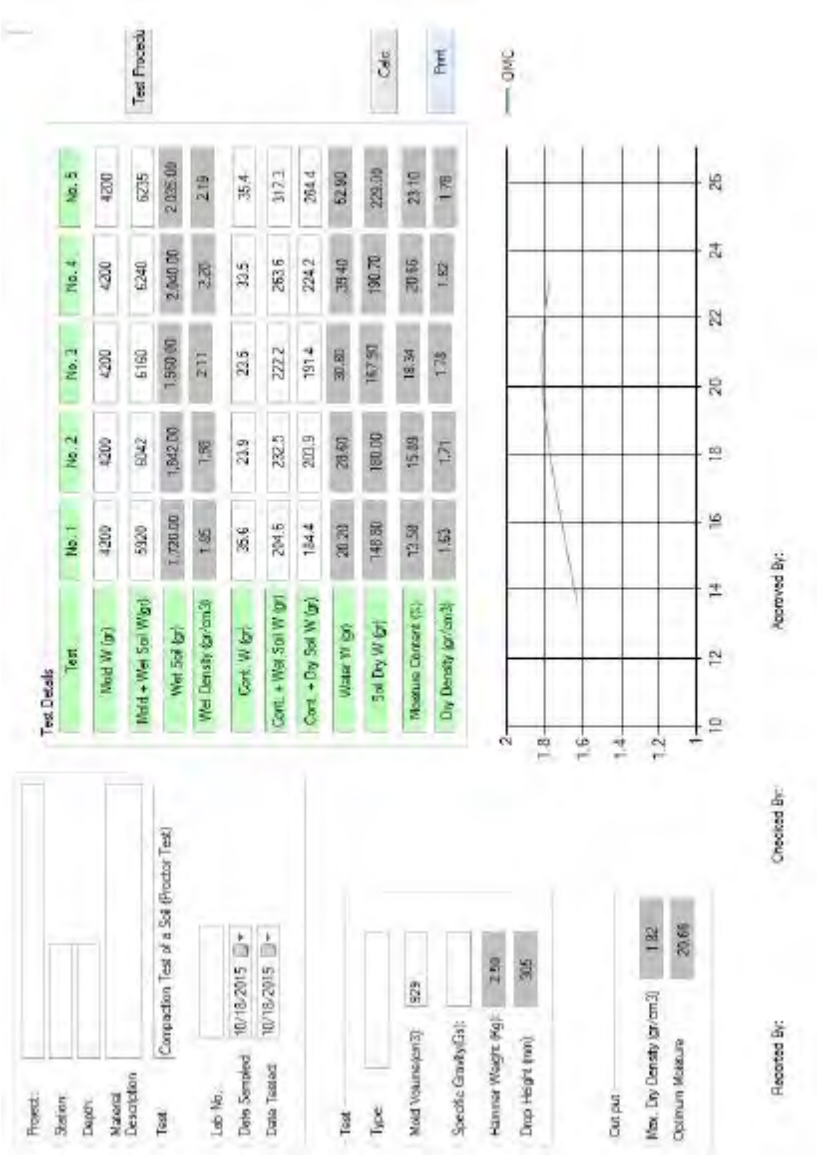
* The dry density is related to the wet density as follows:

$$W = \frac{W_1}{w + 100} \times 100$$

Where:
w = moisture content (percent) of the specimen
W = dry density, in kilograms per cubic meter of compacted soil of compacted soil.

For Sample 1, W = [1.85 / (13.58 + 100)]*100 = 1.63
For Sample 2, W = [1.98 / (15.89 + 100)]*100 = 1.71
For Sample 3, W = [2.11 / (18.34 + 100)]*100 = 1.78
For Sample 4, W = [2.20 / (20.66 + 100)]*100 = 1.82
For Sample 5, W = [2.19 / (23.10 + 100)]*100 = 1.78

- Using the software



Note - As you can see the value we get from hand calculation and using software is equal.

D. Free Swell Test

Data taken from the laboratory after conducting the **Free Swell Test** for two samples of [Initial Volume, Final Volume] respectively is:

For Sample 1 – [15.4, 18.0]
For Sample 2 – [12.0, 15.0]

- Using hand calculation

  Free swell (%) = [(Vf –Vi) / Vi] * 100

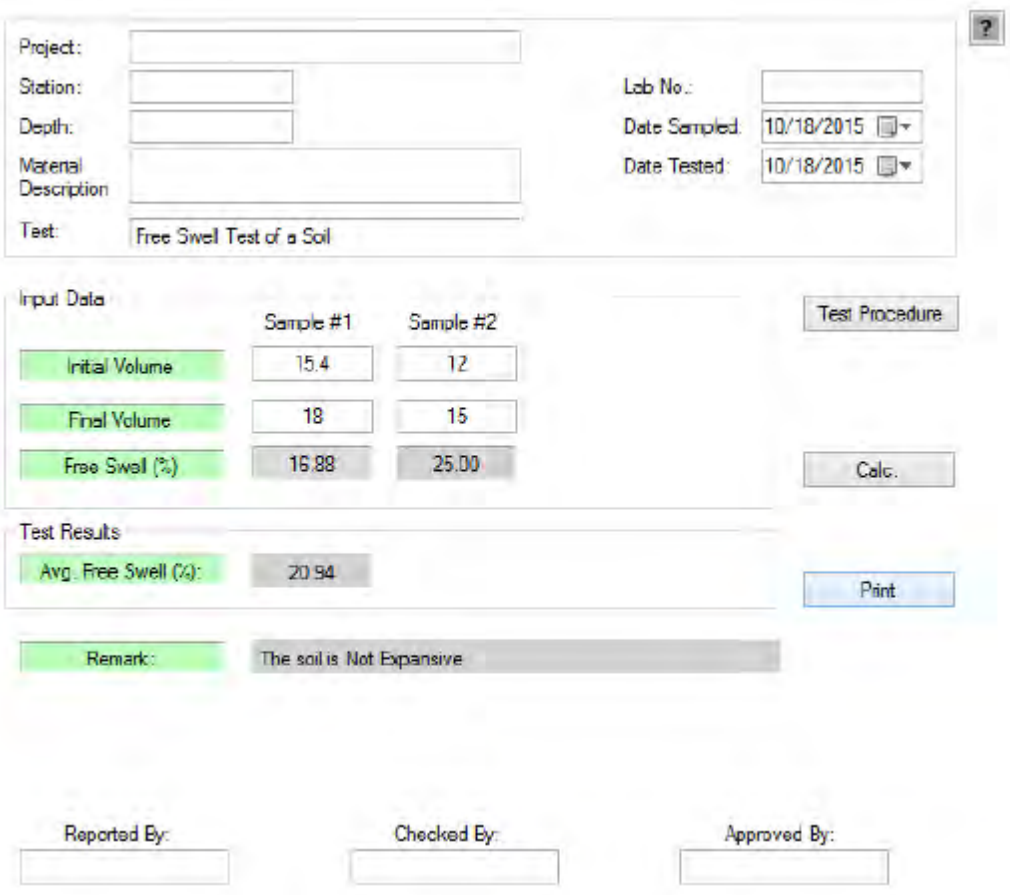
Where
Vi = Initial Volume of the soil sample
Vf = Final Volume of the soil sample

For Sample 1, Free swell1 (%) = [(18.0 – 15.4) / 15.4] * 100 = 16.88%
For Sample 2, Free swell2 (%) = [(15.0 – 12.0) / 12.0] * 100 = 25.0%

Average Free swell (%) = (Free swell1 + Free swell2)/2
Average Free swell (%) = (16.88 + 25.0)/2 = 20.94%

Since the Average Free swell value of 20.94% is less than 50% the soil is Not Expansive.

- Using the software



Note - As you can see the value we get from hand calculation and using software is equal.

2. AGGREGATE MECHANICS LABORATORY TEST

A. Specific Gravity and Water Absorption Test

Data taken from the laboratory after conducting the **Specific Gravity and Water Absorption Test** of aggregate for two samples of [Weigth of Saturated Surface Dry Aggregate in Air (g), Weight of Pycnometer + Sample Filled with Water (g), Weight of Pycnometer filled with Water only (g), and Weight of Oven Dry Aggregate in Air (g)] respectively are:

For Sample 1 – [15.4, 18.3, 8.8, 12.5]
For Sample 2 – [16.1, 19.4, 9.3, 13.2]

- Using hand calculation
  - Calculate the percentage of absorption as follows:

    $$\text{Absorption, \%} = [(A - D)/D] \times 100$$

  - Calculate the apparent specific gravity, 23/23ºC as follows:

    $$\text{Apparent sp gr} = D/(C + D - B)$$

    where:
    A = mass of saturated surface-dry specimen, g; and
    B = mass of pycnometer with specimen and water to calibration mark, g.
    C = mass of pycnometer filled with water, g;
    D = mass of oven-dry specimen in air, g;

For Sample 1,

Absorption, %= [(15.4 – 12.5) / 12.5] × 100 = <u>23.20</u>

Apparent sp gr = 12.5 / (8.8 + 12.5 − 18.3) = <u>4.17</u>

For Sample 2,

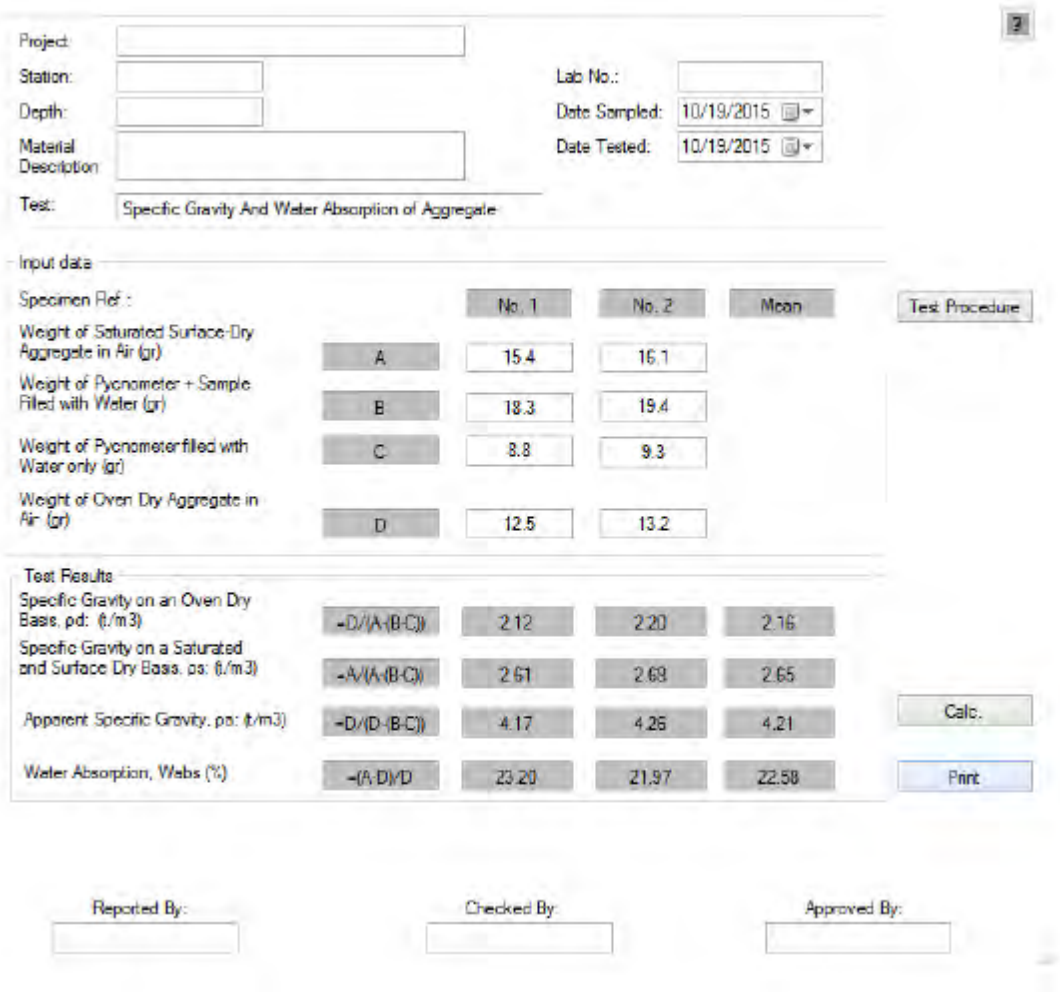
Absorption, %= [(16.1 – 13.2) / 13.2] × 100 = <u>21.97</u>

Apparent sp gr = 13.2 / (9.3 + 13.2 −19.4) = <u>4.26</u>

Average Absorption, % = (Average Absorption1 + Average Absorption2)/2
Average Absorption, % = (23.2 + 21.97)/2 =<u>22.59</u>

Apparent sp gr = (Apparent sp gr1 + Apparent sp gr2)/2
Apparent sp gr = (4.17 + 4.26)/2 =<u>4.22</u>

- Using the software



Note - As you can see the value we get from hand calculation and using software is equal.

APPENDIX II – CODES USED FOR THE DEVELOPMENT OF THE SOFTWARE

1. Code Used to develop Moisture Content of Soil

```
Public Class Moisture_Content

    Dim Number1, Number2, Number3 As Double
    Dim Number4, Number5, Number6 As Double
    Dim Number7, Number8, Number9 As Double

    Dim Answer1, Answer2, Answer3 As Double
    Dim Answer4, Answer5, Answer6 As Double
    Dim Answer7, Answer8, Answer9 As Double
    Dim Answer10 As Double



    Private Sub Button3_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button3.Click

        If TextBox3.Text = "" Or TextBox4.Text = "" Or TextBox5.Text = "" Or
TextBox6.Text = "" Or TextBox8.Text = "" Or TextBox9.Text = "" Or TextBox10.Text = ""
Or TextBox11.Text = "" Or TextBox12.Text = "" Then
            MessageBox.Show("Please fill all the input data in the Input Data Box")
        Else

            Number1 = TextBox3.Text
            Number2 = TextBox4.Text
            Number3 = TextBox5.Text
            Number4 = TextBox9.Text
            Number5 = TextBox8.Text
            Number6 = TextBox6.Text
            Number7 = TextBox12.Text
            Number8 = TextBox11.Text
            Number9 = TextBox10.Text

            If Number1 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of (Container
Weight) is negative, Please Adjust it before Proceeding")
            End If

            If Number2 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of (Wet Soil +
Container Weight) negative, Please Adjust it before Proceeding")
            End If

            If Number3 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of (Dry Soil +
Container Weight) negative, Please Adjust it before Proceeding")
            End If

            If Number1 > Number2 Then
                MessageBox.Show("In Sample Number 1, The Input value of (Container
Weight) greater than (Wet Soil + Container Weight), Please Adjust it before Proceeding
")
            End If

            If Number1 > Number3 Then
```

```
                MessageBox.Show("In Sample Number 1, The Input value of (Container
Weight) greater than (Dry Soil + Container Weight), Please Adjust it before Proceeding
")
            End If

            If Number3 > Number2 Then
                MessageBox.Show("In Sample Number 1, The Input value of (Dry Soil +
Container Weight) greater than (Wet Soil + Container Weight),Please Adjust it before
Proceeding ")
            End If

            If Number4 < 0 Then
                MessageBox.Show("In Sample Number 2, The Input Value of Container
Weight is negative, Please Adjust it before Proceeding")
            End If

            If Number5 < 0 Then
                MessageBox.Show("In Sample Number 2, The Input Value of Wet Soil +
Container Weight negative, Please Adjust it before Proceeding")
            End If

            If Number6 < 0 Then
                MessageBox.Show("In Sample Number 2, The Input Value of Dry Soil +
Container Weight negative, Please Adjust it before Proceeding")
            End If

            If Number4 > Number5 Then
                MessageBox.Show("In Sample Number 2, The Input value of (Container
Weight) greater than (Wet Soil + Container Weight),Please Adjust it before Proceeding
")
            End If

            If Number4 > Number6 Then
                MessageBox.Show("In Sample Number 2, The Input value of (Container
Weight) greater than (Dry Soil + Container Weight),Please Adjust it before Proceeding
")
            End If

            If Number6 > Number5 Then
                MessageBox.Show("In Sample Number 2, The Input value of (Dry Soil +
Container Weight) greater than (Wet Soil + Container Weight),Please Adjust it before
Proceeding ")
            End If

            If Number7 < 0 Then
                MessageBox.Show("In Sample Number 3, The Input Value of Container
Weight is negative, Please Adjust it before Proceeding")
            End If

            If Number8 < 0 Then
                MessageBox.Show("In Sample Number 3, The Input Value of Wet Soil +
Container Weight negative, Please Adjust it before Proceeding")
            End If

            If Number9 < 0 Then
                MessageBox.Show("In Sample Number 3, The Input Value of Dry Soil +
Container Weight negative, Please Adjust it before Proceeding")
            End If

            If Number7 > Number8 Then
```

```
                MessageBox.Show("In Sample Number 3, The Input value of (Container
Weight) greater than (Wet Soil + Container Weight), Please Adjust it before Proceeding
")
            End If

            If Number7 > Number9 Then
                MessageBox.Show("In Sample Number 3, The Input value of (Container
Weight) greater than (Dry Soil + Container Weight), Please Adjust it before Proceeding
")
            End If

            If Number9 > Number8 Then
                MessageBox.Show("In Sample Number 3, The Input value of (Dry Soil +
Container Weight) greater than (Wet Soil + Container Weight),Please Adjust it before
Proceeding ")
            End If


            If Number1 > 0 And Number2 > 0 And Number3 > 0 And Number2 > Number1 And
Number3 > Number1 And Number2 > Number3 And Number4 > 0 And Number5 > 0 And Number6 >
0 And Number5 > Number4 And Number6 > Number4 And
                Number5 > Number6 And Number7 > 0 And Number8 > 0 And Number9 > 0 And
Number8 > Number7 And Number9 > Number7 And Number8 > Number9 Then

                Answer1 = Number2 - Number3
                Answer2 = Number3 - Number1
                Answer3 = (Answer1 / Answer2) * 100

                Answer4 = Number5 - Number6
                Answer5 = Number6 - Number4
                Answer6 = (Answer4 / Answer5) * 100

                Answer7 = Number8 - Number9
                Answer8 = Number9 - Number7
                Answer9 = (Answer7 / Answer8) * 100

                Answer10 = ((Answer3 + Answer6 + Answer9) / 3)

                Label11.Text = Convert.ToString(FormatNumber(Answer1, 2))
                Label12.Text = Convert.ToString(FormatNumber(Answer2, 2))
                Label13.Text = Convert.ToString(FormatNumber(Answer3, 2))

                Label21.Text = Convert.ToString(FormatNumber(Answer4, 2))
                Label20.Text = Convert.ToString(FormatNumber(Answer5, 2))
                Label18.Text = Convert.ToString(FormatNumber(Answer6, 2))

                Label25.Text = Convert.ToString(FormatNumber(Answer7, 2))
                Label24.Text = Convert.ToString(FormatNumber(Answer8, 2))
                Label22.Text = Convert.ToString(FormatNumber(Answer9, 2))


                Label16.Text = Convert.ToString(FormatNumber(Answer10, 2))

            End If
        End If

    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button1.Click
        My.Forms.Moisture_Test_Procedure.ShowDialog()
    End Sub
```

```
    Private Sub Label5_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Label5.Click

    End Sub

    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button2.Click

        PrintForm1.PrinterSettings.DefaultPageSettings.Margins.Left = 50
        PrintForm1.PrinterSettings.DefaultPageSettings.Margins.Top = 50
        PrintForm1.PrintAction = Printing.PrintAction.PrintToPreview
        PrintForm1.Print()
    End Sub


    Private Sub Moisture_Content_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load

        ToolTip1.SetToolTip(Button1, "Shows Test Procedure of the test")
        ToolTip1.SetToolTip(Button2, "Print the output")
        ToolTip1.SetToolTip(Button3, "Calculate the output")

        ToolTip1.SetToolTip(TextBox13, "Please enter the Project Name")
        ToolTip1.SetToolTip(TextBox1, "Please enter the Station Chainage")
        ToolTip1.SetToolTip(TextBox14, "Please enter the Depth of sample is taken")
        ToolTip1.SetToolTip(TextBox15, "Please enter the Material Description")
        ToolTip1.SetToolTip(TextBox2, "Please enter the Laboratory Number")
        ToolTip1.SetToolTip(DateTimePicker1, "Please enter the Date Sampled")
        ToolTip1.SetToolTip(DateTimePicker2, "Please enter the Date Tested")

    End Sub

    Private Sub TextBox3_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox3.TextChanged
        If IsNumeric(TextBox3.Text) Then
            'nada
        Else
            TextBox3.Clear()
        End If
    End Sub

    Private Sub TextBox4_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox4.TextChanged
        If IsNumeric(TextBox4.Text) Then
            'nada
        Else
            TextBox4.Clear()
        End If
    End Sub

    Private Sub TextBox5_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox5.TextChanged
        If IsNumeric(TextBox5.Text) Then
            'nada
        Else
            TextBox5.Clear()
        End If
    End Sub

    Private Sub TextBox9_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox9.TextChanged
```

```
        If IsNumeric(TextBox9.Text) Then
            'nada
        Else
            TextBox9.Clear()
        End If
    End Sub

    Private Sub TextBox8_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox8.TextChanged
        If IsNumeric(TextBox8.Text) Then
            'nada
        Else
            TextBox8.Clear()
        End If
    End Sub

    Private Sub TextBox6_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox6.TextChanged
        If IsNumeric(TextBox6.Text) Then
            'nada
        Else
            TextBox6.Clear()
        End If
    End Sub

    Private Sub TextBox12_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox12.TextChanged
        If IsNumeric(TextBox12.Text) Then
            'nada
        Else
            TextBox12.Clear()
        End If
    End Sub

    Private Sub TextBox11_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox11.TextChanged
        If IsNumeric(TextBox11.Text) Then
            'nada
        Else
            TextBox11.Clear()
        End If
    End Sub

    Private Sub TextBox10_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox10.TextChanged
        If IsNumeric(TextBox10.Text) Then
            'nada
        Else
            TextBox10.Clear()
        End If
    End Sub


    Private Sub Button4_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button4.Click
        My.Forms.Help.ShowDialog()
    End Sub
End Class
```

2. Code Used to develop Specific Gravity of Soil

```
Public Class Specific_gravity

    Dim Number1, Number2, Number3, Number4, Number5 As Double
    Dim Number6, Number7, Number8, Number9, Number10 As Double


    Dim Answer1, Answer2 As Double
    Dim Answer3, Answer4 As Double
    Dim Answer5 As Double


    Private Sub Button3_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button3.Click
        If TextBox4.Text = "" Or TextBox5.Text = "" Or TextBox6.Text = "" Or
TextBox11.Text = "" Or TextBox8.Text = "" Or TextBox9.Text = "" Or TextBox10.Text = ""
Or TextBox12.Text = "" Or TextBox13.Text = "" Or TextBox14.Text = "" Then
            MessageBox.Show("Please fill all The input data in the Input Data Box")
        Else

            Number1 = TextBox4.Text
            Number2 = TextBox5.Text
            Number3 = TextBox6.Text
            Number4 = TextBox11.Text
            Number5 = TextBox8.Text
            Number6 = TextBox14.Text
            Number7 = TextBox13.Text
            Number8 = TextBox12.Text
            Number9 = TextBox9.Text
            Number10 = TextBox10.Text

            If Number2 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of Weight of Oven
Dried Soil is negative, Please Adjust it before Proceeding")
            End If

            If Number3 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of Weight of
Pycnometer + Water is negative, Please Adjust it before Proceeding")
            End If

            If Number4 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of Weigth of
Bottle + Sample + Water is negative, Please Adjust it before Proceeding")
            End If

            If Number2 > Number4 Then
                MessageBox.Show("In Sample Number 1, The Input Value of Weight of Oven
Dried Soil is greater than Weigth of Bottle + Sample + Water")
            End If

            If Number3 > Number4 Then
                MessageBox.Show("In Sample Number 1, The Input Value of Weight of
Pycnometer + Water is greater than Weigth of Bottle + Sample + Water")
            End If

            If Number7 < 0 Then
                MessageBox.Show("In Sample Number 2, The Input Value of Weight of Oven
Dried Soil is negative, Please Adjust it before Proceeding")
            End If

            If Number8 < 0 Then
```

```
                MessageBox.Show("In Sample Number 2, The Input Value of Weight of
Pycnometer + Water is negative, Please Adjust it before Proceeding")
            End If

            If Number9 < 0 Then
                MessageBox.Show("In Sample Number 2, The Input Value of Weigth of
Bottle + Sample + Water is negative, Please Adjust it before Proceeding")
            End If

            If Number7 > Number9 Then
                MessageBox.Show("In Sample Number 2, The Input Value of Weight of Oven
Dried Soil is greater than Weigth of Bottle + Sample + Water")
            End If

            If Number8 > Number9 Then
                MessageBox.Show("In Sample Number 2, The Input Value of Weight of
Pycnometer + Water is greater than Weigth of Bottle + Sample + Water")
            End If

            If Number4 > Number2 And Number4 > Number3 And Number9 > Number7 And
Number9 > Number8 Then

                Answer1 = Number2 / (Number2 + (Number3 - Number4))
                Answer2 = Number5 * Answer1

                Label11.Text = Convert.ToString(FormatNumber(Answer1, 2))
                Label12.Text = Convert.ToString(FormatNumber(Answer2, 2))

                Answer3 = Number7 / (Number7 + (Number8 - Number9))
                Answer4 = Number10 * Answer3

                Label17.Text = Convert.ToString(FormatNumber(Answer3, 2))
                Label14.Text = Convert.ToString(FormatNumber(Answer4, 2))


                Answer5 = (Answer2 + Answer4) * 0.5

                Label21.Text = Convert.ToString(FormatNumber(Answer5, 2))
            End If
        End If

    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button1.Click
        My.Forms.Specific_Gravity_Test_Procedure.ShowDialog()
    End Sub

    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button2.Click
        PrintForm1.PrinterSettings.DefaultPageSettings.Margins.Left = 50
        PrintForm1.PrinterSettings.DefaultPageSettings.Margins.Top = 50
        PrintForm1.PrintAction = Printing.PrintAction.PrintToPreview
        PrintForm1.Print()
    End Sub

    Private Sub TextBox4_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox4.TextChanged
        If IsNumeric(TextBox4.Text) Then
            'nada
        Else
            TextBox4.Clear()
```

```
        End If
    End Sub

    Private Sub TextBox5_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox5.TextChanged
        If IsNumeric(TextBox5.Text) Then
            'nada
        Else
            TextBox5.Clear()
        End If
    End Sub

    Private Sub TextBox6_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox6.TextChanged
        If IsNumeric(TextBox6.Text) Then
            'nada
        Else
            TextBox6.Clear()
        End If
    End Sub

    Private Sub TextBox11_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox11.TextChanged
        If IsNumeric(TextBox11.Text) Then
            'nada
        Else
            TextBox11.Clear()
        End If
    End Sub

    Private Sub TextBox8_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox8.TextChanged
        If IsNumeric(TextBox8.Text) Then
            'nada
        Else
            TextBox8.Clear()
        End If
    End Sub

    Private Sub TextBox14_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox14.TextChanged
        If IsNumeric(TextBox14.Text) Then
            'nada
        Else
            TextBox14.Clear()
        End If
    End Sub

    Private Sub TextBox13_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox13.TextChanged
        If IsNumeric(TextBox13.Text) Then
            'nada
        Else
            TextBox13.Clear()
        End If
    End Sub

    Private Sub TextBox12_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox12.TextChanged
        If IsNumeric(TextBox12.Text) Then
            'nada
        Else
```

```
            TextBox12.Clear()
        End If
    End Sub

    Private Sub TextBox9_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox9.TextChanged
        If IsNumeric(TextBox9.Text) Then
            'nada
        Else
            TextBox9.Clear()
        End If
    End Sub

    Private Sub TextBox10_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox10.TextChanged
        If IsNumeric(TextBox10.Text) Then
            'nada
        Else
            TextBox10.Clear()
        End If
    End Sub

    Private Sub Specific_gravity_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load

        ToolTip1.SetToolTip(Button1, "Shows Test Procedure of the test")
        ToolTip1.SetToolTip(Button2, "Print the output")
        ToolTip1.SetToolTip(Button3, "Calculate the output")

        ToolTip1.SetToolTip(TextBox18, "Please enter the Project Name")
        ToolTip1.SetToolTip(TextBox20, "Please enter the Station Chainage")
        ToolTip1.SetToolTip(TextBox2, "Please enter the Depth of sample is taken")
        ToolTip1.SetToolTip(TextBox1, "Please enter the Material Description")
        ToolTip1.SetToolTip(TextBox19, "Please enter the Laboratory Number")
        ToolTip1.SetToolTip(DateTimePicker1, "Please enter the Date Sampled")
        ToolTip1.SetToolTip(DateTimePicker2, "Please enter the Date Tested")
    End Sub

    Private Sub Button4_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button4.Click
        My.Forms.Table_for_Correction_Factor_K.ShowDialog()
    End Sub

    Private Sub Button5_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button5.Click
        My.Forms.Help.ShowDialog()
    End Sub
End Class
```

3. Code Used to develop Unit Weight of Soil

```
Public Class Unit_Weight_Block_Sample_

    Dim Number1, Number2, Number3, Number4, Number5 As Double
    Dim Number6, Number7, Number8, Number9, Number10 As Double

    Dim Answer1, Answer2, Answer3, Answer4, Answer5 As Double
    Dim Answer6, Answer7, Answer8, Answer9, Answer10 As Double
    Dim Answer11, Answer12 As Double
```

```
    Private Sub Button3_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button3.Click
        If TextBox137.Text = "" Or TextBox136.Text = "" Or TextBox135.Text = "" Or
TextBox14.Text = "" Or TextBox13.Text = "" Or TextBox130.Text = "" Or TextBox129.Text
= "" Or TextBox128.Text = "" Or TextBox9.Text = "" Or TextBox8.Text = "" Then
            MessageBox.Show("Please fill all the input data in the Input Data Box")
        Else

            Number1 = TextBox137.Text
            Number2 = TextBox136.Text
            Number3 = TextBox135.Text
            Number4 = TextBox14.Text
            Number5 = TextBox13.Text
            Number6 = TextBox130.Text
            Number7 = TextBox129.Text
            Number8 = TextBox128.Text
            Number9 = TextBox9.Text
            Number10 = TextBox8.Text

            If Number1 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of 'Length of
Sample' is negative, Please Adjust it before Proceeding")
            End If

            If Number2 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of 'Width of
Sample' is negative, Please Adjust it before Proceeding")
            End If

            If Number3 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of 'Height of
Sample' is negative, Please Adjust it before Proceeding")
            End If

            If Number4 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of 'Mass of
Cylinder + Sample' is negative, Please Adjust it before Proceeding")
            End If

            If Number5 < 0 Then
                MessageBox.Show("In Sample Number 1, The Input Value of 'Mass of
Cylinder' is negative, Please Adjust it before Proceeding")
            End If

            If Number5 > Number4 Then
                MessageBox.Show("In Sample Number 1, The input Value of 'Mass of
Cylinder' is greater than ''Mass of Cylinder + Sample', Please Adjust it before
Proceeding ")
            End If

            If Number6 < 0 Then
                MessageBox.Show("In Sample Number 2, The Input Value of 'Length of
Sample' is negative, Please Adjust it before Proceeding")
            End If

            If Number7 < 0 Then
                MessageBox.Show("In Sample Number 2, The Input Value of 'Width of
Sample' is negative, Please Adjust it before Proceeding")
            End If

            If Number8 < 0 Then
```

```
                MessageBox.Show("In Sample Number 2, The Input Value of 'Height of
Sample' is negative, Please Adjust it before Proceeding")
            End If

            If Number9 < 0 Then
                MessageBox.Show("In Sample Number 2, The Input Value of 'Mass of
Cylinder + Sample' is negative, Please Adjust it before Proceeding")
            End If

            If Number10 < 0 Then
                MessageBox.Show("In Sample Number 2, The Input Value of 'Mass of
Cylinder' is negative, Please Adjust it before Proceeding")
            End If

            If Number10 > Number9 Then
                MessageBox.Show("In Sample Number 2, The input Value of 'Mass of
Cylinder' is greater than ''Mass of Cylinder + Sample', Please Adjust it before
Proceeding ")
            End If

            If Number1 > 0 And Number2 > 0 And Number3 > 0 And Number4 > 0 And Number5
> 0 And Number4 > Number5 And Number6 > 0 And Number7 > 0 And Number8 > 0 And Number9
> 0 And Number10 > 0 And Number9 > Number10 Then
                Answer1 = Number1 * Number2
                Answer2 = Answer1 * Number3
                Answer3 = Number4 - Number5
                Answer4 = (Answer3 / Answer2) * 1000
                Answer5 = Answer4 * 9.81 / 1000

                Label11.Text = Convert.ToString(FormatNumber(Answer1, 2))
                Label14.Text = Convert.ToString(FormatNumber(Answer2, 2))
                Label20.Text = Convert.ToString(FormatNumber(Answer3, 2))
                Label22.Text = Convert.ToString(FormatNumber(Answer4, 2))
                Label26.Text = Convert.ToString(FormatNumber(Answer5, 2))

                Answer6 = Number6 * Number7
                Answer7 = Answer6 * Number8
                Answer8 = Number9 - Number10
                Answer9 = (Answer8 / Answer7) * 1000
                Answer10 = Answer9 * 9.81 / 1000

                Label12.Text = Convert.ToString(FormatNumber(Answer6, 2))
                Label13.Text = Convert.ToString(FormatNumber(Answer7, 2))
                Label18.Text = Convert.ToString(FormatNumber(Answer8, 2))
                Label21.Text = Convert.ToString(FormatNumber(Answer9, 2))
                Label25.Text = Convert.ToString(FormatNumber(Answer10, 2))

                Answer11 = (Answer4 + Answer9) / 2
                Answer12 = (Answer5 + Answer10) / 2

                Label19.Text = Convert.ToString(FormatNumber(Answer11, 2))
                Label10.Text = Convert.ToString(FormatNumber(Answer12, 2))
            End If
        End If

    End Sub

    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button2.Click
        PrintForm1.PrinterSettings.DefaultPageSettings.Margins.Left = 50
        PrintForm1.PrinterSettings.DefaultPageSettings.Margins.Top = 50
        PrintForm1.PrintAction = Printing.PrintAction.PrintToPreview
```

```
        PrintForm1.Print()
    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button1.Click
        My.Forms.Unit_Weight_Test_Procedure.ShowDialog()
    End Sub

    Private Sub TextBox137_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox137.TextChanged
        If IsNumeric(TextBox137.Text) Then
            'nada
        Else
            TextBox137.Clear()
        End If
    End Sub

    Private Sub TextBox136_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox136.TextChanged
        If IsNumeric(TextBox136.Text) Then
            'nada
        Else
            TextBox136.Clear()
        End If
    End Sub

    Private Sub TextBox135_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox135.TextChanged
        If IsNumeric(TextBox135.Text) Then
            'nada
        Else
            TextBox135.Clear()
        End If
    End Sub

    Private Sub TextBox14_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox14.TextChanged
        If IsNumeric(TextBox14.Text) Then
            'nada
        Else
            TextBox14.Clear()
        End If
    End Sub

    Private Sub TextBox13_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox13.TextChanged
        If IsNumeric(TextBox13.Text) Then
            'nada
        Else
            TextBox13.Clear()
        End If
    End Sub

    Private Sub TextBox130_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox130.TextChanged
        If IsNumeric(TextBox130.Text) Then
            'nada
        Else
            TextBox130.Clear()
        End If
    End Sub
```

```
    Private Sub TextBox129_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox129.TextChanged
        If IsNumeric(TextBox129.Text) Then
            'nada
        Else
            TextBox129.Clear()
        End If
    End Sub

    Private Sub TextBox128_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox128.TextChanged
        If IsNumeric(TextBox128.Text) Then
            'nada
        Else
            TextBox128.Clear()
        End If
    End Sub

    Private Sub TextBox9_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox9.TextChanged
        If IsNumeric(TextBox9.Text) Then
            'nada
        Else
            TextBox9.Clear()
        End If
    End Sub

    Private Sub TextBox8_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox8.TextChanged
        If IsNumeric(TextBox8.Text) Then
            'nada
        Else
            TextBox8.Clear()
        End If
    End Sub

    Private Sub Unit_Weight_Block_Sample__Load(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles MyBase.Load

        ToolTip1.SetToolTip(Button1, "Shows Test Procedure of the test")
        ToolTip1.SetToolTip(Button2, "Print the output")
        ToolTip1.SetToolTip(Button3, "Calculate the output")

        ToolTip1.SetToolTip(TextBox18, "Please enter the Project Name")
        ToolTip1.SetToolTip(TextBox20, "Please enter the Station Chainage")
        ToolTip1.SetToolTip(TextBox2, "Please enter the Depth of sample is taken")
        ToolTip1.SetToolTip(TextBox1, "Please enter the Material Description")
        ToolTip1.SetToolTip(TextBox19, "Please enter the Laboratory Number")
        ToolTip1.SetToolTip(DateTimePicker1, "Please enter the Date Sampled")
        ToolTip1.SetToolTip(DateTimePicker2, "Please enter the Date Tested")
    End Sub


    Private Sub Button4_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button4.Click
        My.Forms.Help.ShowDialog()
    End Sub
End Class
```

4. Code Used to develop Sieve Analysis of Soil

```
Public Class Sieve_Analysis

    Dim Number1, Number2, Number3, Number4, Number5, Number6, Number7, Number8,
Number9, Number10, Number11, Number12 As Double
    Dim Number13, Number14, Number15, Number16, Number17, Number18, Number19,
Number20, Number21, Number22, Number23, Number24 As Double
    Dim Number25, Number26, Number27, Number28 As Double
    Dim Number29, Number30, Number31, Number32, Number33, Number34, Number35,
Number36, Number37, Number38, Number39, Number40, Number41, Number42 As Double
    Dim Number43, Number44, Number45, Number46, Number47, Number48, Number49,
Number50, Number51, Number52, Number53, Number54, Number55 As Double
    Dim Number56, Number57, Number58, Number59, Number60, Number61, Number62,
Number63, Number64, Number65, Number66, Number67, Number68, Number69 As Double

    Dim Answer1, Answer2, Answer3, Answer4, Answer5, Answer6, Answer7, Answer8,
Answer9, Answer10, Answer11, Answer12, Answer13 As Double
    Dim Answer14, Answer15, Answer16, Answer17, Answer18, Answer19, Answer20,
Answer21, Answer22, Answer23, Answer24, Answer25 As Double
    Dim Answer26, Answer27, Answer28, Answer29, Answer30, Answer31, Answer32,
Answer33, Answer34, Answer35, Answer36, Answer37 As Double
    Dim Answer38, Answer39, Answer40, Answer41, Answer42, Answer43, Answer44,
Answer45, Answer46, Answer47, Answer48, Answer49 As Double
    Dim Answer50, Answer51, Answer52, Answer53, Answer54, Answer55, Answer56,
Answer57, Answer58, Answer59, Answer60, Answer61, Answer62, Answer63 As Double
    Dim Answer64, Answer65, Answer66, Answer67, Answer68, Answer69, Answer70,
Answer71, Answer72, Answer73, Answer74, Answer75, Answer76, Answer77 As Double
    Dim Answer78, Answer79, Answer80, Answer81, Answer82, Answer83, Answer84,
Answer85, Answer86, Answer87, Answer88, Answer89, Answer90, Answer91 As Double
    Dim Answer92, Answer93, Answer94, Answer95, Answer96, Answer97, Answer98,
Answer99, Answer100, Answer101, Answer102, Answer103, Answer104, Answer105 As Double


    Private Sub Button3_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button3.Click

        ' For Sieve Analysis with 152H Hydrometer

        If RadioButton1.Checked = True Then

            If TextBox5.Text = "" Or TextBox6.Text = "" Or TextBox7.Text = "" Or
TextBox8.Text = "" Or TextBox9.Text = "" Or TextBox10.Text = "" Or TextBox11.Text = ""
Or TextBox12.Text = "" Or
                TextBox13.Text = "" Or TextBox14.Text = "" Or TextBox15.Text = "" Or
TextBox40.Text = "" Or TextBox16.Text = "" Or TextBox17.Text = "" Or TextBox18.Text =
"" Or TextBox19.Text = "" Or
                TextBox20.Text = "" Or TextBox21.Text = "" Or TextBox22.Text = "" Or
TextBox23.Text = "" Or TextBox24.Text = "" Or TextBox25.Text = "" Or TextBox26.Text =
"" Or TextBox39.Text = "" Or
                TextBox48.Text = "" Or TextBox49.Text = "" Or TextBox50.Text = "" Or
TextBox51.Text = "" Or TextBox52.Text = "" Or TextBox53.Text = "" Or TextBox54.Text =
"" Or TextBox55.Text = "" Or
                TextBox56.Text = "" Or TextBox57.Text = "" Or TextBox58.Text = "" Or
TextBox59.Text = "" Or TextBox60.Text = "" Or TextBox61.Text = "" Or TextBox62.Text =
"" Or TextBox63.Text = "" Or
                TextBox64.Text = "" Or TextBox65.Text = "" Or TextBox66.Text = "" Or
TextBox68.Text = "" Or TextBox69.Text = "" Or TextBox70.Text = "" Or TextBox71.Text =
"" Or TextBox72.Text = "" Or
                TextBox73.Text = "" Or TextBox74.Text = "" Or TextBox75.Text = "" Or
TextBox76.Text = "" Or TextBox77.Text = "" Or TextBox78.Text = "" Or TextBox79.Text =
"" Then
```

```
            MessageBox.Show("Please fill all the input data in the Input Data
Box")
        Else

            ' Sieve Analysis
            Number1 = TextBox5.Text
            Number2 = TextBox6.Text
            Number3 = TextBox7.Text
            Number4 = TextBox8.Text
            Number5 = TextBox9.Text
            Number6 = TextBox10.Text
            Number7 = TextBox11.Text
            Number8 = TextBox12.Text
            Number9 = TextBox13.Text
            Number10 = TextBox14.Text
            Number11 = TextBox15.Text
            Number12 = TextBox40.Text

            Number13 = TextBox26.Text
            Number14 = TextBox25.Text
            Number15 = TextBox24.Text
            Number16 = TextBox23.Text
            Number17 = TextBox22.Text
            Number18 = TextBox21.Text
            Number19 = TextBox20.Text
            Number20 = TextBox19.Text
            Number21 = TextBox18.Text
            Number22 = TextBox17.Text
            Number23 = TextBox16.Text
            Number24 = TextBox39.Text

            ' the number belows are for Hydrometer test
            Number25 = TextBox64.Text
            Number26 = TextBox65.Text
            Number27 = TextBox66.Text

            Number29 = TextBox61.Text
            Number30 = TextBox60.Text
            Number31 = TextBox59.Text
            Number32 = TextBox58.Text
            Number33 = TextBox57.Text
            Number34 = TextBox56.Text
            Number35 = TextBox55.Text
            Number36 = TextBox54.Text
            Number37 = TextBox53.Text
            Number38 = TextBox52.Text
            Number39 = TextBox51.Text
            Number40 = TextBox50.Text
            Number41 = TextBox49.Text
            Number42 = TextBox48.Text

            Number28 = TextBox79.Text
            Number43 = TextBox78.Text
            Number44 = TextBox77.Text
            Number45 = TextBox76.Text
            Number46 = TextBox75.Text
            Number47 = TextBox74.Text
            Number48 = TextBox73.Text
            Number49 = TextBox72.Text
            Number50 = TextBox71.Text
            Number51 = TextBox70.Text
```

```
                Number52 = TextBox69.Text
                Number53 = TextBox68.Text
                Number54 = TextBox63.Text
                Number55 = TextBox62.Text

                Number56 = TextBox93.Text
                Number57 = TextBox92.Text
                Number58 = TextBox91.Text
                Number59 = TextBox90.Text
                Number60 = TextBox89.Text
                Number61 = TextBox88.Text
                Number62 = TextBox87.Text
                Number63 = TextBox86.Text
                Number64 = TextBox85.Text
                Number65 = TextBox84.Text
                Number66 = TextBox83.Text
                Number67 = TextBox82.Text
                Number68 = TextBox81.Text
                Number69 = TextBox80.Text



                If Number1 < 0 Or Number2 < 0 Or Number3 < 0 Or Number4 < 0 Or Number5
< 0 Or Number6 < 0 Or Number7 < 0 Or Number8 < 0 Or Number9 < 0 Or Number10 < 0 Or
Number11 < 0 Or Number12 < 0 Then
                    MessageBox.Show("In Sieve Analysis, One of The Input Value of
(Weight of Sieve) is negative, Please Adjust it before Proceeding")
                End If

                If Number13 < 0 Or Number14 < 0 Or Number15 < 0 Or Number16 < 0 Or
Number17 < 0 Or Number18 < 0 Or Number19 < 0 Or Number20 < 0 Or Number21 < 0 Or
Number22 < 0 Or Number23 < 0 Or Number24 < 0 Then
                    MessageBox.Show("In Sieve Analysis, One of The Input Value of
(Weight of Sieve + Soil Retained) is negative, Please Adjust it before Proceeding")
                End If

                If Number1 > Number13 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 75mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number2 > Number14 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 37.5mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number3 > Number15 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 19mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number4 > Number16 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 9.5mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number5 > Number17 Then
```

```
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 4.75mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number6 > Number18 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 2.00mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number7 > Number19 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 0.85mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number8 > Number20 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 0.425mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number9 > Number21 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 0.25mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number10 > Number22 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 0.15mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number11 > Number23 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 0.075mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number12 > Number24 Then
                    MessageBox.Show("In Sieve Analysis, On the Pan the input value of
(Weight of Sieve) is greater than (Weight of Sieve + Soil Retained),Please Adjust it
before Proceeding ")
                End If

                ' the If clause below are for Hydrometer test

                If Number29 < 0 Or Number30 < 0 Or Number31 < 0 Or Number32 < 0 Or
Number33 < 0 Or Number34 < 0 Or Number35 < 0 Or Number36 < 0 Or Number37 < 0 Or
Number38 < 0 Or Number39 < 0 Or Number40 < 0 Or Number41 < 0 Or Number42 < 0 Then
                    MessageBox.Show("In Hydrometer Analysis, One of The Input Value of
(Actual Hydrometer Reading) is negative, Please Adjust it before Proceeding")
                End If

                If Number28 < 0 Or Number43 < 0 Or Number44 < 0 Or Number45 < 0 Or
Number46 < 0 Or Number47 < 0 Or Number48 < 0 Or Number49 < 0 Or Number50 < 0 Or
Number51 < 0 Or Number52 < 0 Or Number53 < 0 Or Number54 < 0 Or Number55 < 0 Then
                    MessageBox.Show("In Hydrometer Analysis, One of The Input Value of
(Effective Depth) is negative, Please Adjust it before Proceeding")
                End If
```

```
                If Number56 < 0 Or Number57 < 0 Or Number58 < 0 Or Number59 < 0 Or
Number60 < 0 Or Number61 < 0 Or Number62 < 0 Or Number63 < 0 Or Number64 < 0 Or
Number65 < 0 Or Number66 < 0 Or Number67 < 0 Or Number68 < 0 Or Number69 < 0 Then
                    MessageBox.Show("In Hydrometer Analysis, One of The Input Value of
(K Factor) is negative, Please Adjust it before Proceeding")
                End If

                If Number25 < 0 Then
                    MessageBox.Show("In Hydrometer Input, the Value of (Weight) is
negative, Please Adjust it before Proceeding")
                End If

                If Number26 < 0 Then
                    MessageBox.Show("In Hydrometer Input, the Value of (Specific
Gravity) is negative, Please Adjust it before Proceeding")
                End If

                If Number1 > 0 And Number2 > 0 And Number3 > 0 And Number4 > 0 And
Number5 > 0 And Number6 > 0 And Number7 > 0 And Number8 > 0 And Number9 > 0 And
Number10 > 0 And Number11 > 0 And Number12 > 0 And Number13 > 0 And Number14 > 0 And
                    Number15 > 0 And Number16 > 0 And Number17 > 0 And Number18 > 0
And Number19 > 0 And Number20 > 0 And Number21 > 0 And Number22 > 0 And Number23 > 0
And Number24 > 0 And Number13 >= Number1 And Number14 >= Number2 And Number15 >=
Number3 And
                    Number16 >= Number4 And Number17 >= Number5 And Number18 >=
Number6 And Number19 >= Number7 And Number20 >= Number8 And Number21 >= Number9 And
Number22 >= Number10 And Number23 >= Number11 And Number24 >= Number12 And Number25 >
0 And
                    Number26 > 0 And Number29 > 0 And Number30 > 0 And Number31 > 0
And Number32 > 0 And Number33 > 0 And Number34 > 0 And Number35 > 0 And Number36 > 0
And Number37 > 0 And Number38 > 0 And Number39 > 0 And Number40 > 0 And Number41 > 0
And Number42 > 0 And
                    Number28 > 0 And Number43 > 0 And Number44 > 0 And Number45 > 0
And Number46 > 0 And Number47 > 0 And Number48 > 0 And Number49 > 0 And Number50 > 0
And Number51 > 0 And Number52 > 0 And Number53 > 0 And Number54 > 0 And Number55 > 0
And Number56 > 0 And
                    Number57 > 0 And Number58 > 0 And Number59 > 0 And Number60 > 0
And Number61 > 0 And Number62 > 0 And Number63 > 0 And Number64 > 0 And Number65 > 0
And Number66 > 0 And Number67 > 0 And Number68 > 0 And Number69 > 0 Then

                    Answer1 = Number13 - Number1
                    Answer2 = Number14 - Number2
                    Answer3 = Number15 - Number3
                    Answer4 = Number16 - Number4
                    Answer5 = Number17 - Number5
                    Answer6 = Number18 - Number6
                    Answer7 = Number19 - Number7
                    Answer8 = Number20 - Number8
                    Answer9 = Number21 - Number9
                    Answer10 = Number22 - Number10
                    Answer11 = Number23 - Number11
                    Answer12 = Number24 - Number12
                    Answer13 = Answer1 + Answer2 + Answer3 + Answer4 + Answer5 +
Answer6 + Answer7 + Answer8 + Answer9 + Answer10 + Answer11 + Answer12

                    Answer14 = (Answer1 / Answer13) * 100
                    Answer15 = (Answer2 / Answer13) * 100
                    Answer16 = (Answer3 / Answer13) * 100
                    Answer17 = (Answer4 / Answer13) * 100
                    Answer18 = (Answer5 / Answer13) * 100
                    Answer19 = (Answer6 / Answer13) * 100
```

```
Answer20 = (Answer7 / Answer13) * 100
Answer21 = (Answer8 / Answer13) * 100
Answer22 = (Answer9 / Answer13) * 100
Answer23 = (Answer10 / Answer13) * 100
Answer24 = (Answer11 / Answer13) * 100
Answer25 = (Answer12 / Answer13) * 100

Answer26 = Answer14
Answer27 = Answer15 + Answer26
Answer28 = Answer16 + Answer27
Answer29 = Answer17 + Answer28
Answer30 = Answer18 + Answer29
Answer31 = Answer19 + Answer30
Answer32 = Answer20 + Answer31
Answer33 = Answer21 + Answer32
Answer34 = Answer22 + Answer33
Answer35 = Answer23 + Answer34
Answer36 = Answer24 + Answer35
Answer37 = Answer25 + Answer36

Answer38 = 100 - Answer26
Answer39 = 100 - Answer27
Answer40 = 100 - Answer28
Answer41 = 100 - Answer29
Answer42 = 100 - Answer30
Answer43 = 100 - Answer31
Answer44 = 100 - Answer32
Answer45 = 100 - Answer33
Answer46 = 100 - Answer34
Answer47 = 100 - Answer35
Answer48 = 100 - Answer36
Answer49 = 100 - Answer37

Label56.Text = Convert.ToString(FormatNumber(Answer1, 2))
Label57.Text = Convert.ToString(FormatNumber(Answer2, 2))
Label58.Text = Convert.ToString(FormatNumber(Answer3, 2))
Label59.Text = Convert.ToString(FormatNumber(Answer4, 2))
Label60.Text = Convert.ToString(FormatNumber(Answer5, 2))
Label61.Text = Convert.ToString(FormatNumber(Answer6, 2))
Label62.Text = Convert.ToString(FormatNumber(Answer7, 2))
Label63.Text = Convert.ToString(FormatNumber(Answer8, 2))
Label64.Text = Convert.ToString(FormatNumber(Answer9, 2))
Label65.Text = Convert.ToString(FormatNumber(Answer10, 2))
Label66.Text = Convert.ToString(FormatNumber(Answer11, 2))
Label67.Text = Convert.ToString(FormatNumber(Answer12, 2))
Label22.Text = Convert.ToString(FormatNumber(Answer13, 2))

Label80.Text = Convert.ToString(FormatNumber(Answer14, 2))
Label79.Text = Convert.ToString(FormatNumber(Answer15, 2))
Label77.Text = Convert.ToString(FormatNumber(Answer16, 2))
Label76.Text = Convert.ToString(FormatNumber(Answer17, 2))
Label75.Text = Convert.ToString(FormatNumber(Answer18, 2))
Label74.Text = Convert.ToString(FormatNumber(Answer19, 2))
Label73.Text = Convert.ToString(FormatNumber(Answer20, 2))
Label72.Text = Convert.ToString(FormatNumber(Answer21, 2))
Label71.Text = Convert.ToString(FormatNumber(Answer22, 2))
Label70.Text = Convert.ToString(FormatNumber(Answer23, 2))
Label69.Text = Convert.ToString(FormatNumber(Answer24, 2))
Label68.Text = Convert.ToString(FormatNumber(Answer25, 2))

Label93.Text = Convert.ToString(FormatNumber(Answer26, 2))
Label92.Text = Convert.ToString(FormatNumber(Answer27, 2))
```

```
Label91.Text = Convert.ToString(FormatNumber(Answer28, 2))
Label89.Text = Convert.ToString(FormatNumber(Answer29, 2))
Label88.Text = Convert.ToString(FormatNumber(Answer30, 2))
Label87.Text = Convert.ToString(FormatNumber(Answer31, 2))
Label86.Text = Convert.ToString(FormatNumber(Answer32, 2))
Label85.Text = Convert.ToString(FormatNumber(Answer33, 2))
Label84.Text = Convert.ToString(FormatNumber(Answer34, 2))
Label83.Text = Convert.ToString(FormatNumber(Answer35, 2))
Label82.Text = Convert.ToString(FormatNumber(Answer36, 2))
Label81.Text = Convert.ToString(FormatNumber(Answer37, 2))

Label105.Text = Convert.ToString(FormatNumber(Answer38, 2))
Label104.Text = Convert.ToString(FormatNumber(Answer39, 2))
Label103.Text = Convert.ToString(FormatNumber(Answer40, 2))
Label102.Text = Convert.ToString(FormatNumber(Answer41, 2))
Label101.Text = Convert.ToString(FormatNumber(Answer42, 2))
Label100.Text = Convert.ToString(FormatNumber(Answer43, 2))
Label99.Text = Convert.ToString(FormatNumber(Answer44, 2))
Label98.Text = Convert.ToString(FormatNumber(Answer45, 2))
Label97.Text = Convert.ToString(FormatNumber(Answer46, 2))
Label96.Text = Convert.ToString(FormatNumber(Answer47, 2))
Label95.Text = Convert.ToString(FormatNumber(Answer48, 2))
Label94.Text = Convert.ToString(FormatNumber(Answer49, 2))


' Hydrometer Analysis

Answer50 = Number29 + Number27
Answer51 = Number30 + Number27
Answer52 = Number31 + Number27
Answer53 = Number32 + Number27
Answer54 = Number33 + Number27
Answer55 = Number34 + Number27
Answer56 = Number35 + Number27
Answer57 = Number36 + Number27
Answer58 = Number37 + Number27
Answer59 = Number38 + Number27
Answer60 = Number39 + Number27
Answer61 = Number40 + Number27
Answer62 = Number41 + Number27
Answer63 = Number42 + Number27

Label118.Text = Convert.ToString(FormatNumber(Answer50, 4))
Label117.Text = Convert.ToString(FormatNumber(Answer51, 4))
Label116.Text = Convert.ToString(FormatNumber(Answer52, 4))
Label115.Text = Convert.ToString(FormatNumber(Answer53, 4))
Label38.Text = Convert.ToString(FormatNumber(Answer54, 4))
Label36.Text = Convert.ToString(FormatNumber(Answer55, 4))
Label35.Text = Convert.ToString(FormatNumber(Answer56, 4))
Label34.Text = Convert.ToString(FormatNumber(Answer57, 4))
Label33.Text = Convert.ToString(FormatNumber(Answer58, 4))
Label32.Text = Convert.ToString(FormatNumber(Answer59, 4))
Label31.Text = Convert.ToString(FormatNumber(Answer60, 4))
Label30.Text = Convert.ToString(FormatNumber(Answer61, 4))
Label120.Text = Convert.ToString(FormatNumber(Answer62, 4))
Label119.Text = Convert.ToString(FormatNumber(Answer63, 4))


Answer64 = Number56 * ((Number28 / 0.25) ^ 0.5)
Answer65 = Number57 * ((Number43 / 0.5) ^ 0.5)
Answer66 = Number58 * ((Number44 / 1) ^ 0.5)
Answer67 = Number59 * ((Number45 / 2) ^ 0.5)
```

```
                    Answer68 = Number60 * ((Number46 / 4) ^ 0.5)
                    Answer69 = Number61 * ((Number47 / 8) ^ 0.5)
                    Answer70 = Number62 * ((Number48 / 15) ^ 0.5)
                    Answer71 = Number63 * ((Number49 / 30) ^ 0.5)
                    Answer72 = Number64 * ((Number50 / 60) ^ 0.5)
                    Answer73 = Number65 * ((Number51 / 120) ^ 0.5)
                    Answer74 = Number66 * ((Number52 / 240) ^ 0.5)
                    Answer75 = Number67 * ((Number53 / 480) ^ 0.5)
                    Answer76 = Number68 * ((Number54 / 960) ^ 0.5)
                    Answer77 = Number69 * ((Number55 / 1440) ^ 0.5)

                    Label135.Text = Convert.ToString(FormatNumber(Answer64, 4))
                    Label134.Text = Convert.ToString(FormatNumber(Answer65, 4))
                    Label133.Text = Convert.ToString(FormatNumber(Answer66, 4))
                    Label132.Text = Convert.ToString(FormatNumber(Answer67, 4))
                    Label131.Text = Convert.ToString(FormatNumber(Answer68, 4))
                    Label130.Text = Convert.ToString(FormatNumber(Answer69, 4))
                    Label129.Text = Convert.ToString(FormatNumber(Answer70, 4))
                    Label128.Text = Convert.ToString(FormatNumber(Answer71, 4))
                    Label127.Text = Convert.ToString(FormatNumber(Answer72, 4))
                    Label126.Text = Convert.ToString(FormatNumber(Answer73, 4))
                    Label125.Text = Convert.ToString(FormatNumber(Answer74, 4))
                    Label124.Text = Convert.ToString(FormatNumber(Answer75, 4))
                    Label123.Text = Convert.ToString(FormatNumber(Answer76, 4))
                    Label122.Text = Convert.ToString(FormatNumber(Answer77, 4))

                    Answer78 = ((1.65 * Answer50 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer79 = ((1.65 * Answer51 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer80 = ((1.65 * Answer52 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer81 = ((1.65 * Answer53 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer82 = ((1.65 * Answer54 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer83 = ((1.65 * Answer55 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer84 = ((1.65 * Answer56 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer85 = ((1.65 * Answer57 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer86 = ((1.65 * Answer58 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer87 = ((1.65 * Answer59 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer88 = ((1.65 * Answer60 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer89 = ((1.65 * Answer61 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer90 = ((1.65 * Answer62 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100
                    Answer91 = ((1.65 * Answer63 * Number26) / (2.65 * Number25 *
(Number26 - 1))) * 100

                    Label150.Text = Convert.ToString(FormatNumber(Answer78, 2))
                    Label149.Text = Convert.ToString(FormatNumber(Answer79, 2))
                    Label148.Text = Convert.ToString(FormatNumber(Answer80, 2))
                    Label147.Text = Convert.ToString(FormatNumber(Answer81, 2))
                    Label146.Text = Convert.ToString(FormatNumber(Answer82, 2))
                    Label145.Text = Convert.ToString(FormatNumber(Answer83, 2))
                    Label144.Text = Convert.ToString(FormatNumber(Answer84, 2))
```

```
                    Label143.Text = Convert.ToString(FormatNumber(Answer85, 2))
                    Label142.Text = Convert.ToString(FormatNumber(Answer86, 2))
                    Label141.Text = Convert.ToString(FormatNumber(Answer87, 2))
                    Label140.Text = Convert.ToString(FormatNumber(Answer88, 2))
                    Label139.Text = Convert.ToString(FormatNumber(Answer89, 2))
                    Label138.Text = Convert.ToString(FormatNumber(Answer90, 2))
                    Label137.Text = Convert.ToString(FormatNumber(Answer91, 2))


                    Answer92 = (Answer12 * Answer78) / Answer13
                    Answer93 = (Answer12 * Answer79) / Answer13
                    Answer94 = (Answer12 * Answer80) / Answer13
                    Answer95 = (Answer12 * Answer81) / Answer13
                    Answer96 = (Answer12 * Answer82) / Answer13
                    Answer97 = (Answer12 * Answer83) / Answer13
                    Answer98 = (Answer12 * Answer84) / Answer13
                    Answer99 = (Answer12 * Answer85) / Answer13
                    Answer100 = (Answer12 * Answer86) / Answer13
                    Answer101 = (Answer12 * Answer87) / Answer13
                    Answer102 = (Answer12 * Answer88) / Answer13
                    Answer103 = (Answer12 * Answer89) / Answer13
                    Answer104 = (Answer12 * Answer90) / Answer13
                    Answer105 = (Answer12 * Answer91) / Answer13

                    Label165.Text = Convert.ToString(FormatNumber(Answer92, 2))
                    Label164.Text = Convert.ToString(FormatNumber(Answer93, 2))
                    Label163.Text = Convert.ToString(FormatNumber(Answer94, 2))
                    Label162.Text = Convert.ToString(FormatNumber(Answer95, 2))
                    Label161.Text = Convert.ToString(FormatNumber(Answer96, 2))
                    Label160.Text = Convert.ToString(FormatNumber(Answer97, 2))
                    Label159.Text = Convert.ToString(FormatNumber(Answer98, 2))
                    Label158.Text = Convert.ToString(FormatNumber(Answer99, 2))
                    Label157.Text = Convert.ToString(FormatNumber(Answer100, 2))
                    Label156.Text = Convert.ToString(FormatNumber(Answer101, 2))
                    Label155.Text = Convert.ToString(FormatNumber(Answer102, 2))
                    Label154.Text = Convert.ToString(FormatNumber(Answer103, 2))
                    Label153.Text = Convert.ToString(FormatNumber(Answer104, 2))
                    Label42.Text = Convert.ToString(FormatNumber(Answer105, 2))

                End If
            End If
        End If


        ' For Sieve Analysis with 151H Hydrometer

        If RadioButton2.Checked = True Then

            If TextBox5.Text = "" Or TextBox6.Text = "" Or TextBox7.Text = "" Or
TextBox8.Text = "" Or TextBox9.Text = "" Or TextBox10.Text = "" Or TextBox11.Text = ""
Or TextBox12.Text = "" Or
                TextBox13.Text = "" Or TextBox14.Text = "" Or TextBox15.Text = "" Or
TextBox40.Text = "" Or TextBox16.Text = "" Or TextBox17.Text = "" Or TextBox18.Text =
"" Or TextBox19.Text = "" Or
                TextBox20.Text = "" Or TextBox21.Text = "" Or TextBox22.Text = "" Or
TextBox23.Text = "" Or TextBox24.Text = "" Or TextBox25.Text = "" Or TextBox26.Text =
"" Or TextBox39.Text = "" Or
                TextBox48.Text = "" Or TextBox49.Text = "" Or TextBox50.Text = "" Or
TextBox51.Text = "" Or TextBox52.Text = "" Or TextBox53.Text = "" Or TextBox54.Text =
"" Or TextBox55.Text = "" Or
```

```
                TextBox56.Text = "" Or TextBox57.Text = "" Or TextBox58.Text = "" Or
TextBox59.Text = "" Or TextBox60.Text = "" Or TextBox61.Text = "" Or TextBox62.Text =
"" Or TextBox63.Text = "" Or
                TextBox64.Text = "" Or TextBox65.Text = "" Or TextBox66.Text = "" Or
TextBox68.Text = "" Or TextBox69.Text = "" Or TextBox70.Text = "" Or TextBox71.Text =
"" Or TextBox72.Text = "" Or
                TextBox73.Text = "" Or TextBox74.Text = "" Or TextBox75.Text = "" Or
TextBox76.Text = "" Or TextBox77.Text = "" Or TextBox78.Text = "" Or TextBox79.Text =
"" Then

                MessageBox.Show("Please fill all the input data in the Input Data
Box")
            Else

                ' Sieve Analysis
                Number1 = TextBox5.Text
                Number2 = TextBox6.Text
                Number3 = TextBox7.Text
                Number4 = TextBox8.Text
                Number5 = TextBox9.Text
                Number6 = TextBox10.Text
                Number7 = TextBox11.Text
                Number8 = TextBox12.Text
                Number9 = TextBox13.Text
                Number10 = TextBox14.Text
                Number11 = TextBox15.Text
                Number12 = TextBox40.Text

                Number13 = TextBox26.Text
                Number14 = TextBox25.Text
                Number15 = TextBox24.Text
                Number16 = TextBox23.Text
                Number17 = TextBox22.Text
                Number18 = TextBox21.Text
                Number19 = TextBox20.Text
                Number20 = TextBox19.Text
                Number21 = TextBox18.Text
                Number22 = TextBox17.Text
                Number23 = TextBox16.Text
                Number24 = TextBox39.Text

                ' the number belows are for Hydrometer test
                Number25 = TextBox64.Text
                Number26 = TextBox65.Text
                Number27 = TextBox66.Text

                Number29 = TextBox61.Text
                Number30 = TextBox60.Text
                Number31 = TextBox59.Text
                Number32 = TextBox58.Text
                Number33 = TextBox57.Text
                Number34 = TextBox56.Text
                Number35 = TextBox55.Text
                Number36 = TextBox54.Text
                Number37 = TextBox53.Text
                Number38 = TextBox52.Text
                Number39 = TextBox51.Text
                Number40 = TextBox50.Text
                Number41 = TextBox49.Text
                Number42 = TextBox48.Text

                Number28 = TextBox79.Text
```

```
                Number43 = TextBox78.Text
                Number44 = TextBox77.Text
                Number45 = TextBox76.Text
                Number46 = TextBox75.Text
                Number47 = TextBox74.Text
                Number48 = TextBox73.Text
                Number49 = TextBox72.Text
                Number50 = TextBox71.Text
                Number51 = TextBox70.Text
                Number52 = TextBox69.Text
                Number53 = TextBox68.Text
                Number54 = TextBox63.Text
                Number55 = TextBox62.Text

                Number56 = TextBox93.Text
                Number57 = TextBox92.Text
                Number58 = TextBox91.Text
                Number59 = TextBox90.Text
                Number60 = TextBox89.Text
                Number61 = TextBox88.Text
                Number62 = TextBox87.Text
                Number63 = TextBox86.Text
                Number64 = TextBox85.Text
                Number65 = TextBox84.Text
                Number66 = TextBox83.Text
                Number67 = TextBox82.Text
                Number68 = TextBox81.Text
                Number69 = TextBox80.Text



                If Number1 < 0 Or Number2 < 0 Or Number3 < 0 Or Number4 < 0 Or Number5
< 0 Or Number6 < 0 Or Number7 < 0 Or Number8 < 0 Or Number9 < 0 Or Number10 < 0 Or
Number11 < 0 Or Number12 < 0 Then
                    MessageBox.Show("In Sieve Analysis, One of The Input Value of
(Weight of Sieve) is negative, Please Adjust it before Proceeding")
                End If

                If Number13 < 0 Or Number14 < 0 Or Number15 < 0 Or Number16 < 0 Or
Number17 < 0 Or Number18 < 0 Or Number19 < 0 Or Number20 < 0 Or Number21 < 0 Or
Number22 < 0 Or Number23 < 0 Or Number24 < 0 Then
                    MessageBox.Show("In Sieve Analysis, One of The Input Value of
(Weight of Sieve + Soil Retained) is negative, Please Adjust it before Proceeding")
                End If

                If Number1 > Number13 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 75mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number2 > Number14 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 37.5mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number3 > Number15 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 19mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If
```

```
                If Number4 > Number16 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 9.5mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number5 > Number17 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 4.75mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number6 > Number18 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 2.00mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number7 > Number19 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 0.85mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number8 > Number20 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 0.425mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number9 > Number21 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 0.25mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number10 > Number22 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 0.15mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number11 > Number23 Then
                    MessageBox.Show("In Sieve Analysis, On Sieve Opening 0.075mm the
input value of (Weight of Sieve) is greater than (Weight of Sieve + Soil
Retained),Please Adjust it before Proceeding ")
                End If

                If Number12 > Number24 Then
                    MessageBox.Show("In Sieve Analysis, On the Pan the input value of
(Weight of Sieve) is greater than (Weight of Sieve + Soil Retained),Please Adjust it
before Proceeding ")
                End If

                ' the If clause below are for Hydrometer test

                If Number29 < 0 Or Number30 < 0 Or Number31 < 0 Or Number32 < 0 Or
Number33 < 0 Or Number34 < 0 Or Number35 < 0 Or Number36 < 0 Or Number37 < 0 Or
Number38 < 0 Or Number39 < 0 Or Number40 < 0 Or Number41 < 0 Or Number42 < 0 Then
                    MessageBox.Show("In Hydrometer Analysis, One of The Input Value of
(Actual Hydrometer Reading) is negative, Please Adjust it before Proceeding")
```

```
                End If

                If Number28 < 0 Or Number43 < 0 Or Number44 < 0 Or Number45 < 0 Or
Number46 < 0 Or Number47 < 0 Or Number48 < 0 Or Number49 < 0 Or Number50 < 0 Or
Number51 < 0 Or Number52 < 0 Or Number53 < 0 Or Number54 < 0 Or Number55 < 0 Then
                    MessageBox.Show("In Hydrometer Analysis, One of The Input Value of
(Effective Depth) is negative, Please Adjust it before Proceeding")
                End If

                If Number56 < 0 Or Number57 < 0 Or Number58 < 0 Or Number59 < 0 Or
Number60 < 0 Or Number61 < 0 Or Number62 < 0 Or Number63 < 0 Or Number64 < 0 Or
Number65 < 0 Or Number66 < 0 Or Number67 < 0 Or Number68 < 0 Or Number69 < 0 Then
                    MessageBox.Show("In Hydrometer Analysis, One of The Input Value of
(K Factor) is negative, Please Adjust it before Proceeding")
                End If

                If Number25 < 0 Then
                    MessageBox.Show("In Hydrometer Input, the Value of (Weight) is
negative, Please Adjust it before Proceeding")
                End If

                If Number26 < 0 Then
                    MessageBox.Show("In Hydrometer Input, the Value of (Specific
Gravity) is negative, Please Adjust it before Proceeding")
                End If

                If Number1 > 0 And Number2 > 0 And Number3 > 0 And Number4 > 0 And
Number5 > 0 And Number6 > 0 And Number7 > 0 And Number8 > 0 And Number9 > 0 And
Number10 > 0 And Number11 > 0 And Number12 > 0 And Number13 > 0 And Number14 > 0 And
                    Number15 > 0 And Number16 > 0 And Number17 > 0 And Number18 > 0
And Number19 > 0 And Number20 > 0 And Number21 > 0 And Number22 > 0 And Number23 > 0
And Number24 > 0 And Number13 >= Number1 And Number14 >= Number2 And Number15 >=
Number3 And
                    Number16 >= Number4 And Number17 >= Number5 And Number18 >=
Number6 And Number19 >= Number7 And Number20 >= Number8 And Number21 >= Number9 And
Number22 >= Number10 And Number23 >= Number11 And Number24 >= Number12 And Number25 >
0 And Number26 > 0 And
                    Number29 > 0 And Number30 > 0 And Number31 > 0 And Number32 > 0
And Number33 > 0 And Number34 > 0 And Number35 > 0 And Number36 > 0 And Number37 > 0
And Number38 > 0 And Number39 > 0 And Number40 > 0 And Number41 > 0 And Number42 > 0
And Number28 > 0 And
                    Number43 > 0 And Number44 > 0 And Number45 > 0 And Number46 > 0
And Number47 > 0 And Number48 > 0 And Number49 > 0 And Number50 > 0 And Number51 > 0
And Number52 > 0 And Number53 > 0 And Number54 > 0 And Number55 > 0 And Number56 > 0
And
                    Number57 > 0 And Number58 > 0 And Number59 > 0 And Number60 > 0
And Number61 > 0 And Number62 > 0 And Number63 > 0 And Number64 > 0 And Number65 > 0
And Number66 > 0 And Number67 > 0 And Number68 > 0 And Number69 > 0 Then

                    Answer1 = Number13 - Number1
                    Answer2 = Number14 - Number2
                    Answer3 = Number15 - Number3
                    Answer4 = Number16 - Number4
                    Answer5 = Number17 - Number5
                    Answer6 = Number18 - Number6
                    Answer7 = Number19 - Number7
                    Answer8 = Number20 - Number8
                    Answer9 = Number21 - Number9
                    Answer10 = Number22 - Number10
                    Answer11 = Number23 - Number11
                    Answer12 = Number24 - Number12
```

```
                    Answer13 = Answer1 + Answer2 + Answer3 + Answer4 + Answer5 +
Answer6 + Answer7 + Answer8 + Answer9 + Answer10 + Answer11 + Answer12

                    Answer14 = (Answer1 / Answer13) * 100
                    Answer15 = (Answer2 / Answer13) * 100
                    Answer16 = (Answer3 / Answer13) * 100
                    Answer17 = (Answer4 / Answer13) * 100
                    Answer18 = (Answer5 / Answer13) * 100
                    Answer19 = (Answer6 / Answer13) * 100
                    Answer20 = (Answer7 / Answer13) * 100
                    Answer21 = (Answer8 / Answer13) * 100
                    Answer22 = (Answer9 / Answer13) * 100
                    Answer23 = (Answer10 / Answer13) * 100
                    Answer24 = (Answer11 / Answer13) * 100
                    Answer25 = (Answer12 / Answer13) * 100

                    Answer26 = Answer14
                    Answer27 = Answer15 + Answer26
                    Answer28 = Answer16 + Answer27
                    Answer29 = Answer17 + Answer28
                    Answer30 = Answer18 + Answer29
                    Answer31 = Answer19 + Answer30
                    Answer32 = Answer20 + Answer31
                    Answer33 = Answer21 + Answer32
                    Answer34 = Answer22 + Answer33
                    Answer35 = Answer23 + Answer34
                    Answer36 = Answer24 + Answer35
                    Answer37 = Answer25 + Answer36

                    Answer38 = 100 - Answer26
                    Answer39 = 100 - Answer27
                    Answer40 = 100 - Answer28
                    Answer41 = 100 - Answer29
                    Answer42 = 100 - Answer30
                    Answer43 = 100 - Answer31
                    Answer44 = 100 - Answer32
                    Answer45 = 100 - Answer33
                    Answer46 = 100 - Answer34
                    Answer47 = 100 - Answer35
                    Answer48 = 100 - Answer36
                    Answer49 = 100 - Answer37

                    Label56.Text = Convert.ToString(FormatNumber(Answer1, 2))
                    Label57.Text = Convert.ToString(FormatNumber(Answer2, 2))
                    Label58.Text = Convert.ToString(FormatNumber(Answer3, 2))
                    Label59.Text = Convert.ToString(FormatNumber(Answer4, 2))
                    Label60.Text = Convert.ToString(FormatNumber(Answer5, 2))
                    Label61.Text = Convert.ToString(FormatNumber(Answer6, 2))
                    Label62.Text = Convert.ToString(FormatNumber(Answer7, 2))
                    Label63.Text = Convert.ToString(FormatNumber(Answer8, 2))
                    Label64.Text = Convert.ToString(FormatNumber(Answer9, 2))
                    Label65.Text = Convert.ToString(FormatNumber(Answer10, 2))
                    Label66.Text = Convert.ToString(FormatNumber(Answer11, 2))
                    Label67.Text = Convert.ToString(FormatNumber(Answer12, 2))
                    Label22.Text = Convert.ToString(FormatNumber(Answer13, 2))

                    Label80.Text = Convert.ToString(FormatNumber(Answer14, 2))
                    Label79.Text = Convert.ToString(FormatNumber(Answer15, 2))
                    Label77.Text = Convert.ToString(FormatNumber(Answer16, 2))
                    Label76.Text = Convert.ToString(FormatNumber(Answer17, 2))
                    Label75.Text = Convert.ToString(FormatNumber(Answer18, 2))
                    Label74.Text = Convert.ToString(FormatNumber(Answer19, 2))
```

```
Label73.Text = Convert.ToString(FormatNumber(Answer20, 2))
Label72.Text = Convert.ToString(FormatNumber(Answer21, 2))
Label71.Text = Convert.ToString(FormatNumber(Answer22, 2))
Label70.Text = Convert.ToString(FormatNumber(Answer23, 2))
Label69.Text = Convert.ToString(FormatNumber(Answer24, 2))
Label68.Text = Convert.ToString(FormatNumber(Answer25, 2))

Label93.Text = Convert.ToString(FormatNumber(Answer26, 2))
Label92.Text = Convert.ToString(FormatNumber(Answer27, 2))
Label91.Text = Convert.ToString(FormatNumber(Answer28, 2))
Label89.Text = Convert.ToString(FormatNumber(Answer29, 2))
Label88.Text = Convert.ToString(FormatNumber(Answer30, 2))
Label87.Text = Convert.ToString(FormatNumber(Answer31, 2))
Label86.Text = Convert.ToString(FormatNumber(Answer32, 2))
Label85.Text = Convert.ToString(FormatNumber(Answer33, 2))
Label84.Text = Convert.ToString(FormatNumber(Answer34, 2))
Label83.Text = Convert.ToString(FormatNumber(Answer35, 2))
Label82.Text = Convert.ToString(FormatNumber(Answer36, 2))
Label81.Text = Convert.ToString(FormatNumber(Answer37, 2))

Label105.Text = Convert.ToString(FormatNumber(Answer38, 2))
Label104.Text = Convert.ToString(FormatNumber(Answer39, 2))
Label103.Text = Convert.ToString(FormatNumber(Answer40, 2))
Label102.Text = Convert.ToString(FormatNumber(Answer41, 2))
Label101.Text = Convert.ToString(FormatNumber(Answer42, 2))
Label100.Text = Convert.ToString(FormatNumber(Answer43, 2))
Label99.Text = Convert.ToString(FormatNumber(Answer44, 2))
Label98.Text = Convert.ToString(FormatNumber(Answer45, 2))
Label97.Text = Convert.ToString(FormatNumber(Answer46, 2))
Label96.Text = Convert.ToString(FormatNumber(Answer47, 2))
Label95.Text = Convert.ToString(FormatNumber(Answer48, 2))
Label94.Text = Convert.ToString(FormatNumber(Answer49, 2))


' Hydrometer Analysis

Answer50 = Number29 + Number27
Answer51 = Number30 + Number27
Answer52 = Number31 + Number27
Answer53 = Number32 + Number27
Answer54 = Number33 + Number27
Answer55 = Number34 + Number27
Answer56 = Number35 + Number27
Answer57 = Number36 + Number27
Answer58 = Number37 + Number27
Answer59 = Number38 + Number27
Answer60 = Number39 + Number27
Answer61 = Number40 + Number27
Answer62 = Number41 + Number27
Answer63 = Number42 + Number27

Label118.Text = Convert.ToString(FormatNumber(Answer50, 4))
Label117.Text = Convert.ToString(FormatNumber(Answer51, 4))
Label116.Text = Convert.ToString(FormatNumber(Answer52, 4))
Label115.Text = Convert.ToString(FormatNumber(Answer53, 4))
Label38.Text = Convert.ToString(FormatNumber(Answer54, 4))
Label36.Text = Convert.ToString(FormatNumber(Answer55, 4))
Label35.Text = Convert.ToString(FormatNumber(Answer56, 4))
Label34.Text = Convert.ToString(FormatNumber(Answer57, 4))
Label33.Text = Convert.ToString(FormatNumber(Answer58, 4))
Label32.Text = Convert.ToString(FormatNumber(Answer59, 4))
Label31.Text = Convert.ToString(FormatNumber(Answer60, 4))
```

```
                    Label130.Text = Convert.ToString(FormatNumber(Answer61, 4))
                    Label120.Text = Convert.ToString(FormatNumber(Answer62, 4))
                    Label119.Text = Convert.ToString(FormatNumber(Answer63, 4))


                    Answer64 = Number56 * ((Number28 / 0.25) ^ 0.5)
                    Answer65 = Number57 * ((Number43 / 0.5) ^ 0.5)
                    Answer66 = Number58 * ((Number44 / 1) ^ 0.5)
                    Answer67 = Number59 * ((Number45 / 2) ^ 0.5)
                    Answer68 = Number60 * ((Number46 / 4) ^ 0.5)
                    Answer69 = Number61 * ((Number47 / 8) ^ 0.5)
                    Answer70 = Number62 * ((Number48 / 15) ^ 0.5)
                    Answer71 = Number63 * ((Number49 / 30) ^ 0.5)
                    Answer72 = Number64 * ((Number50 / 60) ^ 0.5)
                    Answer73 = Number65 * ((Number51 / 120) ^ 0.5)
                    Answer74 = Number66 * ((Number52 / 240) ^ 0.5)
                    Answer75 = Number67 * ((Number53 / 480) ^ 0.5)
                    Answer76 = Number68 * ((Number54 / 960) ^ 0.5)
                    Answer77 = Number69 * ((Number55 / 1440) ^ 0.5)

                    Label135.Text = Convert.ToString(FormatNumber(Answer64, 4))
                    Label134.Text = Convert.ToString(FormatNumber(Answer65, 4))
                    Label133.Text = Convert.ToString(FormatNumber(Answer66, 4))
                    Label132.Text = Convert.ToString(FormatNumber(Answer67, 4))
                    Label131.Text = Convert.ToString(FormatNumber(Answer68, 4))
                    Label130.Text = Convert.ToString(FormatNumber(Answer69, 4))
                    Label129.Text = Convert.ToString(FormatNumber(Answer70, 4))
                    Label128.Text = Convert.ToString(FormatNumber(Answer71, 4))
                    Label127.Text = Convert.ToString(FormatNumber(Answer72, 4))
                    Label126.Text = Convert.ToString(FormatNumber(Answer73, 4))
                    Label125.Text = Convert.ToString(FormatNumber(Answer74, 4))
                    Label124.Text = Convert.ToString(FormatNumber(Answer75, 4))
                    Label123.Text = Convert.ToString(FormatNumber(Answer76, 4))
                    Label122.Text = Convert.ToString(FormatNumber(Answer77, 4))

                    Answer78 = ((1606 * 1.65 * Number26 * (Answer50 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer79 = ((1606 * 1.65 * Number26 * (Answer51 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer80 = ((1606 * 1.65 * Number26 * (Answer52 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer81 = ((1606 * 1.65 * Number26 * (Answer53 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer82 = ((1606 * 1.65 * Number26 * (Answer54 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer83 = ((1606 * 1.65 * Number26 * (Answer55 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer84 = ((1606 * 1.65 * Number26 * (Answer56 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer85 = ((1606 * 1.65 * Number26 * (Answer57 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer86 = ((1606 * 1.65 * Number26 * (Answer58 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100
```

```
                    Answer87 = ((1606 * 1.65 * Number26 * (Answer59 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer88 = ((1606 * 1.65 * Number26 * (Answer60 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer89 = ((1606 * 1.65 * Number26 * (Answer61 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer90 = ((1606 * 1.65 * Number26 * (Answer62 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Answer91 = ((1606 * 1.65 * Number26 * (Answer63 - 1)) / (2.65 *
Number25 * (Number26 - 1))) * 100

                    Label150.Text = Convert.ToString(FormatNumber(Answer78, 2))
                    Label149.Text = Convert.ToString(FormatNumber(Answer79, 2))
                    Label148.Text = Convert.ToString(FormatNumber(Answer80, 2))
                    Label147.Text = Convert.ToString(FormatNumber(Answer81, 2))
                    Label146.Text = Convert.ToString(FormatNumber(Answer82, 2))
                    Label145.Text = Convert.ToString(FormatNumber(Answer83, 2))
                    Label144.Text = Convert.ToString(FormatNumber(Answer84, 2))
                    Label143.Text = Convert.ToString(FormatNumber(Answer85, 2))
                    Label142.Text = Convert.ToString(FormatNumber(Answer86, 2))
                    Label141.Text = Convert.ToString(FormatNumber(Answer87, 2))
                    Label140.Text = Convert.ToString(FormatNumber(Answer88, 2))
                    Label139.Text = Convert.ToString(FormatNumber(Answer89, 2))
                    Label138.Text = Convert.ToString(FormatNumber(Answer90, 2))
                    Label137.Text = Convert.ToString(FormatNumber(Answer91, 2))


                    Answer92 = (Answer12 * Answer78) / Answer13
                    Answer93 = (Answer12 * Answer79) / Answer13
                    Answer94 = (Answer12 * Answer80) / Answer13
                    Answer95 = (Answer12 * Answer81) / Answer13
                    Answer96 = (Answer12 * Answer82) / Answer13
                    Answer97 = (Answer12 * Answer83) / Answer13
                    Answer98 = (Answer12 * Answer84) / Answer13
                    Answer99 = (Answer12 * Answer85) / Answer13
                    Answer100 = (Answer12 * Answer86) / Answer13
                    Answer101 = (Answer12 * Answer87) / Answer13
                    Answer102 = (Answer12 * Answer88) / Answer13
                    Answer103 = (Answer12 * Answer89) / Answer13
                    Answer104 = (Answer12 * Answer90) / Answer13
                    Answer105 = (Answer12 * Answer91) / Answer13

                    Label165.Text = Convert.ToString(FormatNumber(Answer92, 2))
                    Label164.Text = Convert.ToString(FormatNumber(Answer93, 2))
                    Label163.Text = Convert.ToString(FormatNumber(Answer94, 2))
                    Label162.Text = Convert.ToString(FormatNumber(Answer95, 2))
                    Label161.Text = Convert.ToString(FormatNumber(Answer96, 2))
                    Label160.Text = Convert.ToString(FormatNumber(Answer97, 2))
                    Label159.Text = Convert.ToString(FormatNumber(Answer98, 2))
                    Label158.Text = Convert.ToString(FormatNumber(Answer99, 2))
                    Label157.Text = Convert.ToString(FormatNumber(Answer100, 2))
                    Label156.Text = Convert.ToString(FormatNumber(Answer101, 2))
                    Label155.Text = Convert.ToString(FormatNumber(Answer102, 2))
                    Label154.Text = Convert.ToString(FormatNumber(Answer103, 2))
                    Label153.Text = Convert.ToString(FormatNumber(Answer104, 2))
                    Label42.Text = Convert.ToString(FormatNumber(Answer105, 2))

                End If
```

```
            End If
        End If

        If RadioButton1.Checked = False And RadioButton2.Checked = False Then

            MessageBox.Show("Please Select the Type of the Hydrometer Type")

        End If

    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button1.Click
        My.Forms.Sieve_Analysis_Test_Procedure.ShowDialog()
    End Sub


    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button2.Click
        PrintForm1.PrinterSettings.DefaultPageSettings.Margins.Left = 5
        PrintForm1.PrinterSettings.DefaultPageSettings.Margins.Right = 5
        PrintForm1.PrinterSettings.DefaultPageSettings.Margins.Left = 25
        PrintForm1.PrinterSettings.DefaultPageSettings.Margins.Top = 25
        PrintForm1.PrinterSettings.DefaultPageSettings.Landscape = True
        PrintForm1.PrintAction = Printing.PrintAction.PrintToPreview
        PrintForm1.Print()
    End Sub

    Private Sub TextBox5_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox5.TextChanged
        If IsNumeric(TextBox5.Text) Then
            'nada
        Else
            TextBox5.Clear()
        End If
    End Sub

    Private Sub TextBox6_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox6.TextChanged
        If IsNumeric(TextBox6.Text) Then
            'nada
        Else
            TextBox6.Clear()
        End If
    End Sub

    Private Sub TextBox7_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox7.TextChanged
        If IsNumeric(TextBox7.Text) Then
            'nada
        Else
            TextBox7.Clear()
        End If
    End Sub

    Private Sub TextBox8_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox8.TextChanged
        If IsNumeric(TextBox8.Text) Then
            'nada
        Else
            TextBox8.Clear()
        End If
```

```
    End Sub

    Private Sub TextBox9_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox9.TextChanged
        If IsNumeric(TextBox9.Text) Then
            'nada
        Else
            TextBox9.Clear()
        End If
    End Sub

    Private Sub TextBox10_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox10.TextChanged
        If IsNumeric(TextBox10.Text) Then
            'nada
        Else
            TextBox10.Clear()
        End If
    End Sub

    Private Sub TextBox11_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox11.TextChanged
        If IsNumeric(TextBox11.Text) Then
            'nada
        Else
            TextBox11.Clear()
        End If
    End Sub

    Private Sub TextBox12_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox12.TextChanged
        If IsNumeric(TextBox12.Text) Then
            'nada
        Else
            TextBox12.Clear()
        End If
    End Sub

    Private Sub TextBox13_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox13.TextChanged
        If IsNumeric(TextBox13.Text) Then
            'nada
        Else
            TextBox13.Clear()
        End If
    End Sub

    Private Sub TextBox14_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox14.TextChanged
        If IsNumeric(TextBox14.Text) Then
            'nada
        Else
            TextBox14.Clear()
        End If
    End Sub

    Private Sub TextBox15_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox15.TextChanged
        If IsNumeric(TextBox15.Text) Then
            'nada
        Else
            TextBox15.Clear()
```

```
        End If
    End Sub

    Private Sub TextBox40_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox40.TextChanged
        If IsNumeric(TextBox40.Text) Then
            'nada
        Else
            TextBox40.Clear()
        End If
    End Sub

    Private Sub TextBox26_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox26.TextChanged
        If IsNumeric(TextBox26.Text) Then
            'nada
        Else
            TextBox26.Clear()
        End If
    End Sub

    Private Sub TextBox25_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox25.TextChanged
        If IsNumeric(TextBox25.Text) Then
            'nada
        Else
            TextBox25.Clear()
        End If
    End Sub

    Private Sub TextBox24_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox24.TextChanged
        If IsNumeric(TextBox24.Text) Then
            'nada
        Else
            TextBox24.Clear()
        End If
    End Sub

    Private Sub TextBox23_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox23.TextChanged
        If IsNumeric(TextBox23.Text) Then
            'nada
        Else
            TextBox23.Clear()
        End If
    End Sub

    Private Sub TextBox22_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox22.TextChanged
        If IsNumeric(TextBox22.Text) Then
            'nada
        Else
            TextBox22.Clear()
        End If
    End Sub

    Private Sub TextBox21_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox21.TextChanged
        If IsNumeric(TextBox21.Text) Then
            'nada
        Else
```

```
            TextBox21.Clear()
        End If
    End Sub

    Private Sub TextBox20_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox20.TextChanged
        If IsNumeric(TextBox20.Text) Then
            'nada
        Else
            TextBox20.Clear()
        End If
    End Sub

    Private Sub TextBox19_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox19.TextChanged
        If IsNumeric(TextBox19.Text) Then
            'nada
        Else
            TextBox19.Clear()
        End If
    End Sub

    Private Sub TextBox18_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox18.TextChanged
        If IsNumeric(TextBox18.Text) Then
            'nada
        Else
            TextBox18.Clear()
        End If
    End Sub

    Private Sub TextBox17_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox17.TextChanged
        If IsNumeric(TextBox17.Text) Then
            'nada
        Else
            TextBox17.Clear()
        End If
    End Sub

    Private Sub TextBox16_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox16.TextChanged
        If IsNumeric(TextBox16.Text) Then
            'nada
        Else
            TextBox16.Clear()
        End If
    End Sub

    Private Sub TextBox39_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles TextBox39.TextChanged
        If IsNumeric(TextBox39.Text) Then
            'nada
        Else
            TextBox39.Clear()
        End If
    End Sub

    Private Sub Sieve_Analysis_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load

        ToolTip1.SetToolTip(Button1, "Shows Test Procedure of the test")
```

```
        ToolTip1.SetToolTip(Button2, "Print the output")
        ToolTip1.SetToolTip(Button3, "Calculate the output")

        ToolTip1.SetToolTip(TextBox29, "Please enter the Project Name")
        ToolTip1.SetToolTip(TextBox31, "Please enter the Station Chainage")
        ToolTip1.SetToolTip(TextBox28, "Please enter the Depth of sample is taken")
        ToolTip1.SetToolTip(TextBox27, "Please enter the Material Description")
        ToolTip1.SetToolTip(TextBox30, "Please enter the Laboratory Number")
        ToolTip1.SetToolTip(DateTimePicker1, "Please enter the Date Sampled")
        ToolTip1.SetToolTip(DateTimePicker2, "Please enter the Date Tested")
    End Sub

    Private Sub Button4_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button4.Click
        My.Forms.K_Factor__Effective_Depht_Table.ShowDialog()
    End Sub

    Private Sub Button5_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button5.Click
        My.Forms.Graph_of_Particle_Size_Analysis_of_Soil.ShowDialog()
    End Sub

    Private Sub Button6_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button6.Click
        My.Forms.Help.ShowDialog()
    End Sub

End Class
```