CORRELATION BETWEEN DUCTILITY TEST DONE BY TRADITIONAL METHOD AND BY NEWLY DEVELOPED LOW COST MICRO-UTM ON BITUMEN USING POKER CHIP GEOMETRY

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A Thesis Submitted to the Academic Faculty in Partial Fulfillment of the Requirements for the Degree of

BACHELOR OF SCIENCE CIVIL AND ENVIRONMENTAL ENGINEERING

Department of Civil and Environmental Engineering
Islamic University of Technology (IUT)

Gazipur, Bangladesh

AUGUST 2021

CORRELATION BETWEEN DUCTILITY TEST DONE BY TRADITIONAL METHOD AND BY NEWLY DEVELOPED LOW COST ACCURATE MICRO-UTM ON BITUMEN USING POKER CHIP

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List of Acronyms

UTM	Universal Testing Machine
RTFO	Rolling Thin-film Oven
PATTI	Pneumatic Adhesion Tensile Testing Instrument
PAV	Pressure Aging Vessel
TTI	Texas A&M Transportation Institute
AMPT	Asphalt mixture performance tester
LVDT	linear variable differential transformer
VCM	voice coil motor

Acknowledgements

We express our gratitude to Almighty Allah. We are very grateful to our supervisor Dr. Md. Nazmus Sakib Sir, Assistant Professor of CEE Department of IUT for his continuous guidance and support in our thesis work.

We also pay our tribute to National Professor Dr. Jamilur Reza Chowdhury, who sadly passed away and pray to Allah for his peace and happiness in the afterlife.

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Abstract

Universal testing machine is one among the foremost familiar testing machines within the world of engineering. It’s very useful to live the tensile and compressive strength of materials. It’s a mixture of recent electronic and mechanical transmission technology. Main purpose of this work is to develop a feasible low cost scale down UTM machine which will perform the same tests and also correlate the results with the traditional ductility test. The main purpose is to determine the tensile cracking of bitumen. The tensile properties of bitumen can enormously influence the execution of the bitumen mixture beneath rehashed activity stacking. Furthermore, ageing makes bitumen stiffer and brittle resulting in its susceptibility of thermal cracking. From the very beginning of design and selecting material to make this machine working, In every step accuracy is the one thing we didn’t compromised with. Finally the data found from the machine is being plotted in excel and also being related with the data found from ductility test also.

Chapter 1

Introduction

Universal testing machine is one of the most familiar testing machines in the world of civil engineering. It is very useful to measure the tensile and compressive strength of materials. It is a combination of modern electronic and mechanical transmission technology. In general, a universal testing machine is about 115kg in weight, 1600mm in height, 650mm in width and 450mm in depth. Generally, it costs up to $15,000. Our motive is to lower the cost and reduce the size of a universal testing machine. The machine material of our micro-utm machine is mild steel and the height of our machine is 610mm and the width is 280mm which is lower than a traditional universal testing machine. Our machine has been designed through SOLIDWORKS 2018. There is a huge variety of materials can be tested with traditional universal testing machine. Actually, in traditional ductile test method in universal testing machine, large weighted materials have been used like steel, concrete. The tensile properties of bitumen can enormously influence the execution of the bitumen mixture beneath rehashed activity stacking. Furthermore, ageing makes bitumen stiffer and brittle leading to its susceptibility of thermal cracking. (Rahim et al., 2019) [12]. While the current execution review detail has been in utilize for a long time to characterize the bitumen mixture with respects to fatigue, it has been appeared to be generally incapable. So, for the thin material like bitumen while testing through universal testing machine, there are lot of accuracy issue can be seen in the result which have been achieved from the test. Poulikakos and Partl (2011) performed tensile tests on very thin films (less than 20µm) and measured the strength of the binder. They concluded that binders had lower strengths but exhibited more ductile behavior at the higher temperature. In that test, it was also observed the effect of moisture, and found that moisture had more effect when mineral aggregates bonded the binder rather than steel plates. (Poulikakos & Partl, 2011) [11]. Other researchers also found out aspect ratios (diameter to thickness ratio) to determine the effect of film thickness. Motamed et al. (2014) performed poker chip tests on asphalt binders using multiple specimen diameters and film thicknesses. Sultana et al. (2014) also used the poker chip test to determine the behaviors of thin films of asphalt binder. From the most it was observed that most binders were within their linear viscoelastic range at low strains (less than 1%). (Hajj et al., 2019) [10]. From another research, Sultana and Bhasin (2014) also related the tensile strength of asphalt binder to its chemical properties. Their findings included that a higher amount of the most polar fractions corresponded with a higher tensile strength. These fractions also correlated with smaller and more frequent cavitation instabilities. These observations indicated some insight into the actual fundamental failure properties of asphalt materials. (Hajj et al., 2019) [10]. In our low cost accurate Micro-UTM machine, we have tested several types of bitumen using poker chip geometry. The poker chip test is recommended for further implementation as an indicator for the cracking resistance of bitumen binders due to its good relationship with results from mixture testing. (Hajj et al., 2019) [10]. The test involved tensile loading of a thin film of asphalt binder between two rigid substrates. It determines failure criteria and the study of the binders that have a similar grade based on the current performance grade specification but are expected to perform differently due to difference in their chemical makeup and the study of the effects of nanomaterial as additives on the strength of the binder based on poker chip test results. The poker chip test is similar to the test performed using the Pneumatic Adhesion Tensile Testing Instrument (PATTI). The difference of the PATTI test is normally used to study the adhesive properties of a binder in tension, while poker chip testing is a test of the actual material and its cohesive properties. Poker chip test has been proposed as in indicator of the true strength and fracture properties of an asphalt binder in the state of stress similar to what it actually experiences in a mix. (Hajj et al., 2019) [10]. We have used poker-chip test to understand the bitumen's one of the ductility property which is viscoelastic behavior. Viscoelasticity occurs due to deformation in pavement because of cyclic tensile loading (Motamed, A 2014). (Hajj et al. 2017) indicates that this test can identify large differences in binder strength for binders assigned similar PG grades. (Hajj et al., 2019) [10]. It was already mentioned that Poulikakos and Partl (2011) found through their research that binders had lower strengths but exhibited more ductile behavior at the higher temperature. (Poulikakos & Partl, 2011) [11]. A poker chip test was run on the binders at 18.C in all three aging conditions unaged, RTFO aged, and PAV aged. We have tested our bitumen samples while they were on 25 degree Celsius. Through Proteus Design Suit, the code has been developed to run the electric circuit. To run the electrical circuit, thermocouple MAX6675 has been used. The Arduino UNO R3 has been connected with the Thermocouple MAX6675 with 5 several jumper wires. Through testing procedure in same speed and temperature, we have found out the variety of displacements and dead loads of bitumen binders. We get the load/100ms data and displacement data from Arduino. Temperatures were measured constantly using thermocouple. By plotting the results through Excel, we got the time (sec) vs load (gm) graph. The time (sec) vs load (gm) graph represents all the outcome results.

Chapter 2

Literature Review:

Universal Testing Machine (UTM) is a device which is capable of exerting a tensile, compressive, or transverse stress on a specimen under test. The machine consists essentially of three systems: loading, weighing, and indicating, the loading being applied either mechanically or hydraulically (Inceoğlu, S., 2015) [1]. It has high load cell capacity for high load applications (Kweon, H., 2006) [2]. It is largely used for testing Concrete and Steel. Unlike Steel and Concrete, Bitumen, a thin material, is much more load sensitive. Which means, a significant strain (up to 1 ε= 1 = 1 m/m) can be observed due to 1gm of load (Liu, 2019) [3]. That's why, doing any tensile or compressive test on Bitumen with UTM has significant accuracy issues. (Walubita, 2014) [4] in Texas A&M Transportation Institute (TTI), College Station did a comparative study between Asphalt mixture performance tester (AMPT) and the traditional UTM and found that, for linear variable differential transformer (LVDT) set up, UTM is significantly less accurate and less stable while using it for doing compressive and tensile testing on Bituminous materials. In test repeatability and variability UTM has a CV value >30% (for 40°C, CV = 34.64%; for 50°C, CV = 39.50%) which is statistically unacceptable. UTM is also very less flexible to modify like adding thermal chamber for temperature control or software modifications for better data output. (Walubita, 2014) [4] shows, UTM is 40% less cost effective and 30% less efficient. Besides, traditional UTMs are very expensive which makes it difficult to acquire by the majority of the institutions and authorities in developing countries. It can cost from $13,500 to $30,000. That's why, development of a low cost accurate Micro-UTM for performing tensile and compressive tests on Bitumen like thin materials is important which is cost effective, efficient, simple and modifiable.

In some of the already developed Micro-UTM examples, (Chung, 2008) [5] have used the driving property of the voice coil motor (VCM), and consisted with sensing module, driving module, signal analysis module, and alignment module. (Huerta, 2010) [6] has five components in their Micro-UTM. (i) the main frame, (ii) the drive system, (iii) the movable crosshead, (iv) the load cell, and (v) the digital indicator.

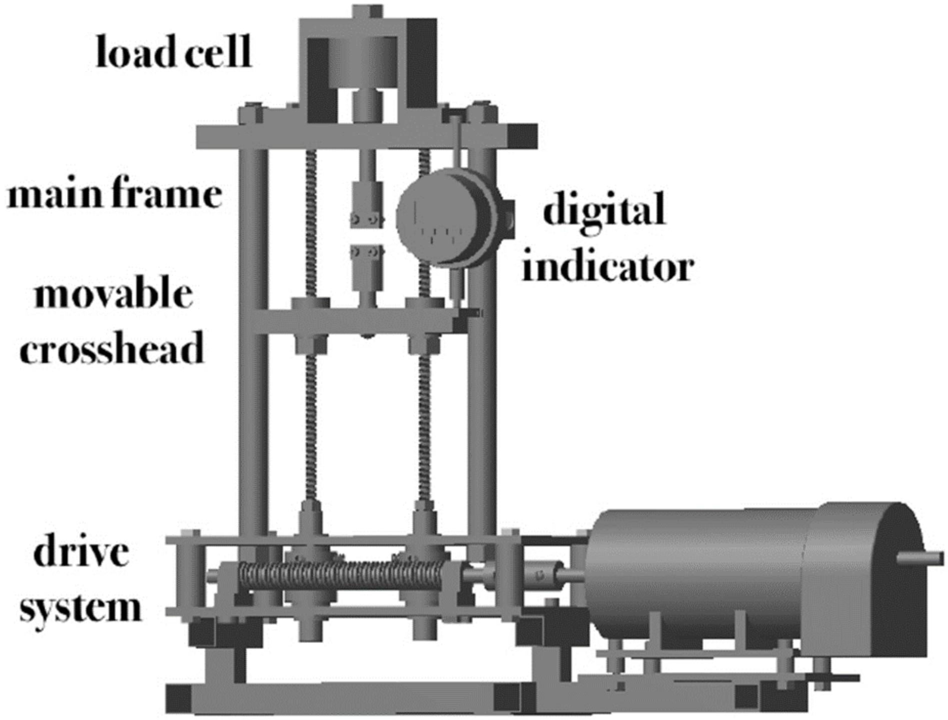


Figure 1: Micro-UTM developed by (Huerta, 2010).

Still, they are fairly complex and expensive due to using complicated drive systems, digital indicator, sensing module and signal analysis module. These complexities can be simplified by using linear actuator, Arduino UNO, accurately aligned load sensor and Arduino module with custom coding in computer for required data outputs.

Bitumen is a black viscous mixture of hydrocarbons acquired naturally or as a residue from petroleum distillation. It is mostly utilized in paving and roofing applications. 85% of all bitumen isused as a binder in asphalt for roads construction (Lesueur, 2009) [7]. In the flexible pavement construction, it is desirable that the bitumen binders used in the bituminous mixes create a ductile thin film around the aggregates. This is a far better physical looking of the aggregates. The binder material that doesn't possess sufficient ductility would crack and spoil the pavement surface. The right ductility of the bitumen binder is essential for better serving roads (Saal, 1955) [8]. Ductility is one the viscoelastic properties of bitumen. Viscoelastic behavior is an important property of bitumen which refers the viscous and elastic behavior when deformed And deformation in pavement occur due to cyclic tensile loading (Motamed, A 2014) [9]. As a material property, it's important to observe a failure criterion for the durability of the binder that's independent of extraneous factors like rate or mode of loading and temperature. (Hajj, R. M. 2016) [10]. Pavement does not experience rutting or cracking at low temperature. However, it has proven more difficult to find an appropriate criterion to classify the binder as far as fatigue and fracture at intermediate temperatures (typically 10° C to 30° C) is concerned (Hajj, R. M. 2016) [10].

For understanding the viscoelastic behavior of the bitumen, Poker-chip test is a better alternative than traditional methods as it typically has a high diameter-to-thickness ratio, and consequently the radial displacement in the specimen can be neglected. (Motamed, A 2014) [9]. Poker-chip method differs greatly from the current specification, which, is based on stiffness, and is performed in shear rather than tension. In addition, this test method is considered effective because it more closely simulates the stress state that the binder will experience in an asphalt mixture (Hajj, R. M. 2016) [10].

Schematic of the poker-chip experimental setup of (Gent and Lindley, 1959) in (a) the undeformed configuration and in (b) a deformed configuration at an applied deformation h and corresponding tensile force P. The initial diameter of the elastomer disks – the ‘‘poker-chips’’ – was fixed at D = 2 cm, while their initial thicknesses were H = D/10 to H = D/20.

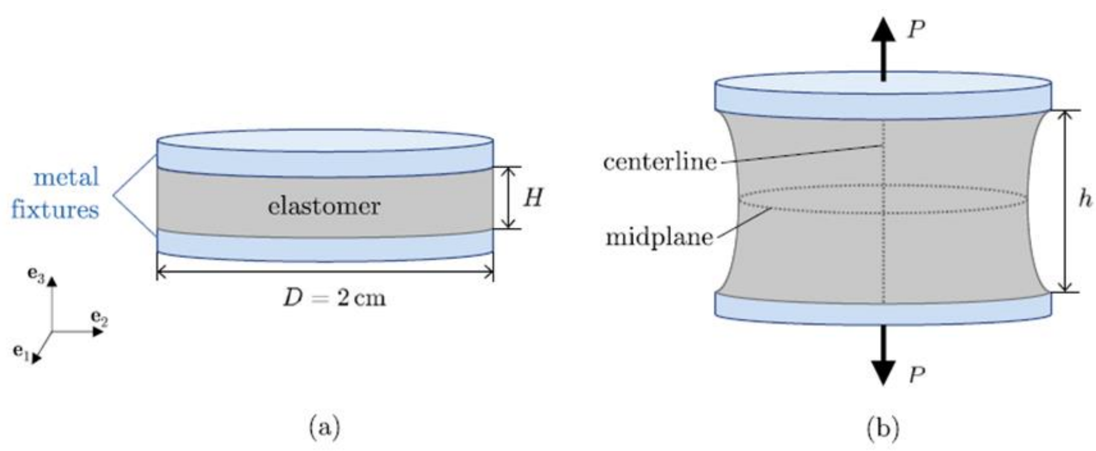


Figure 2: Pokerchip Geometry a & b

Chapter 3

Aims and Objectives

3.1 Our Proposal:

To relate the results found from ductility test and the result found from our mini UTM machine. Bitumen is widely used in our country and the main connecting roads are constructed by using bitumen. Our main motive was to build a new 9scale down machine and test the tensile stress of bitumen and also correlate the results and findings with the results found from the ductility test.

3.2 Motivation Behind Our Proposal:

One of our key motivations behind our proposal is that most of the roads of Bangladesh is bitumen based roads and often we see that there are fracture in highway or rural connecting roads due to cyclic load and continuously rotational load on that bituminous layer there found some fracture. This occurred when bitumen can't absorb the live load and deformed under tensile load. we want to measure the load according to the size and correlate the results with the ductility tests result so that we can design roads with that modified design and make the lifetime of bitumen long-lasting and more durable.

3.3 Objectives of Our Research:

- To know the ultimate tensile stress at which bitumen starts to deform.
- To understand the behavior of bitumen collected from different sources
- To build up a relation between the ductility test results and the data found from the mini UTM machine.

3.4 Thesis Outline:

Our project mainly starts with some introductory talk and statistics of bitumen and tensile stress properties of bitumen. The second chapter includes a literature review on some previous works in this field. The third chapter describes the aims and objectives and motivation of our selected research work. The fourth chapter basically deals with the components of our machine. The fifth chapter includes a description of the coding and electrical design components required for our design along with their specifications and also some other necessary input parameters. The sixth chapter deals with the methodology. The seventh chapter discusses on the results obtained after optimization of our models. The eighth and last chapter includes the conclusion and gives insight into the future possibilities of this project.

Chapter 4

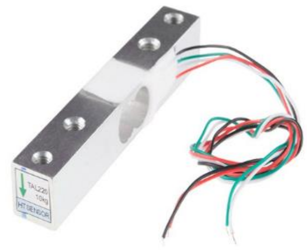
Machine Components

4.1 Electrical Components:

Linear Actuator: Actuator is a device which generates motion from energy. It can lift, drop, push or pull materials with the specific connection. We have used linear actuator in our micro-UTM machine. This kind of actuator can move between two points in a linear motion. We have used linear actuator for the vertical movement. We have connected this linear actuator with the top plate of our micro-UTM machine.

Figure 3: Linear Actuator

Cantilever Load cell: Cantilever load cell has been designed to measure the eccentric load sensitivity. This is actually a strain gauge based bending beam load cell. We have collected the loads of materials through cantilever load cell. The main purpose of this device was to measure



Specification	Measures
Capacity	10kg
Sensitivity	250mg

Figure 4: Cantilever Load cell

Potentiometer: Potentiometer is used to limit the passage of electrical current which causes voltage fall. It is actually a three terminal resistor. It can slide or rotate to contact that forms an adjustable voltage divider. Ppotentiometer has been used in our micro-UTM machine to control the rotation and the speed of the actuator manually. To control the speed, we have divided the speed 0 to 255. Here, the maximum speed is 255 and the minimum speed is 0.

Figure 5: Potentiometer

Specification	Measures
Combined Height	305mm
Stroke	100mm
Speed	12mm/Loa
Capacity	1000N
Max. Volt	6V

Arduino UNO R3: Arduino UNO R3 is a microcontroller board which has 20 digital input/output pins. The boards of Arduino can read several types of inputs like finger on a button, kight on a sensor etc. From the inputs, it delivers outputs as activating motor or turning on an LED. In our micro- UTM machine, Arduino UNO R3 works like the central processing unit. By connecting the electrical wires with Arduino UNO R3 and send commands by computer, it express the datas through computer as output and it helps to run our machine smoothly as well.

Figure 6: Arduino UNO R3

Specification	Measures
Operating Voltage	5 Volts
Input Voltage	7 to 20 Volts
Width	53.4 mm
Weight	25 g

Encoder: Encoder expresses the data of load which has been acted on the load cell. In our micro-UTM machine, we have been used encoder to get the load data as the output value which acted on the cantilever load cell.

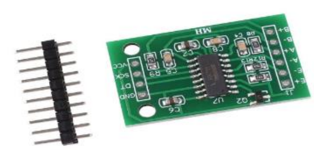


Figure 7: Encoder

Specification	Measures
Type	B20K 20K ohm Single Linear Taper Rotary Potentiometers,
Cycle Life	100,000
Rotational travel	300 °

Motor Driver: Motor driver is a device which converts low-current control signal into a higher current signal which drives a motor.In our micro-UTM machine, motor drive has been used to control the vertical movement of linear actuator.

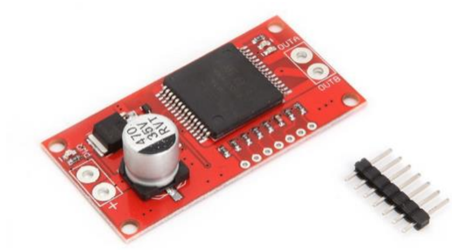


Figure 8: Motor Driver

Specification	Measures
Type	HX711
Differential input voltage	±40mV
Data accuracy	24 bit
Refresh frequency	10/80 Hz
Operating Voltage	2.7V to 5V
DC Operating current	<10 mA

Thermocouple: A thermocouple works as a sensor device which can measure real time temperature data. In our micro-UTM machine, **t**hermocouple ensures the specific temperature at which the bitumen has been taken for the test and the specific temperature after the bitumen has been taken out from the refrigerator. The code has been generated from these readings which has been obtained through thermocouple.

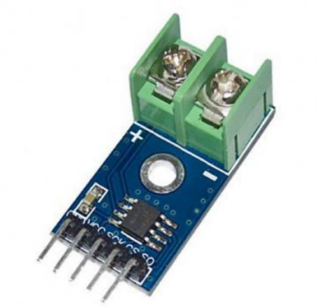


Figure 9: Thermocouple

Specification	Measures
Type	Max6675

Working voltage	DC5V
Operating Current:	50mA
Measuring range	-200°C - 1300 °C [Test procedure for 0-1023 °C]
Measurement accuracy	± 1.5 °C
Temperature resolution	0.25 °C

Breadboard: Breadboard is a plastic board which is thin and it can hold the electrical components which develops electronic circuits. All the jumper wires have been connected with breadboard and the breadboard provides to send the signals to Arduino and other devices and the micro-UTM machine.

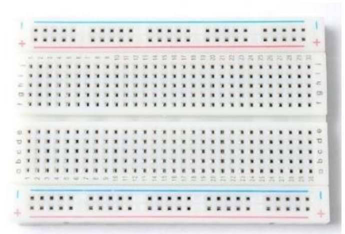


Figure 10: Breadboard

Specification	Measures
Terminal Strips	1 Terminal Strip, with 300 tie-points
Distribution Strips	2 Distribution strips, with 100 tie-points
Plastic material	ABS

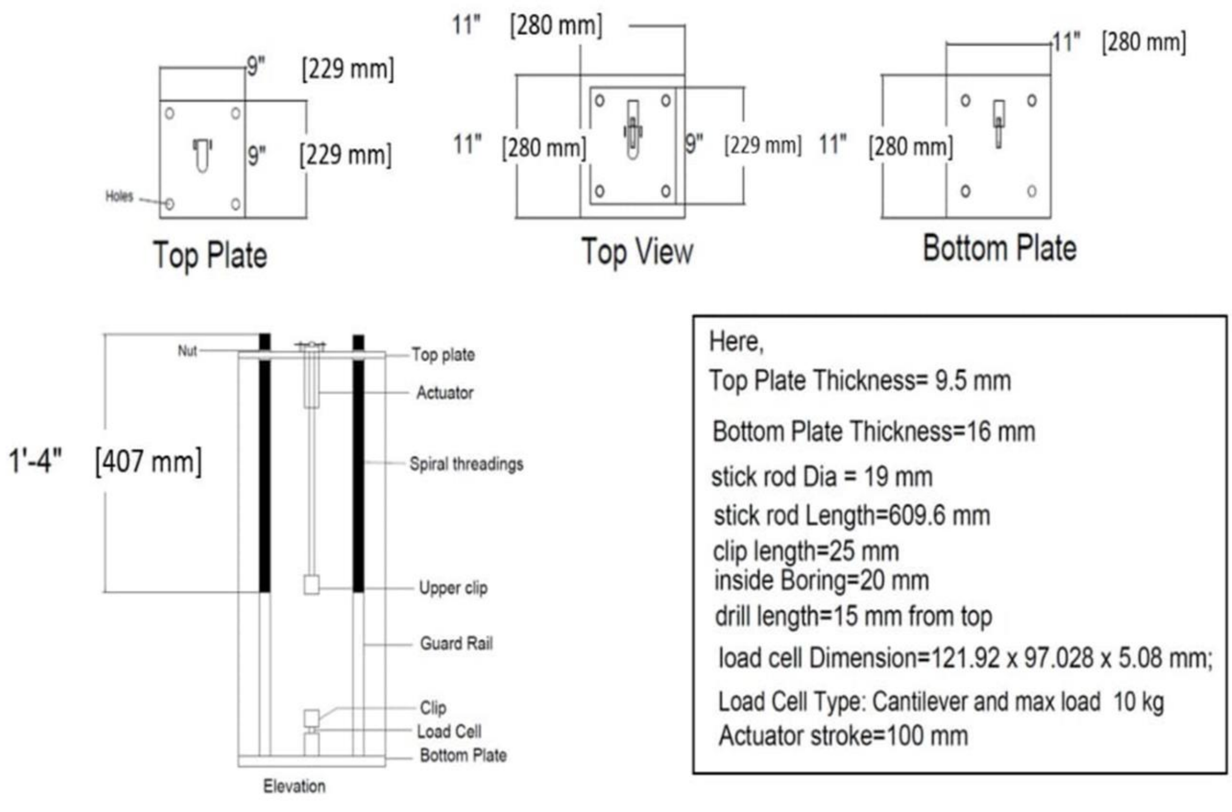
Jumper Wire: Jumper wire is an electrical wire which interconnects the components of the breadboard. We have used several types of jumper wires as female-to-male, male-to-male, female-to-female. Length of our jumper wire is 20cm. Through the jumper wire we have connected the components.

Figure 11: Jumper Wire

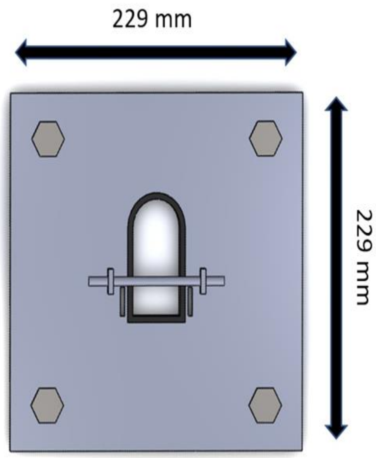
4.2 Structural Components:

In case of structural components, we have designed all the parts and the assemble body in AutoCAD 2018. After that we have implemented that design in SOLIDWORKS 2018 through boss extrude. The design unit was millimeter, gram, second (MMGS). Then from the blue print of our design, we have completed our machinery work in Dholaikhal, Dhaka to construct the machine.

CAD Design:



Top Plate: The top plate of our micro-UTM machine is made of mild steel. Mild steel has been used because it has high tensile strength and high ductility and by using mild steel, welding can be properly done. This is a square plate having dimension of 229mmX229mm (9"X9"). The thickness of the top plate is 9.5mm. There are two rectangular plate has been welded on the upper portion of the top plate. These plates can be connected with a rod which holds the actuator. There are four holes on top plate having same 19mm diameter which have been connected with the guard rails through dual nut bearing system.

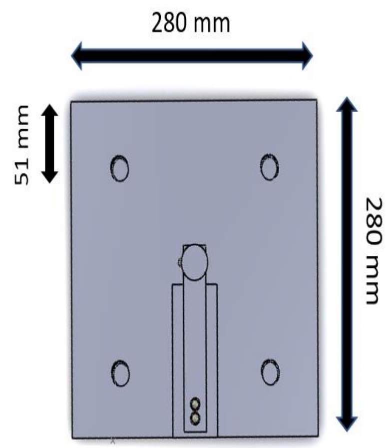


Top Plate

The top plate which we have used in our micro-UTM machine is an adjustable plate which controls the vertical movement of actuator through dual nut bearing system and guard rails. The top plate has been set up with proper alignment which helps the actuator to move properly.

Specification	**Measures**
Material of Top Plate	Mild Steel
Shape of Top Plate	Square
Dimension of The Top Plate	229mmX229mm (9"X9")
Thickness of Top Plate	9.5mm
Holes Diameter	19mm

Bottom Plate: Bottom plate's material is mild steel. It is a square shape plate. The dimension of the bottom plate is 280mm X 280mm(11"X11"). There are guard rails which have been welded with the bottom plate. The welding position is same in case of all guard rails with the bottom plate. The welding position of guard rails is 51mm inner from the outer edge of the bottom plate. The thickness of the bottom plate is 16mm. There is a rectangular holding plate on the bottom plate which has been welded. The rectangular holding plate's dimension is 50.8mm X 63.5mm (2"X2.5"). This plate holds the load sensor on it. We have welded the flat plate which holds the load cell and designed the placement so that the load cell remains aligned with the actuator at the center of the plate. We have welded the stick rod with the bottom plate. The type of weld was T joint.



Bottom Plate

The bottom plate carries the whole load and then distribute that load. The load comes from top plate which has been carried way through guard rails and acted on the bottom plate and then the load has been distributed by the bottom plate.

Specification	**Measures**
Material of Bottom Plate	Mild Steel
Shape of Bottom Plate	Square
Dimension of The Bottom Plate	280mm X 280mm (11"X11")
Thickness of Bottom Plate	16mm
Welding position of guard rails with bottom plate from the outer edge to inner edge	51mm
Rectangular Holding Plate	50.8mm X 63.5mm (2"X2.5")

Guard Rails: There are 4 guard rails in our micro-UTM machine. The guard rails are made of mild steel. The guard rails are 610mm in length. The diameter of the guard rail is 19mm. From the upper portion of the guard rails, threading has been done to 407mm. Because of the threading, the guard rails can adjust the movement and maintain the perfect alignment of Top Plate through dual nut bearing system. The lower portion of the guard rails have been welded with the bottom plate.

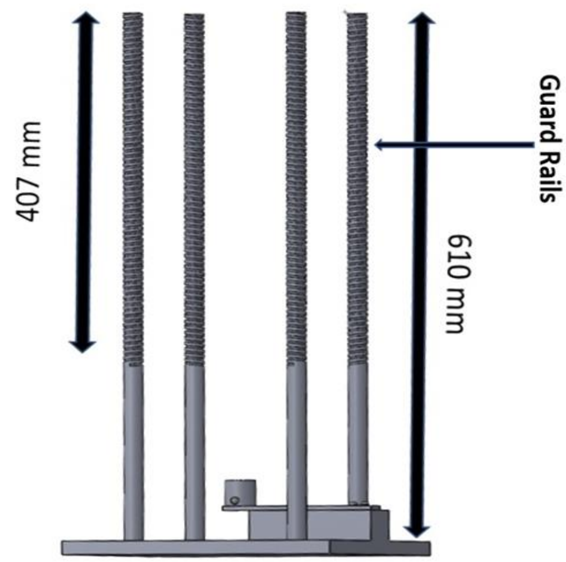


Figure 12: Guard Rails

Specification	**Measures**
Material of Guard Rails	Mild Steel
Length of Guard Rails	610mm
Diameter of Guard Rails	19mm
Threading of Guard Rails from the upper portion	407mm

Mechanical Design: Here, we can see the assemble version of our micro-UTM machine.

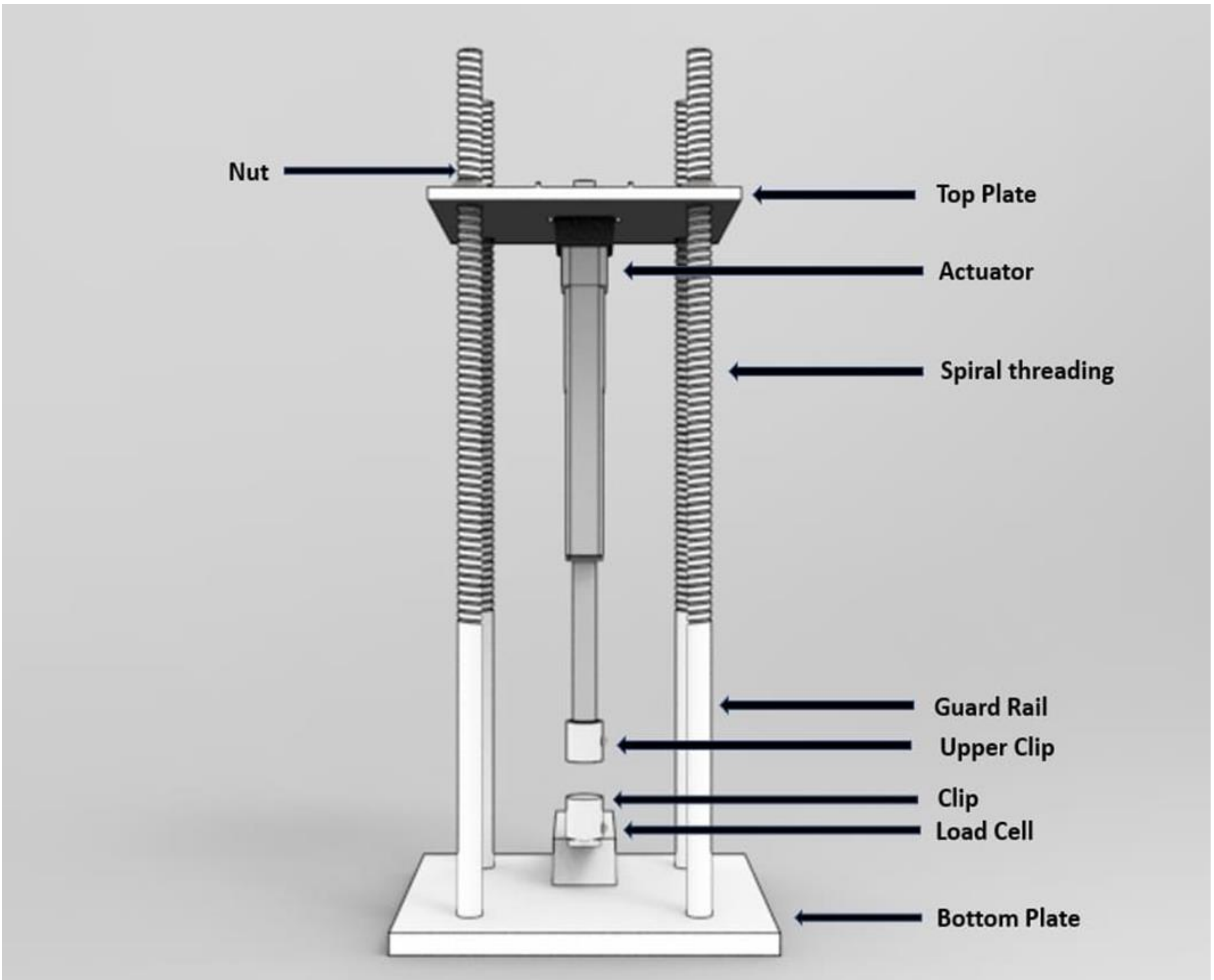


Figure 13: Machine Elevation

Chapter 5

Flowcharts and Circuit Design

5.1 Program Flowchart (Machine Code):

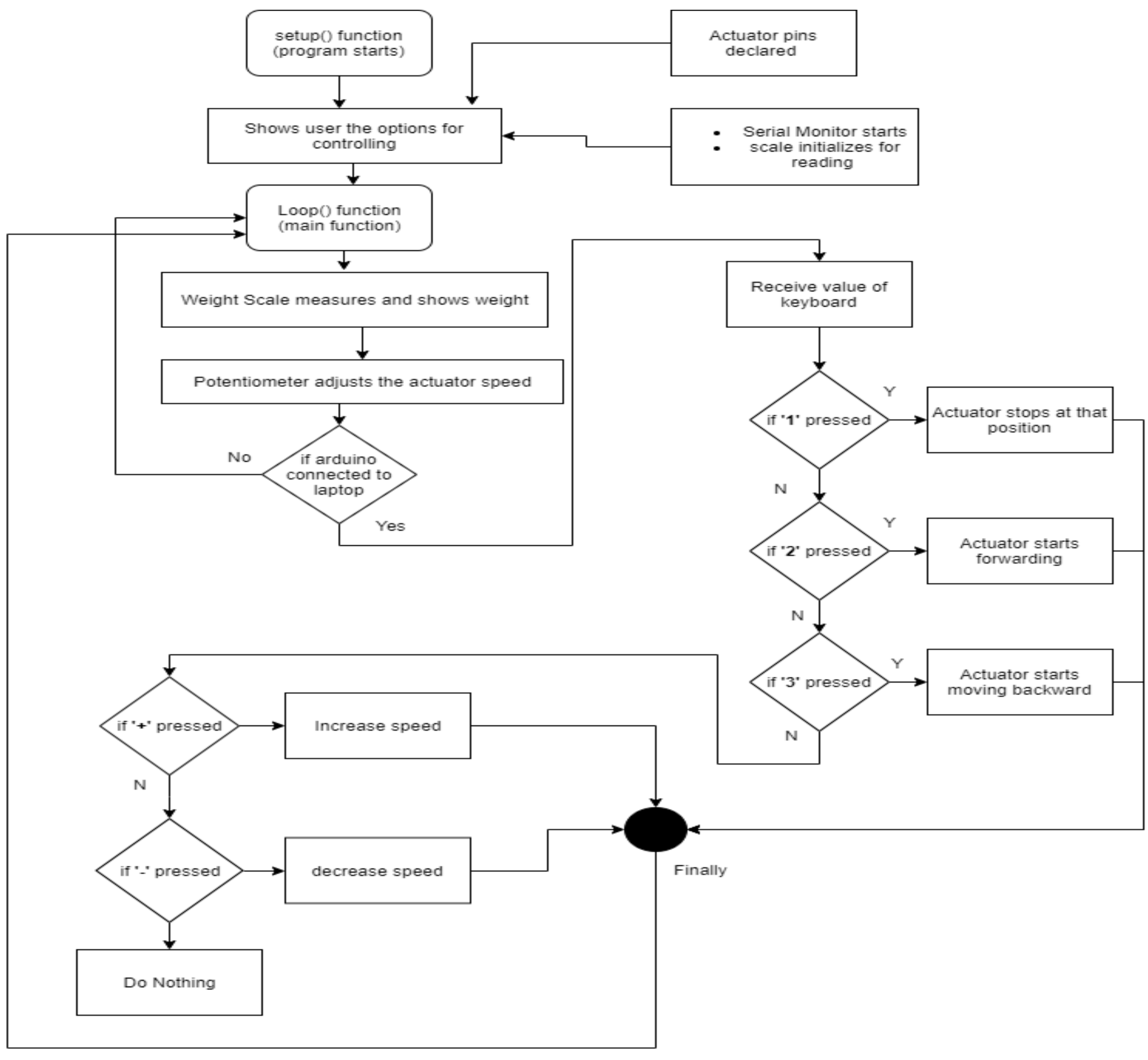


Figure 14: Flowchart

Program Flowchart (Machine Code):

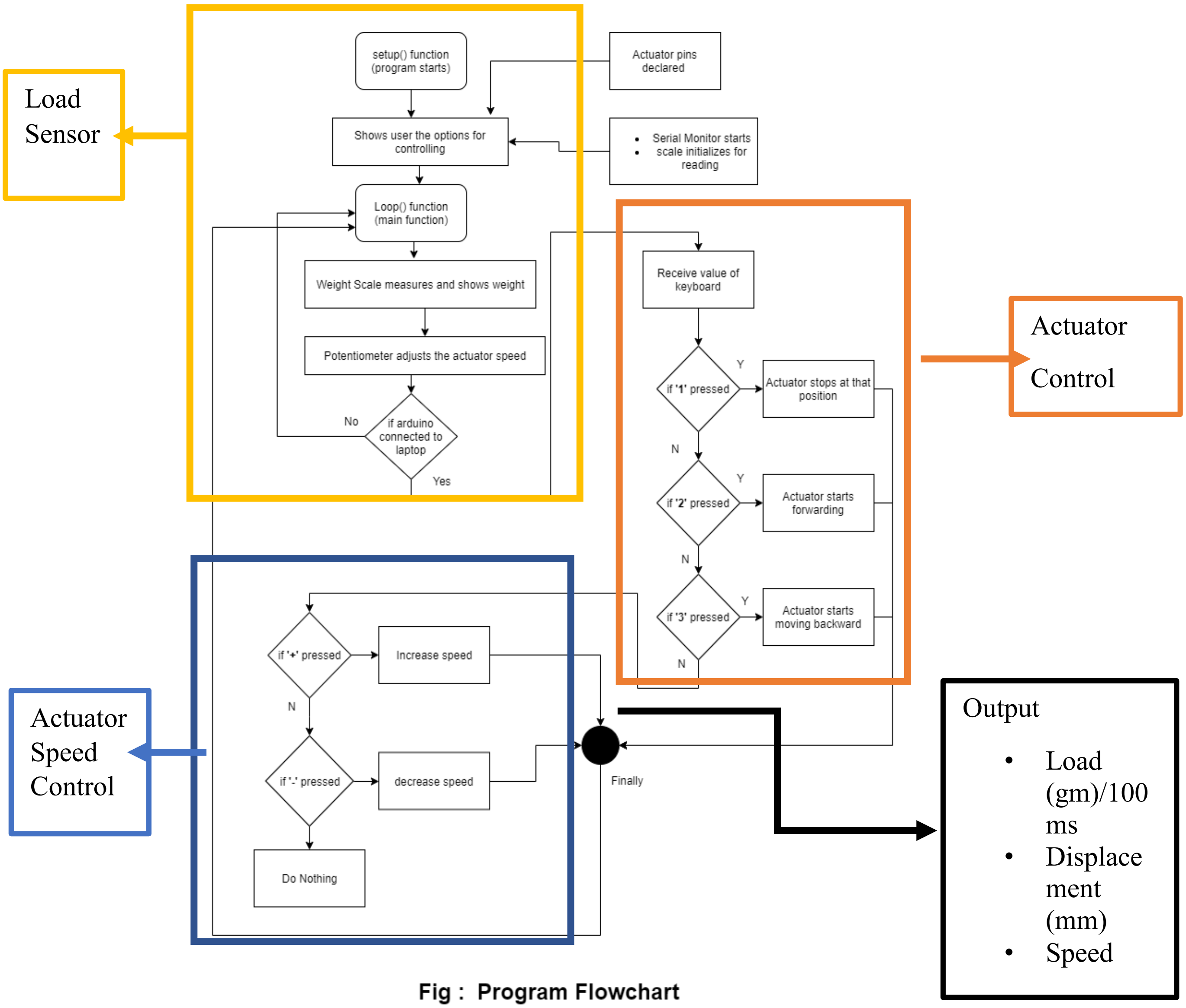


Fig : Program Flowchart

The machine code has been categorized into 3 parts. The load sensor, actuator control and actuator speed control. After starting the program, the code shows controlling option which are declaration of the actuator pins and starting of serial monitor, scale initialization for reading.

After that the loop function which is actually the main function of the machine code has been generated. Loop function generates the weight scale measurement and shows weight. From the weight scale measurement, the adjustment of the actuator speed through potentiometer has been generated.

After it, if the Arduino has been connected to laptop, the code can control the actuator. If the Arduino has not been connected with the laptop, then the loop function again has to generate to run the code. So, if the Arduino has been connected to the laptop, the keyboard will receive value to control the actuator. If '1' pressed, then the actuator stops at that position. If '2' has been pressed, then the actuator will move forward. If '3' has been pressed, then the actuator will start to move backward. And for the speed control of actuator, if '+' has been pressed, then it will increase the speed of actuator to move. If '-' has been pressed, then the actuator's speed will be decreased.

And by the assemble of the loop function, increase speed, decrease speed and the condition of actuator while moving forward or backward or stops, the output value has been generated. The output values are Load (gm)/100 ms, Displacement (mm) and Speed.

5.2 Program Flowchart (Thermocouple Code):

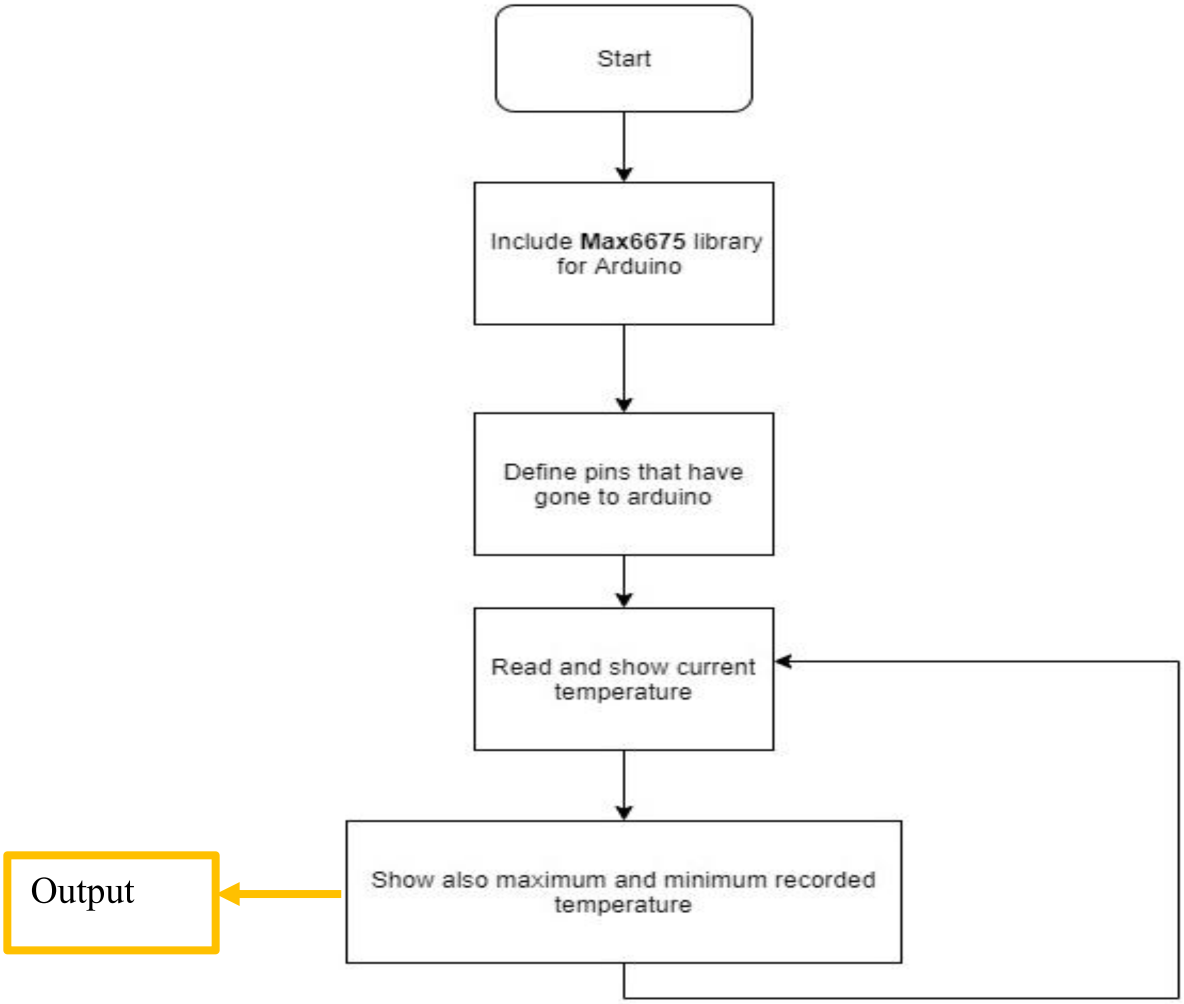
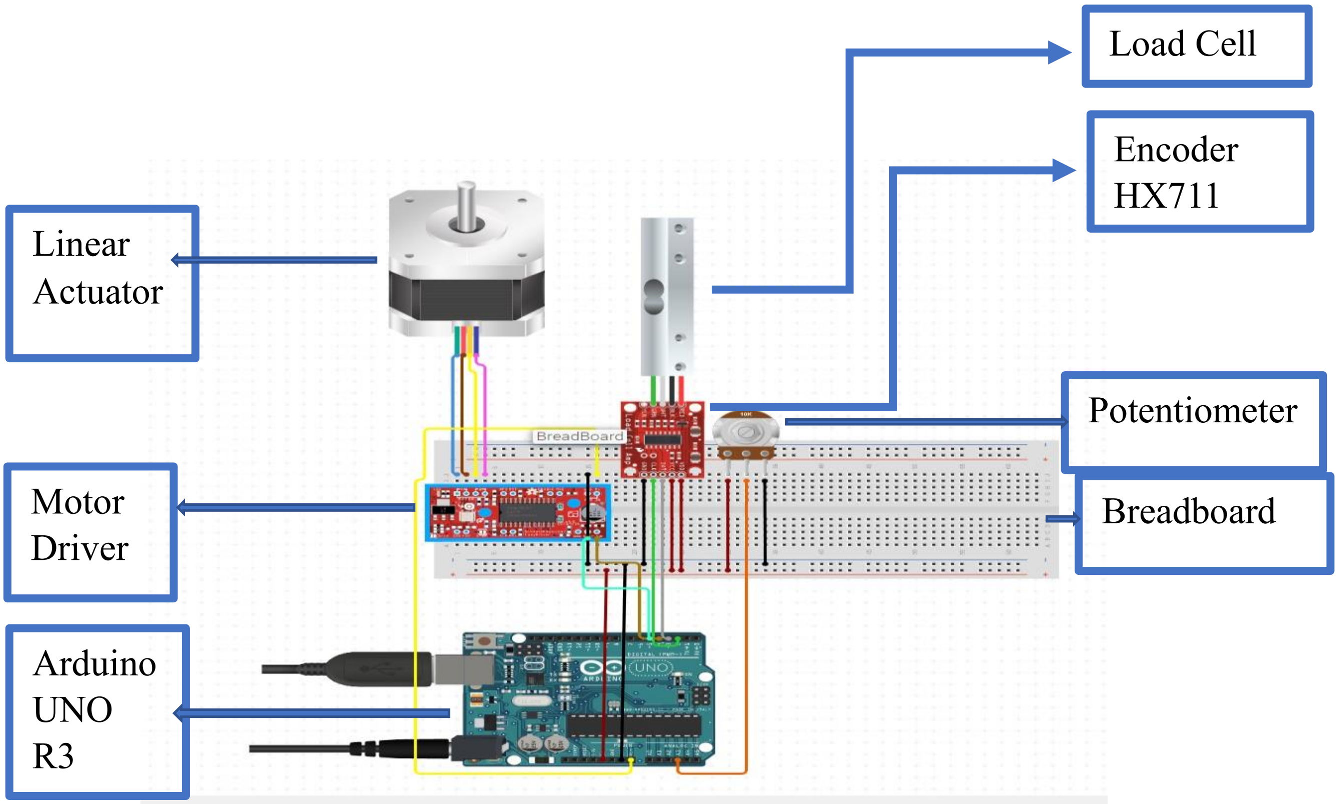


Figure 15: Program Flowchart (Thermocouple Code)

To run the thermocouple code, MAX6675 has been used. It is an electrical component which can measure the temperature reading which range is from 0ºC to 1024ºC. So, after starting the program, MAX6675 library has been included for Arduino. It defines pins that have gone to Arduino. After this, the reading and current temperature of bitumen can be showed. Also, the maximum and minimum recorded temperature can be obtained. From this, the output data has been generated.

5.3 Electrical Circuit (Machine):

Here,the breadboard has been connected with the linear actuator, motor driver, arduino UNO r3, load cell, encoder HX711, potentiometer by jumper wires.



5.4 Electrical Circuit (Thermocouple):

To run the electrical circuit, thermocouple MAX6675 has been used. The accuracy of this device is 8 LSBs for temperatures ranging from 0°C to +700°C. MAX6675 has been used to measure the accurate temperature in our electrical circuit.

The Arduino UNO R3 has been connected with the Thermocouple MAX6675 with 5 several jumper wires. Here, black wire is phase 1, red wire is phase 2, blue wire is phase 3, yellow and green wire is ground wire. Arduino UNO R3 expresses the datas through computer as output and it helps to run our machine smoothly.

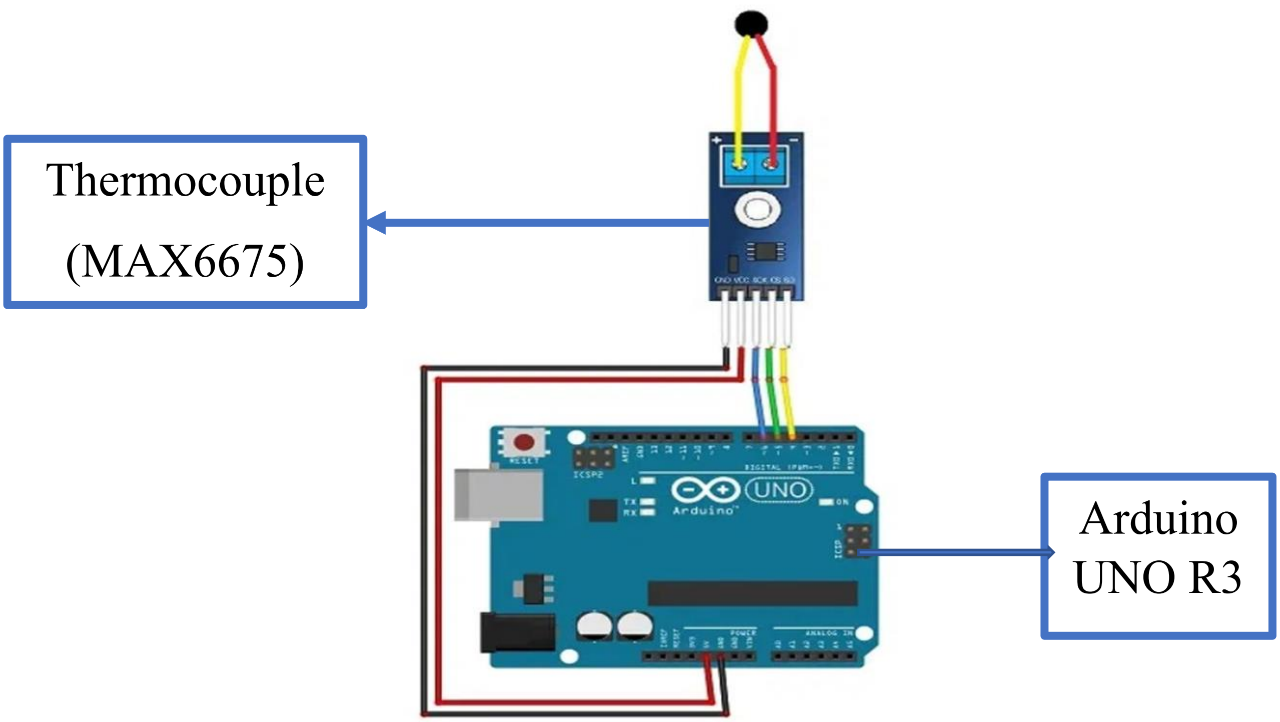


Figure 16:Electrical Circuit (Thermocouple)

5.5 Codes:

Actuator Code:

```
//actuator control test code =========== read from switch or joystick


#define enA 9
#define in1 4
#define in2 5
#define enB 10
#define in3 6
#define in4 7

int motorSpeedA = 0;
int motorSpeedB = 0;

void setup() {
  pinMode(enA, OUTPUT);
  pinMode(enB, OUTPUT);
  pinMode(in1, OUTPUT);
  pinMode(in2, OUTPUT);
  pinMode(in3, OUTPUT);
  pinMode(in4, OUTPUT);
}

void loop() {
  int xAxis = analogRead(A0); // Read Joysticks X-axis
```

```
  int yAxis = analogRead(A1); // Read Joysticks Y-axis

  // Y-axis used for forward and backward control
  if (yAxis < 470) {
    // Set Motor A backward
    digitalWrite(in1, HIGH);
    digitalWrite(in2, LOW);
    // Set Motor B backward
    digitalWrite(in3, HIGH);
    digitalWrite(in4, LOW);
    // Convert the declining Y-axis readings for going backward from 470 to 0 into 0 to 255 value for the PWM signal for increasing the motor speed
    motorSpeedA = map(yAxis, 470, 0, 0, 255);
    motorSpeedB = map(yAxis, 470, 0, 0, 255);
  }
  else if (yAxis > 550) {
    // Set Motor A forward
    digitalWrite(in1, LOW);
    digitalWrite(in2, HIGH);
    // Set Motor B forward
    digitalWrite(in3, LOW);
    digitalWrite(in4, HIGH);
    // Convert the increasing Y-axis readings for going forward from 550 to 1023 into 0 to 255 value for the PWM signal for increasing the motor speed
    motorSpeedA = map(yAxis, 550, 1023, 0, 255);
    motorSpeedB = map(yAxis, 550, 1023, 0, 255);
  }
  // If joystick stays in middle the motors are not moving
  else {
    motorSpeedA = 0;
    motorSpeedB = 0;
```

```
}

// X-axis used for left and right control
if (xAxis < 470) {
  // Convert the declining X-axis readings from 470 to 0 into increasing 0 to 255 value
  int xMapped = map(xAxis, 470, 0, 0, 255);
  // Move to left - decrease left motor speed, increase right motor speed
  motorSpeedA = motorSpeedA - xMapped;
  motorSpeedB = motorSpeedB + xMapped;
  // Confine the range from 0 to 255
  if (motorSpeedA < 0) {
    motorSpeedA = 0;
  }
  if (motorSpeedB > 255) {
    motorSpeedB = 255;
  }
}
if (xAxis > 550) {
  // Convert the increasing X-axis readings from 550 to 1023 into 0 to 255 value
  int xMapped = map(xAxis, 550, 1023, 0, 255);
  // Move right - decrease right motor speed, increase left motor speed
  motorSpeedA = motorSpeedA + xMapped;
  motorSpeedB = motorSpeedB - xMapped;
  // Confine the range from 0 to 255
  if (motorSpeedA > 255) {
    motorSpeedA = 255;
  }
  if (motorSpeedB < 0) {
    motorSpeedB = 0;
  }
```

```
  }
  // Prevent buzzing at low speeds (Adjust according to your motors. My motors couldn't start moving if PWM value was below value of 70)
  if (motorSpeedA < 70) {
    motorSpeedA = 0;
  }
  if (motorSpeedB < 70) {
    motorSpeedB = 0;
  }
  analogWrite(enA, motorSpeedA); // Send PWM signal to motor A
  analogWrite(enB, motorSpeedB); // Send PWM signal to motor B
}
```

LOAD CELL Code:

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(8, 9, 10, 11, 12, 13);

#define DT A0
#define SCK A1
#define sw 2

long sample=0;
float val=0;
long count=0;

unsigned long readCount(void)
{
  unsigned long Count;
  unsigned char i;
  pinMode(DT, OUTPUT);
```

```
  digitalWrite(DT,HIGH);
  digitalWrite(SCK,LOW);
  Count=0;
  pinMode(DT, INPUT);
  while(digitalRead(DT));
  for (i=0;i<24;i++)
  {
    digitalWrite(SCK,HIGH);
    Count=Count<<1;
    digitalWrite(SCK,LOW);
    if(digitalRead(DT))
    Count++;
  }
  digitalWrite(SCK,HIGH);
  Count=Count^0x800000;
  digitalWrite(SCK,LOW);
  return(Count);
}

void setup()
{
  Serial.begin(9600);
  pinMode(SCK, OUTPUT);
  pinMode(sw, INPUT_PULLUP);
  lcd.begin(16, 2);
  lcd.print("    Weight ");
  lcd.setCursor(0,1);
  lcd.print(" Measurement ");
  delay(1000);
  lcd.clear();
```

```
  calibrate();
}

void loop()
{
  count= readCount();
  int w=(((count-sample)/val)-2*((count-sample)/val));
  Serial.print("weight:");
  Serial.print((int)w);
  Serial.println("g");
  lcd.setCursor(0,0);
  lcd.print("Weight            ");
  lcd.setCursor(0,1);
  lcd.print(w);
  lcd.print("g             ");

  if(digitalRead(sw)==0)
  {
    val=0;
    sample=0;
    w=0;
    count=0;
    calibrate();
  }
}

void calibrate()
{
    lcd.clear();
  lcd.print("Calibrating...");
```

```
lcd.setCursor(0,1);
lcd.print("Please Wait...");
for(int i=0;i<100;i++)
{
  count=readCount();
  sample+=count;
  Serial.println(count);
}
sample/=100;
Serial.print("Avg:");
Serial.println(sample);
lcd.clear();
lcd.print("Put 100g & wait");
count=0;
while(count<1000)
{
  count=readCount();
  count=sample-count;
  Serial.println(count);
}
lcd.clear();
lcd.print("Please Wait....");
delay(2000);
for(int i=0;i<100;i++)
{
  count=readCount();
  val+=sample-count;
  Serial.println(sample-count);
}
val=val/100.0;
```

```
  val=val/100.0;        // put here your calibrating weight
  lcd.clear();
}
```

Motor Control with Potemtiometer:

```
#include <Servo.h>
Servo myservo;

int potpin = A0;
int val;

void setup() {
  myservo.attach(9);
  Serial.begin(9600);

}

void loop() {
  val = analogRead(potpin);
  val = map(val, 0, 1023, 0, 180);
  Serial.println(val);
  if(val>0 && val<60)
  {
      myservo.write(90);
  }
  if(val>60 && val<120)
  {
      myservo.write(135);
  }
  if(val>120 && val<180)
```

```
  {
     myservo.write(180);
  }

  delay(15);
}
```

5.6 Final Outlook:

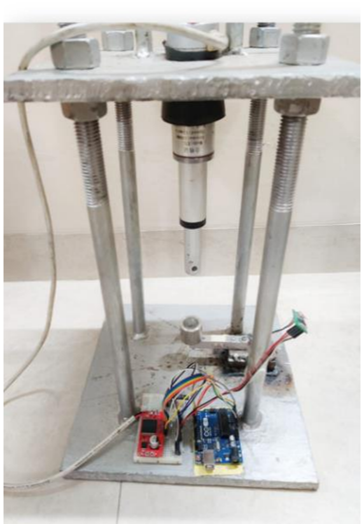


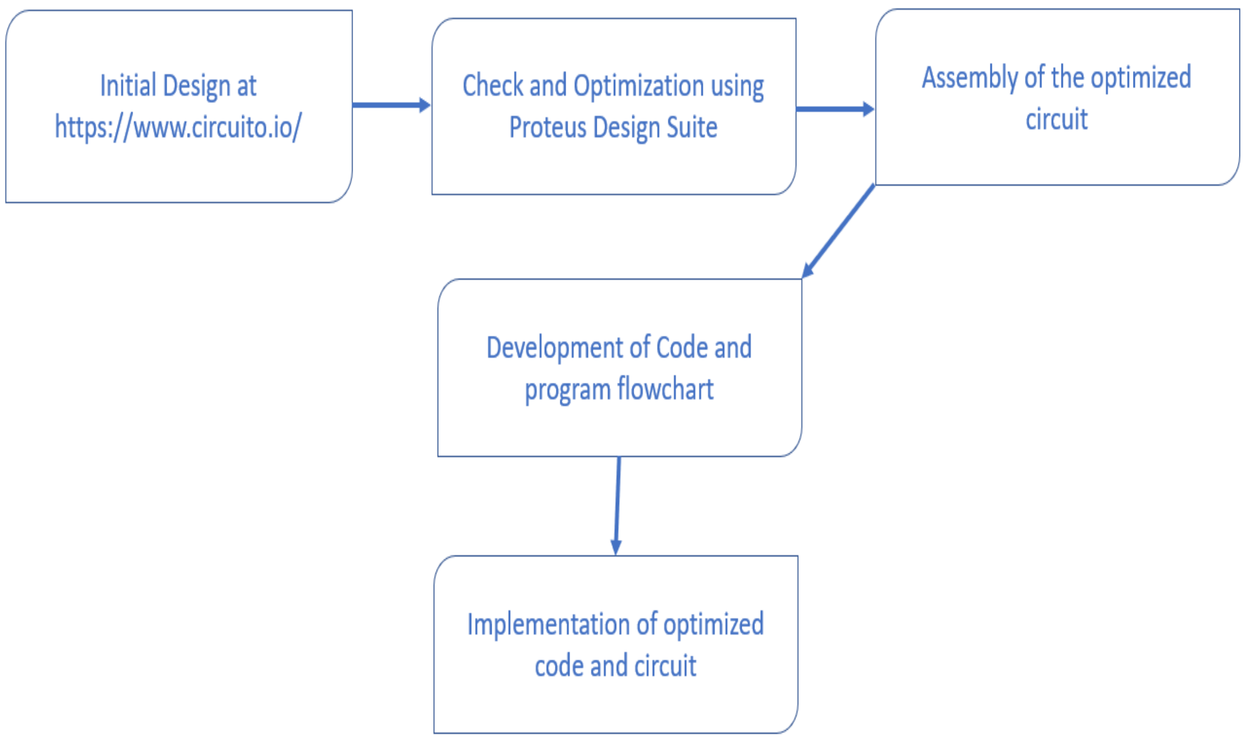
Figure 18: Assembled Electrical Circuit with main structure

Figure 17: Thermocouple Data Collection System

Chapter 6

Methodology

6.1 Methodology (Code & Electrical Circuit Design):

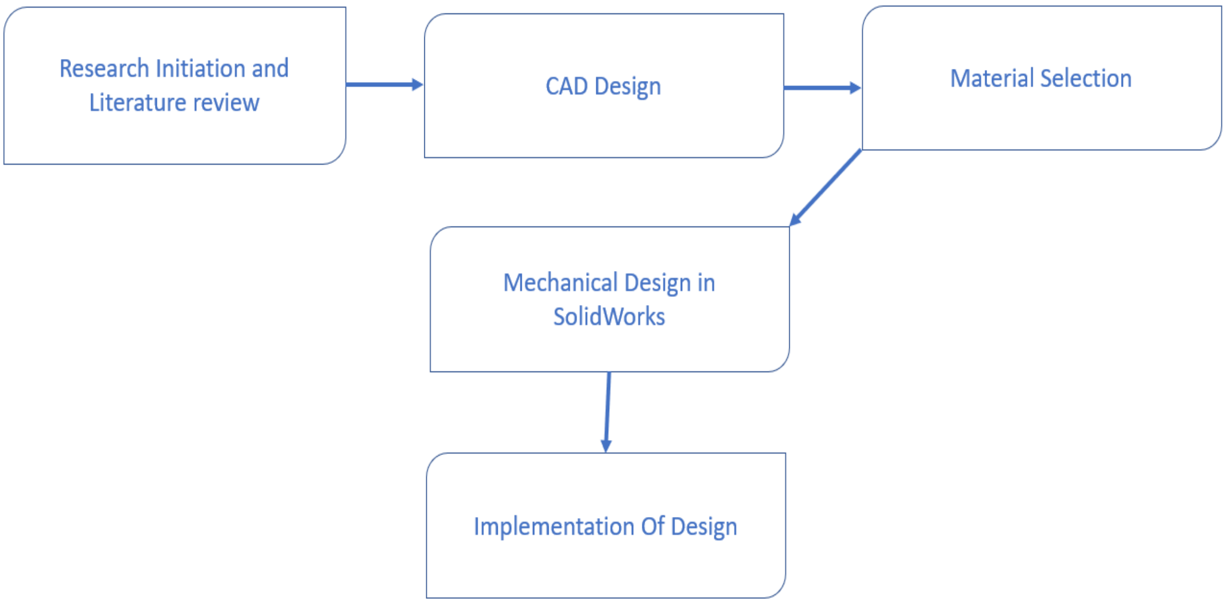


Here, the initial design has been done at https://www.circuito.io/. This is an online platform which has been used to design complete electronic circuits. Through this app, accurate code can be obtained for the specific electronic circuit.

After designing the circuit, we have checked and optimized the circuit through the Proteus Design Suit which is a Windows application. Proteus Design Suit is used for simulation of various types of electrical circuit.

After checking and optimizing through Proteus Design Suit, we have ensured that the circuit is suitable for further progression. Then the code has been developed and after that the code and the circuit has been implemented and optimized for testing.

6.2Methodology (Machine Design & Implementation):



At first, we have researched about several Universal testing machine which has been done for research purposes previously worldwide. Through literature review, we have gained the information about universal testing machine related works. Then we have designed our micro-UTM machine in AutoCAD 2018. After that we have chosen the materials which will be suitable for our machine. After that, we have implemented that CAD design into SOLIDWORKS 2018 through boss extrude process. After the design was completed, we have assembled all the designed parts and turned them into an unit which is the assembled version of micro-UTM machine.

6.3 Clipping Methodology:

For our clipping mechanism, we have used 3 clips. They are: bottom clip, middle clip and top clip. The materials of the clips are aluminum. We have chosen aluminum for its' lightweight property, so we have used the clips which is made of aluminum.

Bottom Clip: The diameter of the bottom clip is 30mm. From the bottom view of the bottom clip, there's another hole in the middle which is 3.6mm in diameter. From the top view, the bottom clip can be seen as drilled and that hole's diameter is 25mm. The length of the bottom clip is 25.5mm. From the elevation view, another hole can be observed which is located at 13.9 from the lower edge of the bottom clip.

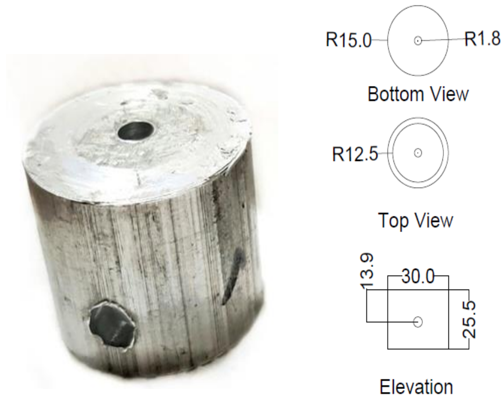


Figure 19: Bottom Clip

Top Clip: The diameter of the top clip is 30mm. From the top view, the top clip can be seen as drilled and that hole's diameter is 25mm. From the elevation view, another hole can be observed which is located at 4.2mm from the upper edge of the top clip.

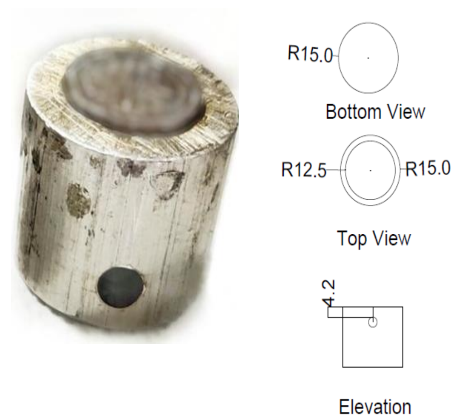


Figure 20: Top Clip

Middle Clip: The diameter of the top clip is 30mm. From the top view, a hole can be seen which is 10mm in diameter. The length of the middle clip is 14mm. From the elevation view, a hole can be seen which is located 3.5 from outer to inner surface.

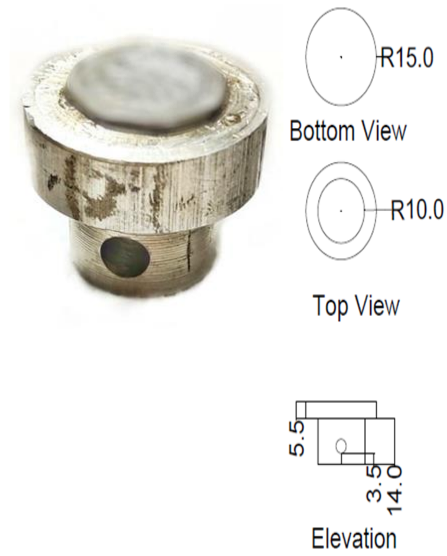
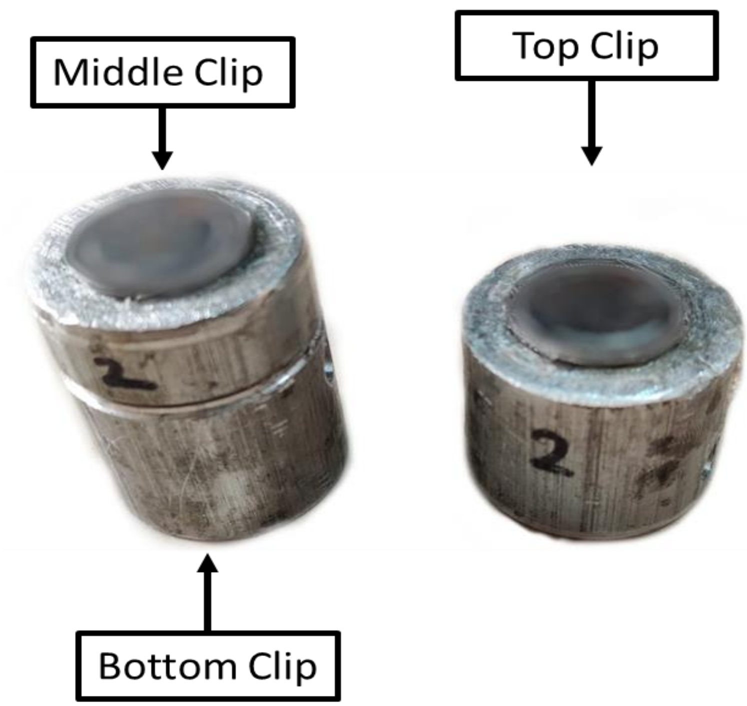


Figure 21: Middle Clip



6.4 Testing Material:

Test 1:

Material: Chalk

Chalk is the composition of the shells of minute marine organisms as coccoliths, foraminifera and rhabdoliths. It is soft, fine-grained. It is mainly used as lime mortar in building construction works.

Sample Size: For testing the chalk, we have taken 1/4" diameter and 3" cylindrical shape's chalk.

Figure 22: Chalk

Properties: Brittle

Chalk is a brittle material as the failure of chalk occurs without higher deformation.

Objective of test 1:

- To understand whether the machine is functioning or not. The test 1 has been conducted to check whether our micro-UTM machine is responding the commands or not for testing procedure. This test has been done at the initial stage because in this stage, the material as chalk is used which can be easily broken and we have confirmed that the machine has the ability to run further tests.

- To understand whether the machine is capable to break brittle material similar to the bitumen properties. As the chalk can be easily broken, so we have confirmed that the further test can be done by the micro-UTM machine which will lead to break bitumen in the further test.

Test 2:

Material: Rubber

Type: Soft (Staedtler)

Staedtler is a soft and pliable rubber eraser. It is composed of Chalk, Gelatine, PVC. It can be kneaded into any type of shape. This rubber has long lasting quality, fully age resistance.

Figure 23: Soft Rubber

Type: Medium (Faber-Castle 4B),

To test medium rubber, we have selected Faber-Castle rubber. Faber-Castle rubber is one of the best rubbers in the world. This type rubber is latex-free.

Figure 24: Medium Rubber

Type: Hard (Pelikan)

To test with hard type of rubber, we have selected Pelikan rubber. It can erase a variety of graphite pencils.

Figure 25: Hard Rubber

Sample Size: For testing with these three types of rubbers, we have selected the same dimensions for all the rubbers. The area of the rubbers are 1X1sq.cm and the length of the rubbers are 4cm.

Properties: There are many properties of rubber. These are elasticity, tensile strength, elongation, abrasion resistance, resilience, hardness. But our main goal is to test the elasticity of these rubbers with our micro-UTM machine.

Objective of test 2:

- We have chosen several types of rubbers to check whether our micro-UTM machine is capable of breaking elastic material similar to the bitumen properties

- We have tested with different types of rubbers in our machine to understand range of elastic material this machine can break. As the different types of rubbers different elastic material range. So, we will understand clearly the capability of the range of our micro-UTM machine how much it is capable to break the elastic material.

Test 3:

Material: Bitumen

Grade: We have taken 80/100 standard penetration grade bitumen. This type of bitumen actually used in the road construction as a paving grade bitumen.

Sample Size: We have taken a disposable plastic spoon. In that spoon, bitumen was taken and then the weight has been measured of bitumen through weight cell device. Then in the clipping mechanism, bitumen has been poured which was 1mm in thickness and 20mm in diameter. We have used poker chip style coins as material above the clipping mechanism which acts on bitumen to hold it inside the clipping mechanism and for that we got the same specific 1mm thickness and 20mm diameter bitumen all the time.

Properties: There are many properties of bitumen. They are: adhesion, resistance to load, hardness, softening point, ductility, durability. The main goal of the third test is to understand the condition of bitumen under tensile stress and at what specific force the bitumen has been torn up.

Objective of test 3:

- This third test has been done with bitumen sample to find out the tensile strength of bitumen.

- To understand the behavior of certain bitumen sample under tensile load.

- To find out at what specific load, the bitumen has been torn up.

Tensile Test:

Tensile test is kind of test where force on furthest edges of the example and pulling apparently until the material breaks. By breaking the material several information about that material can be found as strain, stress, yield disfigurement and different properties. Actually, in tensile test, controlled tension is applied to a sample until it fully fails.

We have used Poker Chip geometry for our tensile test.

Poker Chip geometry has been used to measure the bulk modulus of the asphalt binders. The poker-chip geometry typically has a high diameter-to-thickness ratio, and consequently the radial displacement in the specimen can be neglected. (Motamed, A 2014)

Also, we wanted to replicate the real life tensile stress faced by bitumen on road surfaces.

6.5 Methodology (Testing):

- At first the standard grade of bitumen was taken at a specific portion. It was taken in the disposable spoon at a specific weight. The weight has been measured in the digital weight cell.
- Then the bitumen was heated. The bitumen was heated at 176° C which is the melting point of the bitumen.
- After that the bitumen has been taken into the sampling mold.
- The bitumen has been placed the 3mm spacers inside our mold with 1mm poker chip style coins attached to our clips. As the 1mm poker chip style coins has been used, so the portion of bitumen was not disturbed and it remains same.
- After that we have ensured the 1mm thickness for bitumen sample.
- It was kept for 15 mins to reach the test temperature 23.5° C - 24° C.
- The sampling mold was clipped to the machine, detached the spacer and performed the test. We have ensured that the reading of the load was 0.00. So that the dead load of the clips doesn't hamper our results.
- We get the load/100ms data and displacement data from Arduino.
- The data of displacement we got from computer. But for more accuracy purpose, displacement was checked with digital slide calipers.

- Temperature is one of the most important factors of our testing procedure. We have used thermocouple device to measure the temperature. Thermocouple expresses the exact temperature data. So, temperatures were measured constantly using thermocouple.

6.6 Sampling:

Here, before testing, the top clip and middle clip has been poured with bitumen which has 1mm thickness and 20mm diameter. The 3mm spacer has been placed between the top and middle clip which helps the bitumen to keep the exact dimension. The bottom clip has been connected with the middle clip.

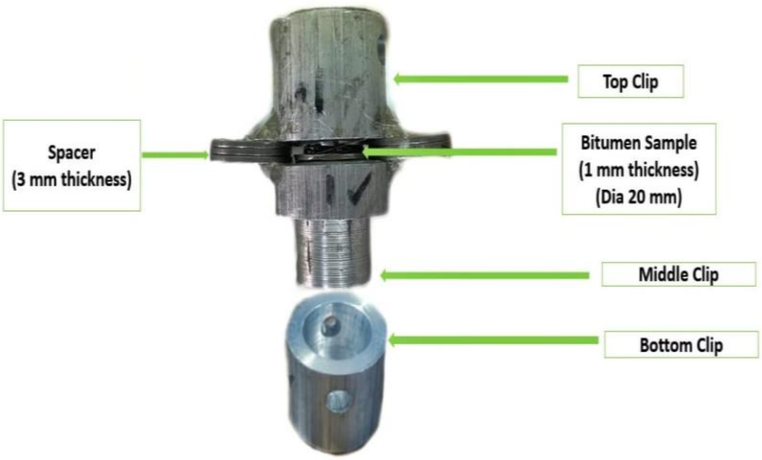


Figure 26: Before Testing

Here, after testing, the bitumen has been torn up due to the applied force which was given by actuator's movement.

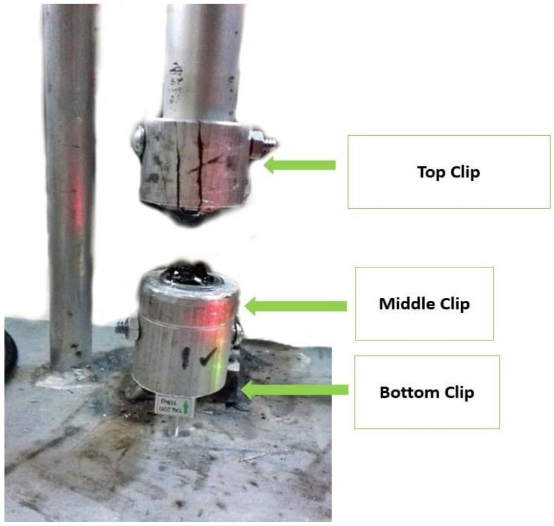


Figure 27: After Testing

Figure 28: Surface Before Testing

Figure 29: Failure Surface

Chapter 7

Results

We used the machine and found those results from our bitumen sample from eastern refinery.

We keep the speed constant on 100 and then we find the variation of results

Speed	100
Temp	25
Dispalcement	47.2
Dead Load	123gm

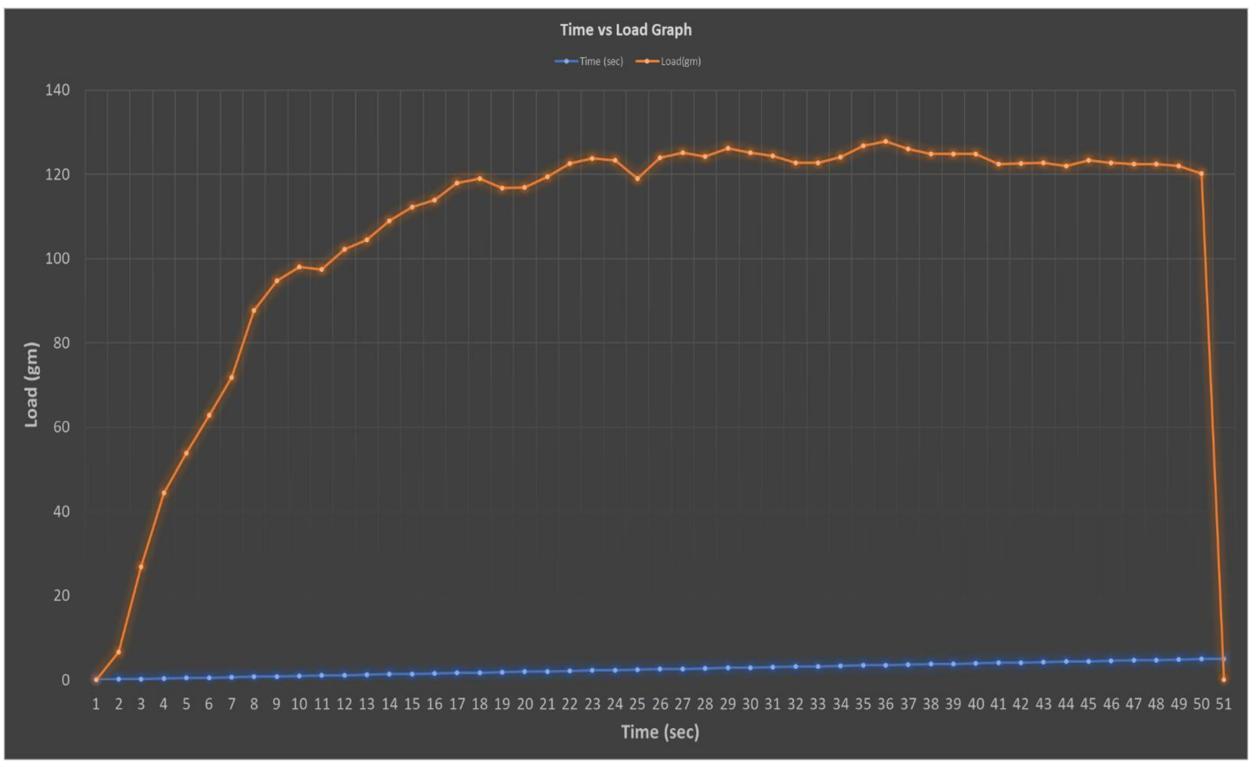


Figure 30: Test Graph

Speed	100
Temp	25
Dispalcement	50
Dead Load	103 gm

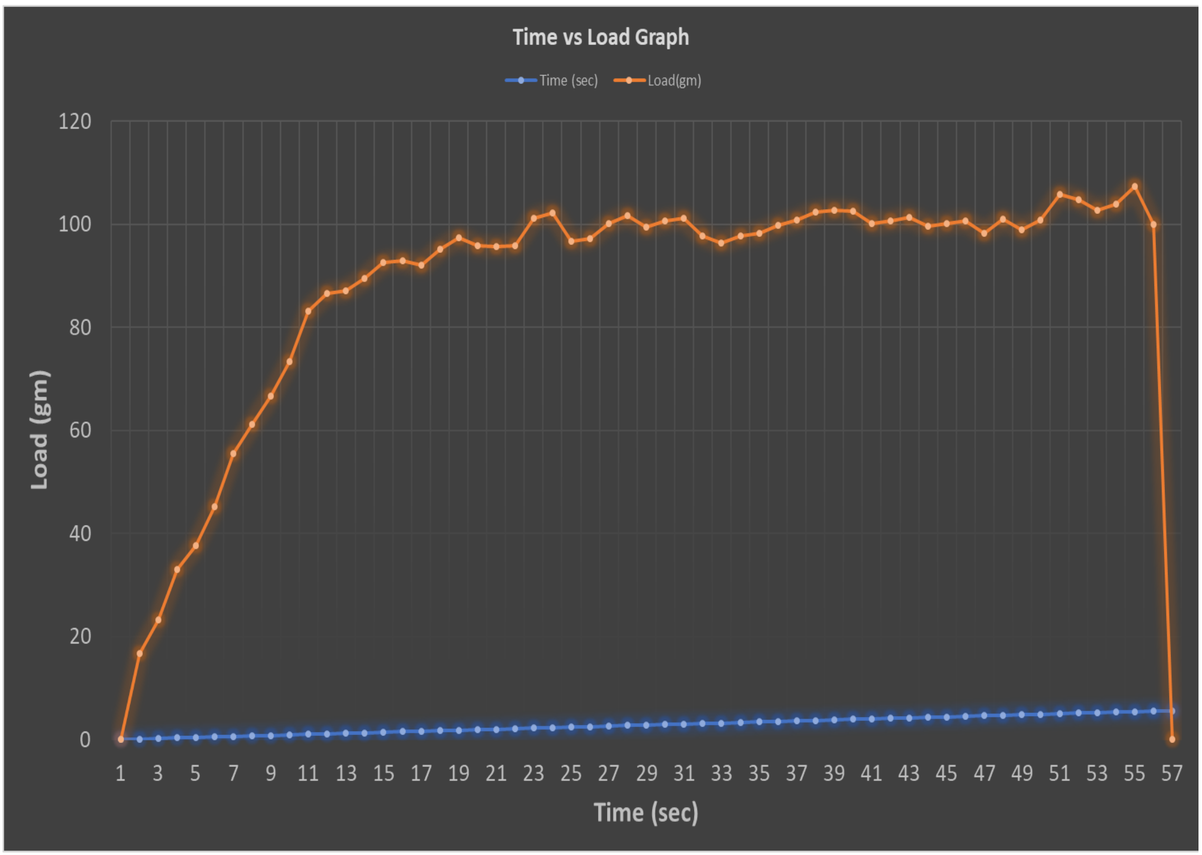


Figure 31: 2nd test graph

Speed	100
Temp	25
Dispalcement	52
Dead Load	117 gm

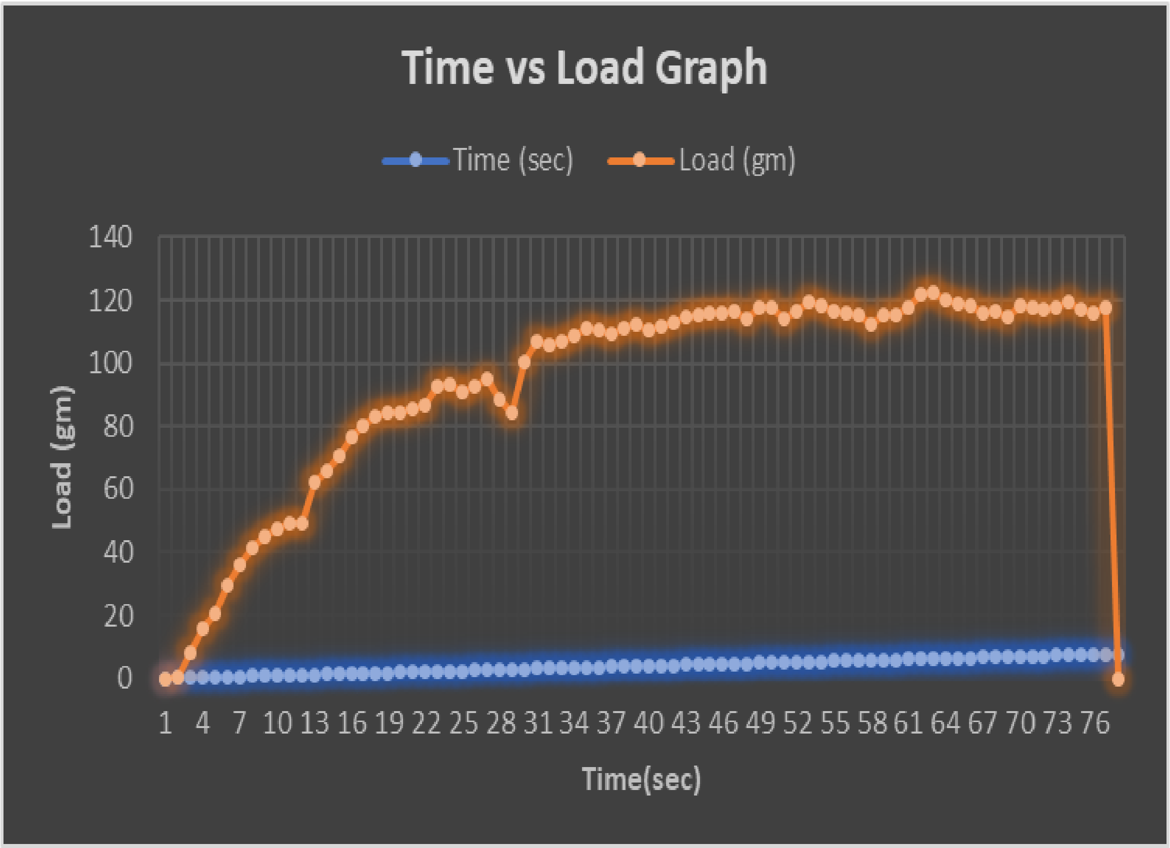


Figure 32: 3rd test graph

Speed	100
Temp	25
Dispalcement	48.8
Dead Load	112 gm

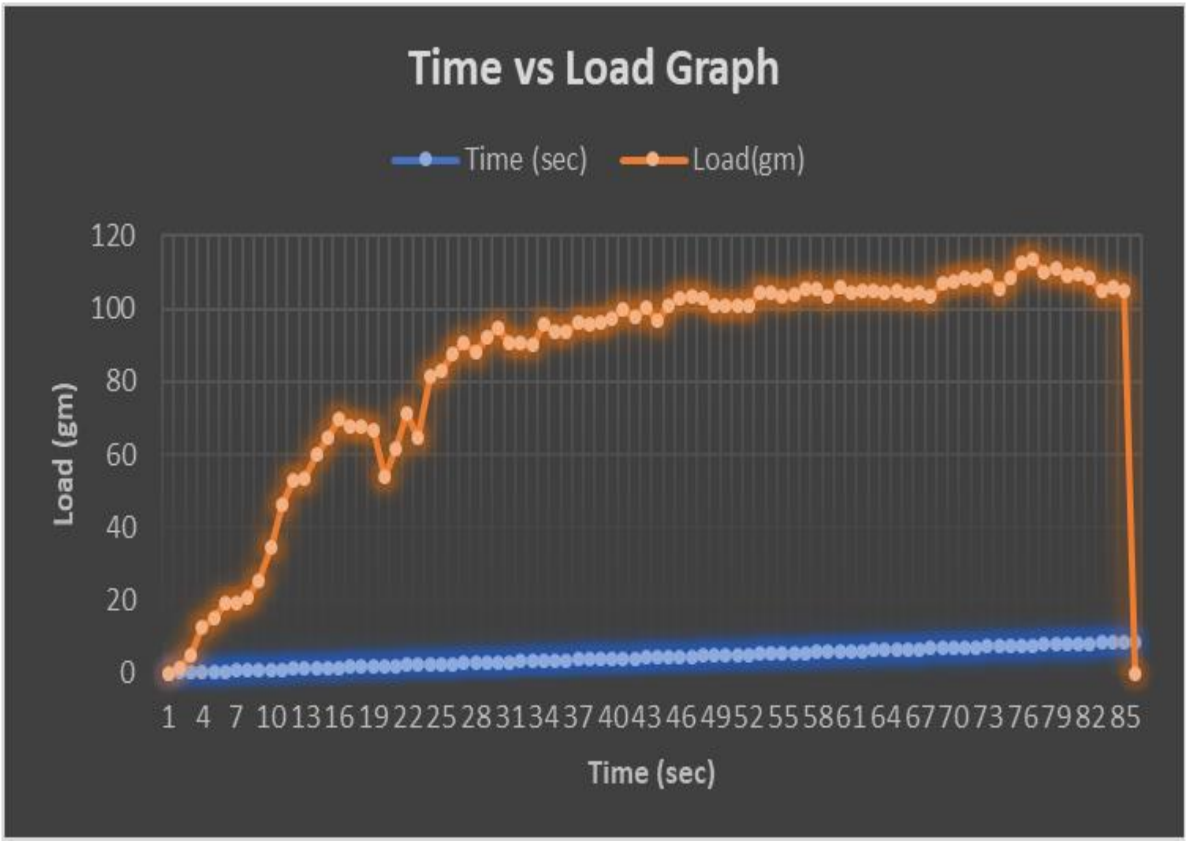


Figure 33: 4th test graph

Speed	100
Temp	25
Dispalcement	47
Dead Load	120 gm

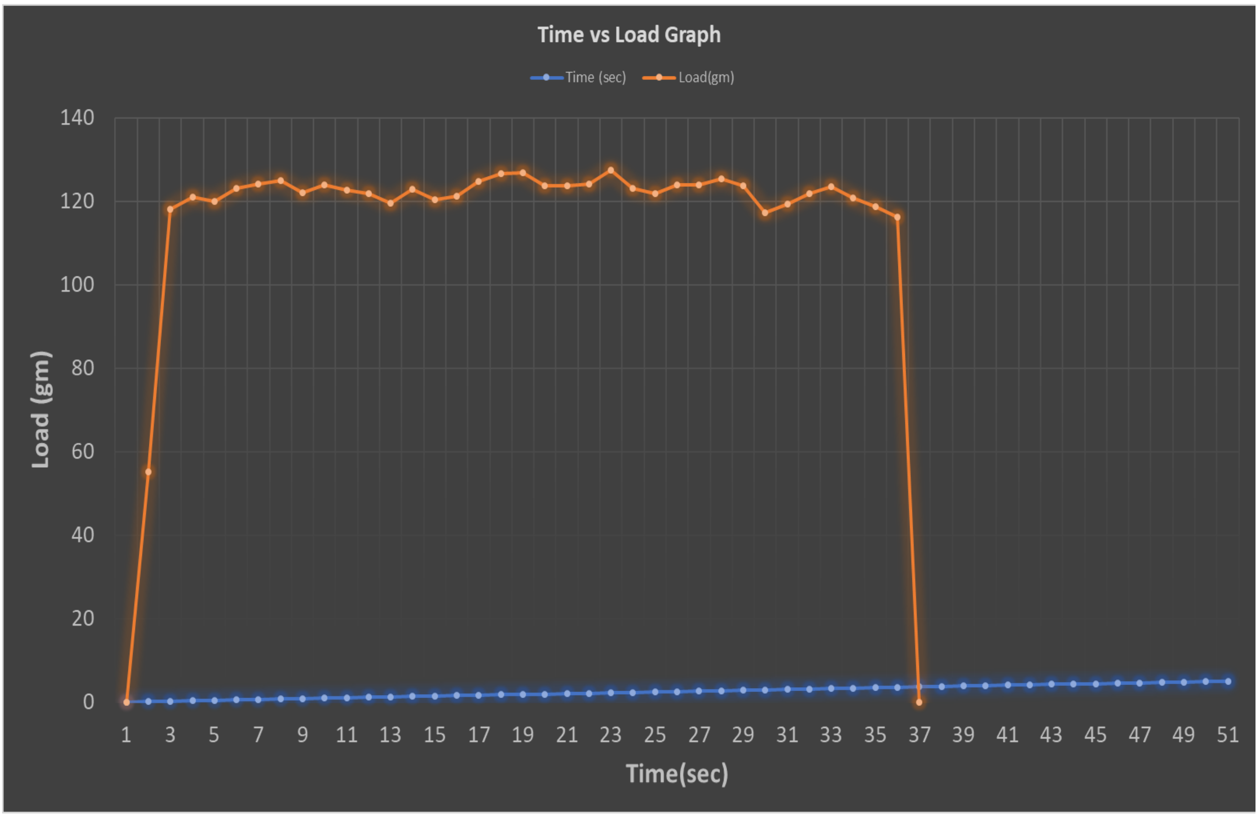


Figure 34: 5th test graph

After successfully completing these we produced a combined graph of more tests with table they are:

Displacements:	Sample 1	47.2 mm
	Sample 2	50 mm
	Sample 3	52 mm
	Sample 4	48.8 mm
	Sample 5	47 mm

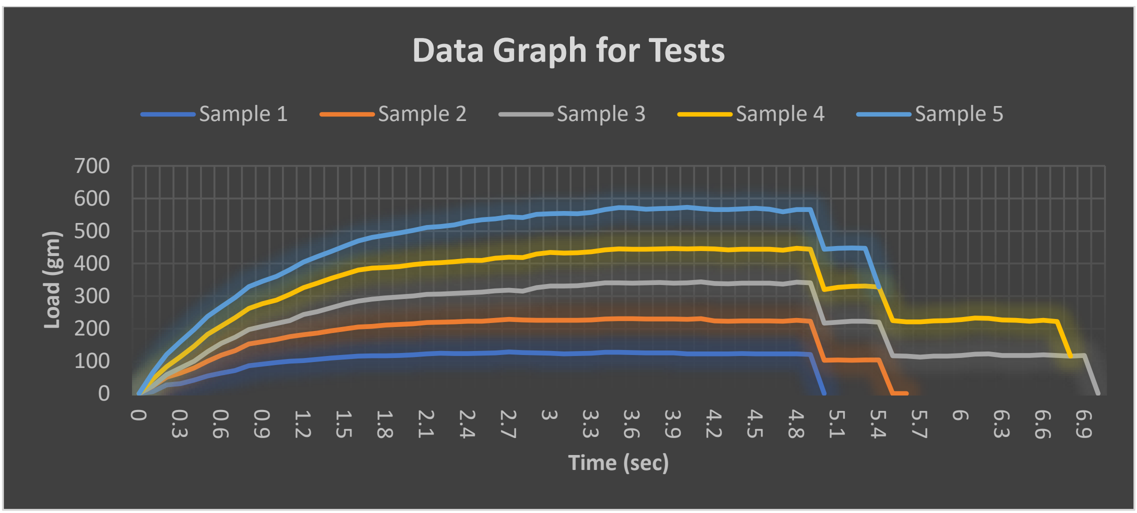


Figure 35: Combined test graph

After this we tested bitumen from different sources and the sources and grades were:

- UAE 60-70(UNITED ARAB AND EMIRATES)
- IRAN 60-70 9 (IRAN)
- PHP 60-70 (BANGLADESHI)
- ER 60-70 (ESTERN REFINARY BANGLADESH)
- ER80-100 (ESTERN REFINARY BANGLADESH)

We have tested 3 batch of each samples and the results are:

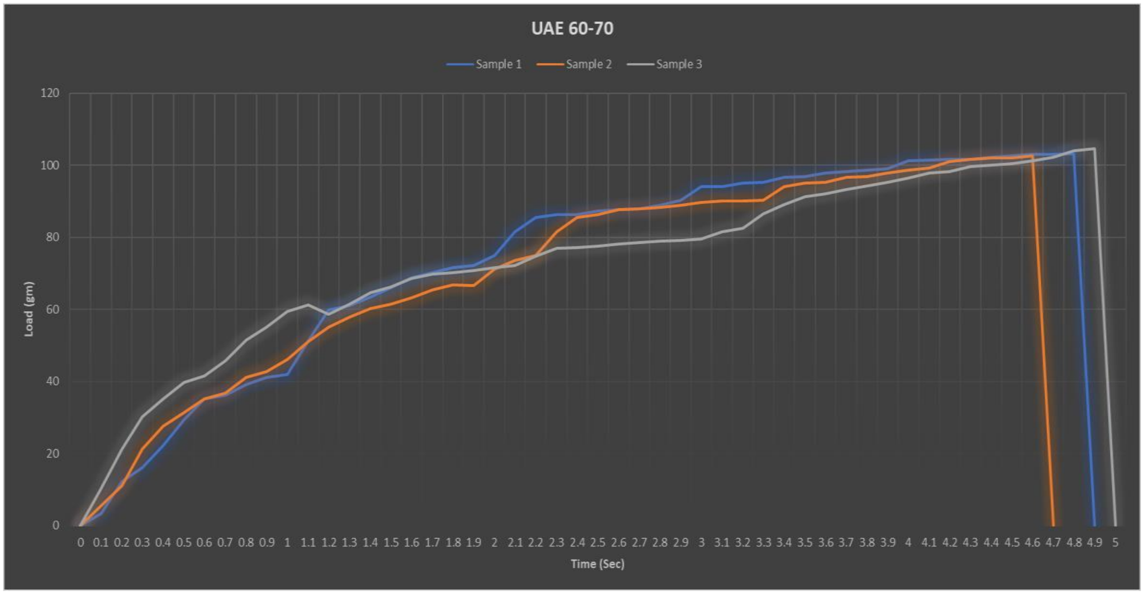


Figure 36: UAE 60-70 test results

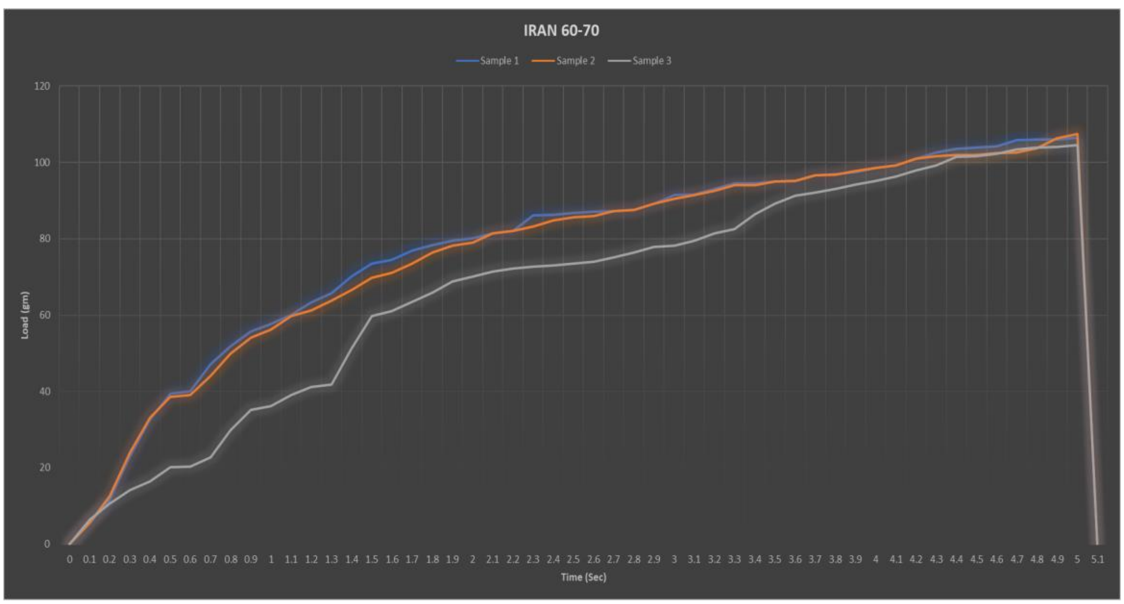


Figure 37: IRAN 60-70 test results

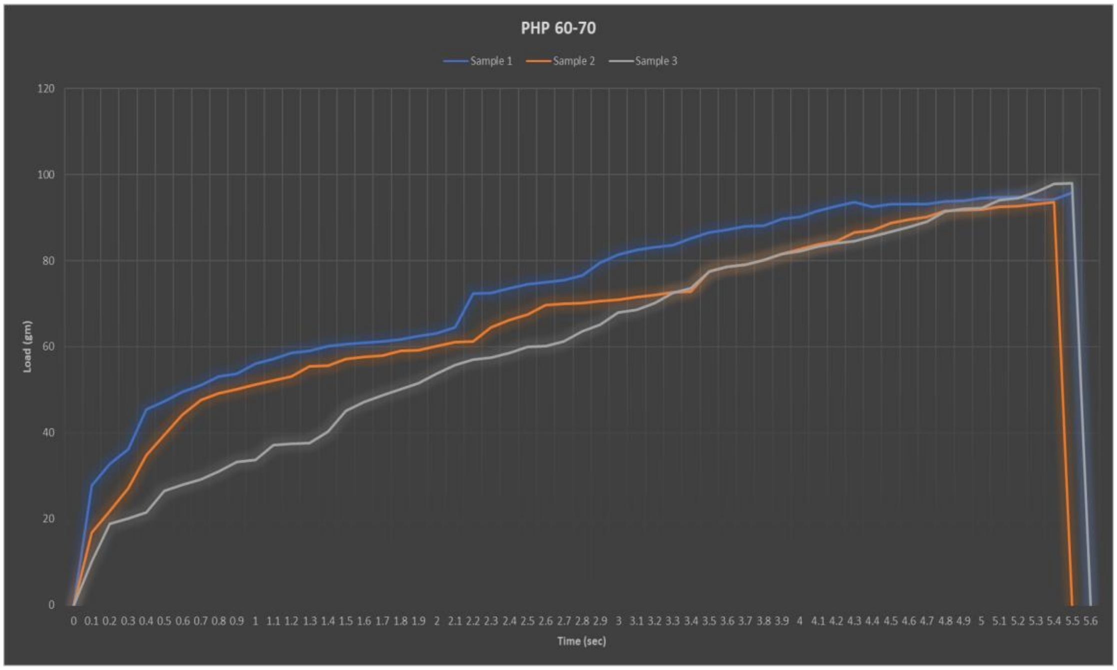


Figure 38: PHP 60-70 test results

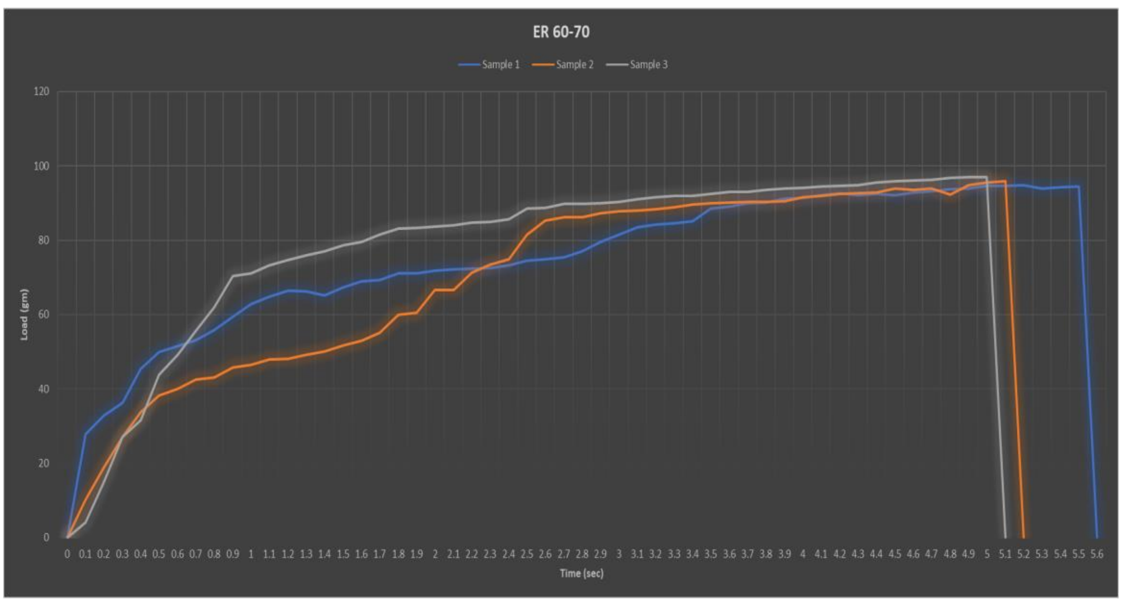


Figure 39: ER 60-70 test results

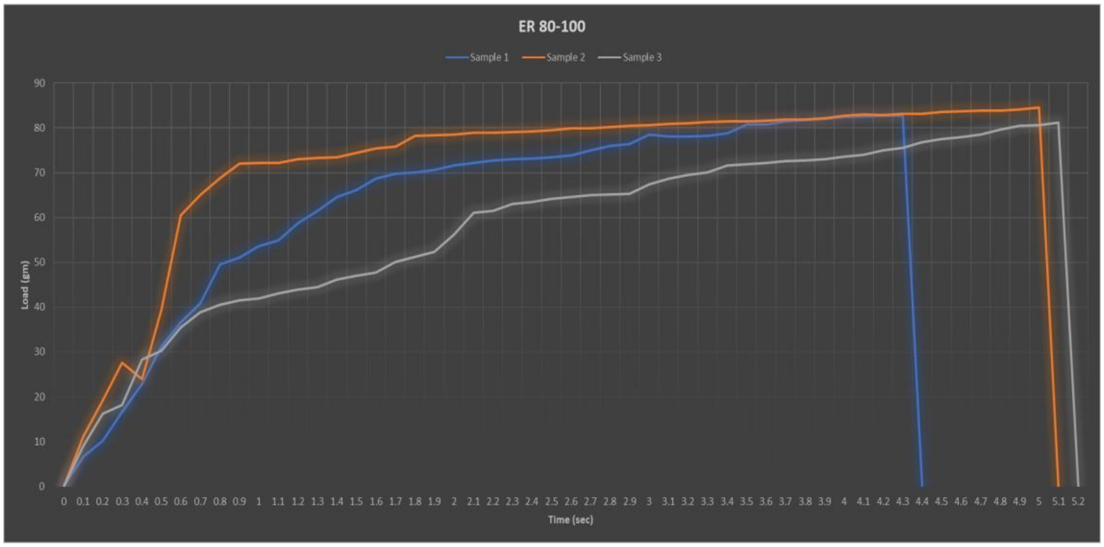


Figure 40: ER 80-100 test results

From these chart we found exactly repetitive behavior from our samples with the micro UTM machine we have developed.

After that we experimented the ductility test in our IUT Transportation laboratory and find the results and the table below shows the results found from our machine and the results found from ductility test.

	Ductility Test Results				
SOURCE	E.R 60/70 (displacement)	E.R 80/100 (displacement)	PHP 60/70 (displacement)	UAE 60/70 (displacement)	IRAN 60/70 (displacement)
TEMPERATURE	25.3	25.3	25.3	25.3	25.3
SAMPLE-1 (in cm)	85	80	86	107	104.5
SAMPLE-2 (in cm)	83	79	87	106	105

Micro UTM Results					
SOURCE	E.R 60/70 (displacement)	E.R 80/100 (displacement)	PHP 60/70 (displacement)	UAE 60/70 (displacement)	IRAN 60/70 (displacement)
TEMPERATURE	25	25	25	25	25
SAMPLE-1 (in mm)	79.6	90	64.9	78	79.9
SAMPLE-2 (in mm)	60.9	87.8	63.7	75.5	73.9
SAMPLE-3 (in mm)	79.6	65.5	72	69.2	65.9

From this two charts we can easily see that the samples that has been deformed in micro UTM in high tensile stress is also has the higher value in ductility tests. So the results found from micro UTM is significant.

Chapter 8

Conclusion And Future Opportunities

Developing a new machine is always very challenging with coping up with the challenges we developed a scale down UTM machine and tested bitumen which has better mobility ,accurate also very cheap to construct. We have designed, implemented and the machine is functioning successfully though we have some issues regarding the consistency of results and accuracy, they are very much improvable.

We have tested some certain samples of bitumen and find out the maximum stress to breakdown. We know the surface area and displacement from that we can find out the stress and strain. We have observed the effect of temperature on the test which has a good impact on our results

In future we will perform the test in a temperature controlled system, we will have a better understanding of the effect of the temperature on the tensile properties of bitumen. Here we have tested bitumen of a single source where we have ignored the effect of inner constituents of bitumen on its tensile properties.

In future when we will test samples from different sources. We will understand the effect of constituents on the tensile properties of bitumen

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