UNI-COMPRESSIVE STRAIN MEASUREMENT OF ROCK SAMPLES USING PIC MICROCONTROLLER

Kumari Renuka[1] *Rakesh Kumar Ray*[2]*Satyakam Sahoo*[3]

1. Department of Computer Science and Enginerring, NIIT University, Neemrana, Rajasthan- 301705, 2. Department of Electronics and Communication Engg, Tezpur University, Napaam, Assam 784028, 3. Department of Electrical Enginerring, NIT Rourkela, Odisha- 769008

Mr. Sateesh Chandrapuri

Scientist, Electrical Geophysics , CSIR-National Geophysical Research Institute, Hyderabad, Telangana- 500007

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Guided by

Mr. Sateesh Chandrapuri

Scientist, Electrical Geophysics , CSIR-National Geophysical Research Institute, Hyderabad, Telangana-500007

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ABSTRACT

In National Geophysical Research Institute, to determine the Uni-Compressive Strain of the rock samples, The Rock Mechanics Department make use of Universal Testing Machine (UTM).A large amount of load is applied by the UTM. Currently, they are able to measure only the breaking point of the rock samples and are only able to take reading from UTM dial gauge. By, keeping the problem in mind discussed above, We made a prototype system for the measurement of the uni-compressive strain and breaking point of the rock samples by providing an interface between the load cell and PIC microcontroller. The signal generated by the load cell is sent to the PIC microcontroller through ADC which is then displayed on LCD, subsequently the data is transferred to computer through serial communication for processing and storage. The experiment have been conducted using three rock samples namely massive basalt, Vesicular basalt and granite rock. In order to measure the accuracy of the proposed prototype system, we compared the calculated load value with the results obtained by the UTM machine. The designed prototype model shows the optimal results with an approximate error for Granite, Massive Basalt and Vesicular Basalt rock samples as 0.0109 %, 0.0353% and 0.051141 % respectively. The data is successfully transferred to the computer for the storage purpose and hence can be used for real-time processing and data analysis in order to make improvements.

Keywords or phrases: Universal Testing mMchine (UTM), Uniaxial Compressive Strength (UCS), PIC microcontroller (18F452), temperature and humidity sensor (HDC1080), Analog to Digital convertor (ADC- HX711), Serial communication (RS232)

ABBREVIATION

LIST OF ABBREVIATION

UTM	Universal Testing Machine
UCS	Uniaxial Compressive Strength
ADC	Analog to Digital Convertor
LCD	Liquid Crystal Display
PCB	Printed Circuit Board
LED	Light Emmiting Diode

1 INTRODUCTION

1.1 Background

The uniaxial compressive strength (UCS) is the maximum axial compressive stress that a right-cylindrical sample of material can withstand before failing. It is also known as the unconfined compressive strength of a material because confining stress is set to zero. It is used to measure the strength of rock or soil sample when crushed in one direction without lateral restraint between the two plate which are moving towards each other gradually. Uniaxial compressive strength is one of the most important mechanical properties of rocks which is mainly used for the design of structures and characterization of intact rock materials. It is mainly used to determine the failure strength of an intact rock specimen. The UCS is undoubtedly the geotechnical property that is most often quoted in rock engineering practice. It is widely understood as a rough index which gives a first approximation of the range of issues that are likely to be encountered in a variety of engineering problems including roof support, pillar design, and excavation technique. For most coal mine design problems, a reasonable approximation of the UCS sufficient. This is due in part to the high variability of UCS measurements. Moreover, the tests are expensive, primarily because of the need to carefully prepare the specimens to ensure that their ends are perfectly parallel.

Rock engineers widely use the uniaxial compressive strength (UCS) of rock in designing surface and underground structures. The procedure for measuring this rock strength has been standardised by both the American Society for Testing and Materials (ASTM) [1] and the International Society for Rock Mechanics(ISRM) [2]. Although, the method is relatively simple, it is time consuming and expensive; also, it requires well prepared rock cores. Therefore, indirect tests are often used to predict the UCS, such as Schmidt rebound number, point load index, impact strength and sound velocity. These are easier tests to carry out because they necessitate less or no sample preparation and the testing equipment is less sophisticated. Also, they can be used easily in the field. As a result, compared to the uniaxial compression test, indirect tests are simpler, faster and more economical. Hence by above it is clear that the measurement of uniaxial compressive strength (UCS) of thr rock sample is diifficult and time consuming. In National Geophysical Research Institute, to determine the UCS the rock mechanics department make use of Universal Testing Machine (UTM) for applying huge amount of pressure. Currently, they are able to measure only the breaking point of the rock samples. Hence our main objective is to design a prototype system for the measurement of the uni-compressive strain and breaking point of the different rock samples.

Hence in order to make the prototype system several components have been used such as **PIC Microcontroller 18F452, LCD Display, Voltagr regulator (LM7805), Crystal Oscillator, Load Cell, Capacitor, Resistor, Potentiometer, ADC Convertor (HX711), Switch, USB Serial (RS232) etc.**

Description of the some of the important components are given below with pin configurations for referenences

A) PIC Microcontroller 18F452

This powerful 10 MIPS (100 nanosecond instruction execution) yet easy-to-program (only 77 single word instructions) CMOS FLASH-based 8-bit microcontroller packs Microchip's powerful PIC architecture into a 40- or 44-pin package and is upwards compatible with the PIC16C5X, PIC12CXXX, PIC16CXX and PIC17CXX devices and thus providing a seamless migration path of software code to higher levels of hardware integration.

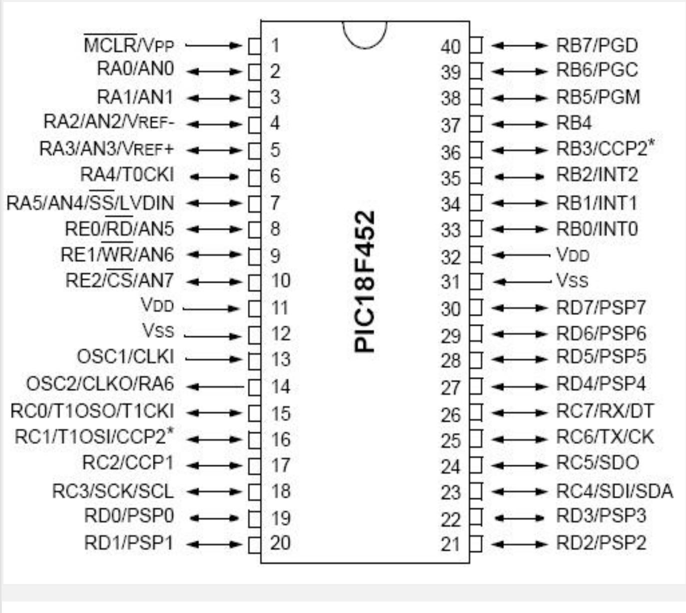

Fig 1 Enter your caption here

B) ADC Convertor (HX711)

The HX711 IC 24-bit ADC allows to easily read the output of the load cells to measure weight. By connecting the amplifier to the microcontroller, we will be able to read the changes in the resistance of the load cell, and with some calibration we will be able to get very accurate weight measurements. This can be handy for creating industrial scale, process control or simple presence detection.

Pin Configuration-

E+ (Excitation VCC), E- (Excitation GND), A- (Channel A Signal-), A+ (Channel A Signal+), B- (Channel B Signal-), B+ (Channel B Signal+), GND (Ground), DT (Data Output), SCK (Clock input), VCC (Power Supply)

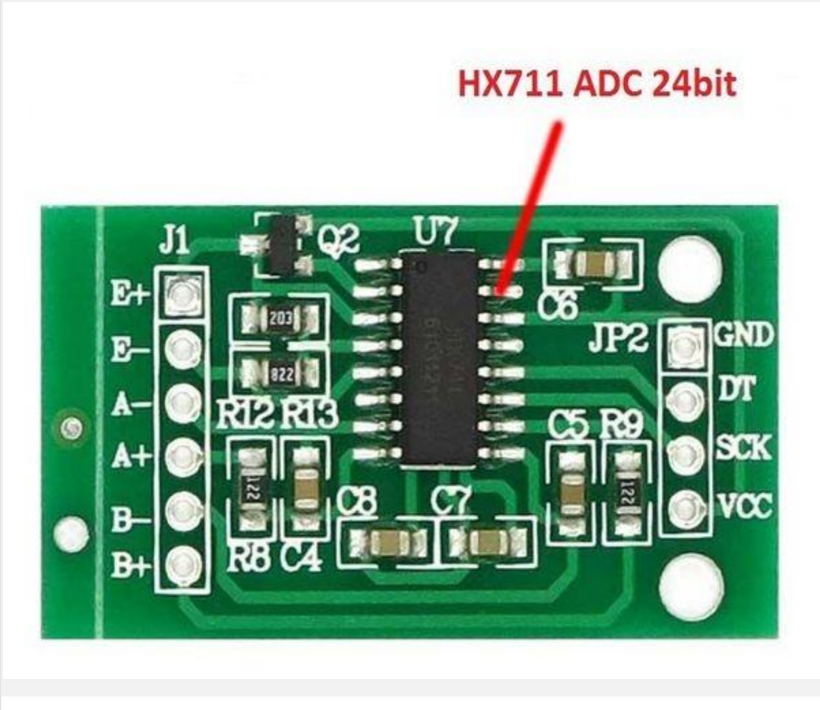

Fig 2 Enter your caption here

C) USB Serial (RS232)

RS-232 is a standard communication protocol for linking computer and its peripheral devices to allow serial data exchange. In simple terms RS232 defines the voltage for the path used for data exchange between the devices.

Pin Configuration- 3V3 – 3.3 Volt Power Supply, TXD – Transmitter, RXD – Receiver, GND – Ground, +5V – VCC-5 Volt Power Supply

D) LOAD CELL

Load cell is a type of transducer which performs the functionality of converting force into an electrical output which can be measured. It is a device that measures strain and then convert force into electrical energy which serves as measurement for further processing. It is used in industrial scales, load test machines etc.

Following above components are used in order to design the prototype.

1.2 Statement of the Problems

In National Geophysical Research Institute, to determine the Uni-Compressive Strain of the rock samples, The Rock Mechanics Department make use of Universal Testing Machine (UTM).A large amount of load is applied by the UTM. Currently, they are able to measure only the breaking point of the rock samples and are only able to take reading from UTM dial gauge. Since, they are able to take reading from only UTM dial gauge, the results obtained are not accurate as they are using analog meter and dial gauge. Hence, in order to address this problem we tried to make a prototype system so that we could digitalize the system and reduce the error which occurs while measuring the data.

1.3 Objectives of the Research

The main objective is to design a prototype system for Uni-compressive Strain Measurement of Rock Sample Using Pic Microcontroller

1.4 Scope

This prototype model can be useful within the CSIR- National Geophysical Research Institute, Hyderabad in the Rocks Mechanics Department. Since in NGRI they are able to measure only the breaking point of the rock samples and are only able to take reading from UTM dial gauge, the results obtained are not accurate as they are using analog meter and dial gauge. The prototype system address the challenges by digitalizing the system and reducing the error which occurs while measuring the data. The scope can also be further extended outside.

2 LITERATURE REVIEW

2.1 Information

Uniaxial compressive strength is one of the most important mechanical properties of rocks which is mainly used for the design of structures and characterization of intact rock materials. It is mainly used to determine the failure strength of an intact rock specimen. The UCS is undoubtedly the geotechnical property that is most often quoted in rock engineering practice. It is widely understood as a rough index which gives a first approximation of the range of issues that are likely to be encountered in a variety of engineering problems including roof support, pillar design, and excavation technique. For most coal mine design problems, a reasonable approximation of the UCS sufficient. This is due in part to the high variability of UCS measurements. Moreover, the tests are expensive, primarily because of the need to carefully prepare the specimens to ensure that their ends are perfectly parallel. Although, the method used to calculate theUniaxial compressive strength is relatively simple, it is time consuming and expensive; also, it requires well prepared rock cores. Therefore, indirect tests are often used to predict the UCS, such as Schmidt rebound number, point load index, impact strength and sound velocity. These are easier tests to carry out because they necessitate less or no sample preparation and the testing equipment is less sophisticated. Also, they can be used easily in the field.

Rusnak, J. and Mark, C in their paper [5] describes a method to measure the rock strength. The International Society of Rock Mechanics has established the basic procedures for testing and calculation of the point load strength index. There are three basic types of point load tests: axial, diametral, and block or lump. The axial and diametral tests are conducted on rock core samples. In the axial test, the core is loaded parallel to the longitudinal axis of the core, and this test is most comparable to a UCS test. Point load testing is used to determine rock strength indexes in geotechnical practice. The PLT is an attractive alternative to the UCS because it can provide similar data at a lower cost. The PLT has been used in geotechnical analysis for over thirty years. The PLT involves the compressing of a rock sample between conical steel platens until failure occurs. The apparatus for this test consists of a rigid frame, two point load platens, a hydraulically activated ram with pressure gauge and a device for measuring the distance between the loading points. The pressure gauge should be of the type in which the failure pressure can be recorded.The point load test apparatus and procedure enables economical testing of core or lump rock samples in either a field or laboratory setting. In order to estimate uniaxial compressive strength, index-to-strength conversion factors are used. These factors have been proposed by various researchers and are dependent upon rock type. This study involved the extensive load frame and point load testing of coal measure rocks in six states. More than 10,000 individual test results, from 908 distinct rock units, were used in the study. Rock lithologies were classified into general categories and conversion factors were determined for each category. This allows for intact rock strength data to be made available through point load testing for numerical geotechnical analysis and empirical rock mass classification systems such as the Coal Mine Roof Rating (CMRR). This paper gives various regression analysis in ordervto prove the results.

Kahraman, S in his paper [4] make use of the published data on 48 different rocks to evaluate the correlations between the uniaxial compressive strength (UCS) values and the corresponding results of point load, Schmidt hammer, sound velocity and impact strength tests. The variability of test results for each test and each rock type was evaluated by calculating the coefficient of variation. Using the method of least squares regression, the UCS values were correlated with the other test values. Also, the test methods were evaluated by plotting the estimated values of compressive strength vs. the measured values of compressive strength for each test. The results indicate that the least variability is shown in the impact strength test. So, among the test methods included in this study, the impact strength test is the most reproducible test; but the variability of test results for the other test methods is within acceptable limits for most engineering purposes. Strong linear relations between the point load strength index values and the UCS values were found for the coal measure rocks and the other rocks included in this study. The Schmidt hammer and the sound velocity tests exhibit significant non-linear correlations with the compressive strength of rock. The The Schmidt hammer is used for testing the quality of concretes and rocks. Schmidt hammer models are designed in different levels of impact energy, While the Schmidt hammer is widely used for the prediction of UCS. The UCS values were correlated with the other test values. Also, the test methods were evaluated by plotting the estimated values of compressive strength vs. the measured values of compressive strength for each test. In the sound velocity test, the data points are scattered at higher strength values. There is no clear relation between the impact strength values and the compressive strength values for the coal measure rocks. A weak non-linear correlation was found between the impact strength values and the compressive strength values for the other rocks. All test methods evaluated in this study, except the impact strength, provide reliable estimate of the compressive strength of rock. However, the prediction equations derived by different researchers are dependent on rock types and test conditions, as they are in this study. This paper gives the correlation analysis of the uniaxial compressive strength (UCS) values and the corresponding results of point load, Schmidt hammer, sound velocity and impact strength tests.

3 METHODOLOGY

3.1 Concepts

The process started with making the PCB Desgin using an online software. After the completion of the PCB Design it was printed on the photo paper. The printed design was transferred onto the PCB board using toner transfer method using a laminator. After this the etching and drilling of the PCB board was completed. When the complete board was ready the fixing of component took place. Then the component were tested in order to check their working. Final Program for Uni-compressive Strain Measurement of Rock Sample was written and testing was done by connecting the designed prototype model to the load cell of Universal Testing Machine. Finally, experiment was conducted with three types of different rocks such as massive basalt, Vesicular basalt and granite rock and data was successfully collected. The complete phases are decribed below in detail.

3.2 Prototype Design and Methods

A) PCB DESIGN

The PCB design was made based on the required circuit using a PCB designing software. The final sketch of the PCB layout is as shown in the figure below.

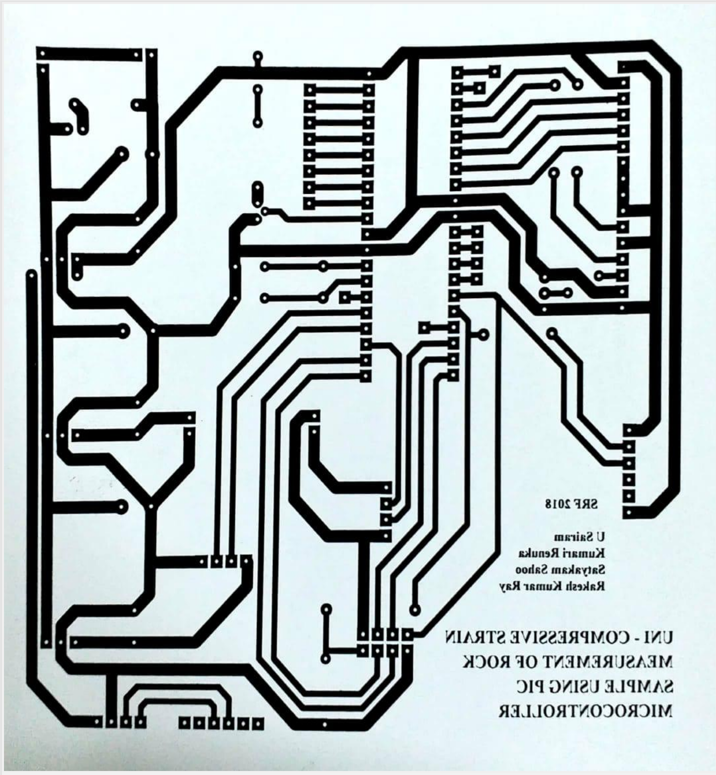

Fig 3 **PCB DESIGN LAYOUT (Photopaper)**

B) TONER TRANSFER

Once the PCB layout was ready, it was printed on a photo-paper. The printed design was transferred onto the PCB board using toner transfer method using a laminator such as the one shown in the following figure below:

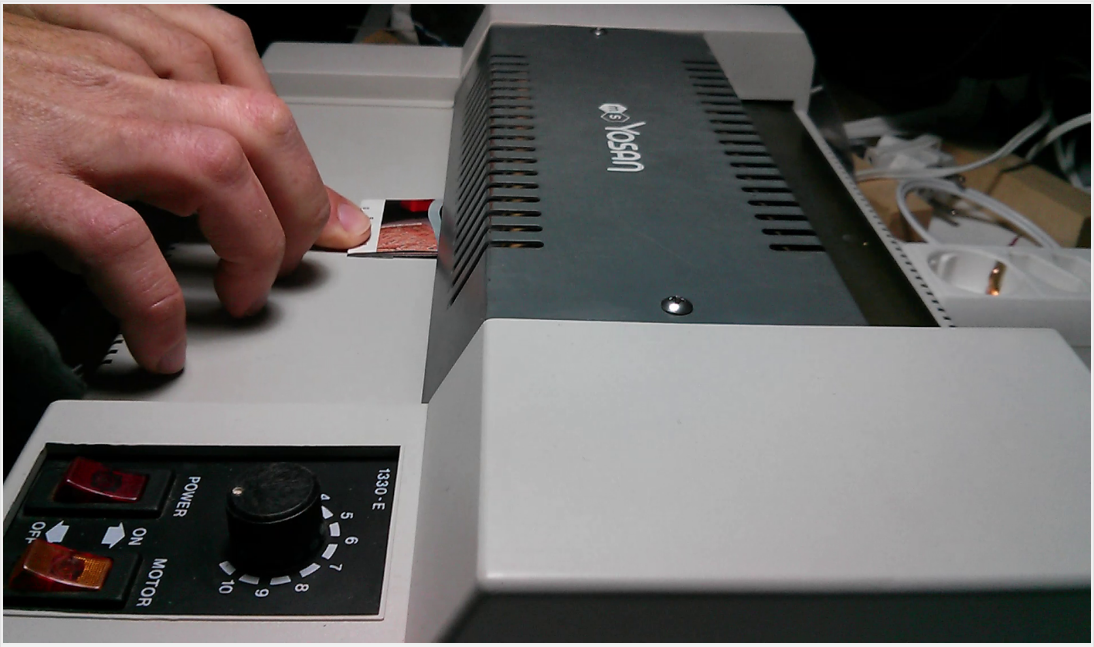

Fig 4 **LAMINATOR (Toner Transfer)**

C) PCB ETCHING AND DRILLING

After transferring the layout onto the PCB board, it was dipped in $FeCl_3$ solution at the required temperature for about 2-3 hours as shown in the figure given below. This process resulted in the etching of the layout on the board.

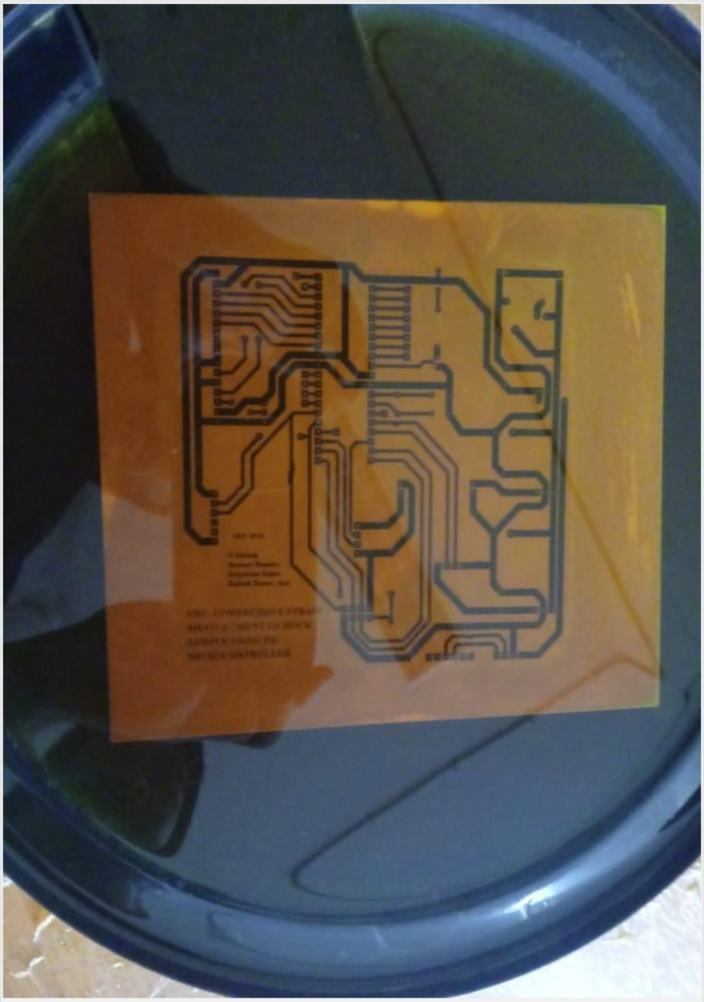

Fig 5 **DURING ETCHING OF PCB**

After removing the board from the solution, it was cleaned using a cleaning agent to remove all the unwanted carbon on it. The result of cleaning was the board as shown in the following figure given below:

Fig 7 **PCB DRILLING**

D) FIXING OF COMPONENTS

Once the PCB is ready with the holes, the components were mounted onto it in an orderly manner. The jumpers were mounted first followed by the IC bases. Next, LED's, capacitors and resistors were mounted. Once all the bases and passive components were mounted, the other remaining components were fixed. Figure 17 represents the diagram after fixing of the components. After this we started the testing phases.

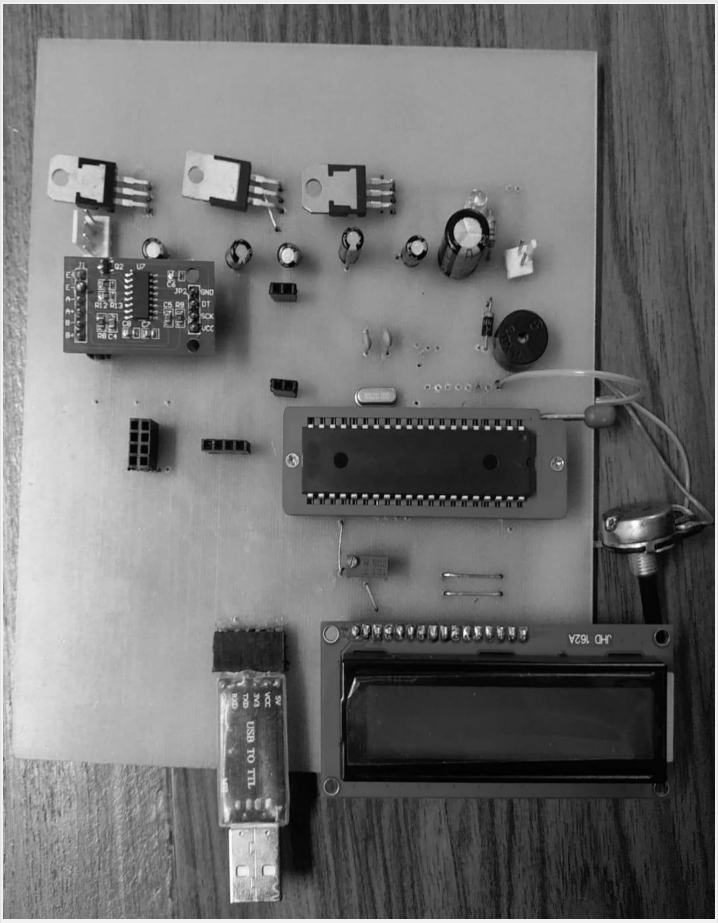

Fig 8 **: BOARD AFTER FIXING THE COMPONENT**

E) FINAL PROGRAM (CODING)

Pic Microcontroller Final Program for Uni-compressive Strain Measurement of Rock Sample

Description-

This program will take the Analog Signal from Load cell through HX711 ADC. Interfacing with HX711 CLK in PIN_C2 and DATA in PIN_C1. Data transfer to PC through serial communication for further processing.

Description-

```
#include <18F452.h>

#fuses HS,NOWDT,NOPROTECT,NOLVP

#use delay(clock=10000000)

#use rs232(baud=9600,parity=N,xmit=PIN_C6,rcv=PIN_C7,bits=8)

#include <LCD_4BIT.c>

int i,j;

int32 q , t ; // Variable Declaration

float v;

void main()

{

 set_tris_D(0x00); // Port setting

 set_tris_C(0x02);

 delay_ms(2000);

 lcd_init (); // LCD initialization

 delay_ms(2000);

 for(;;) // Continuous Loop
```

```
{
delay_us(100);
t = 0;
for (j=0;j<20;j++)
{
output_high(PIN_C1); // data =1;
output_low(PIN_C2); //clk = 0;
q = 0x00000000;
while (input(PIN_C1)); // waiting for data ready
for (i=0;i<24;i++)
{
output_high(PIN_C2); //clk = 1;
q = q << 1;
delay_cycles( 1 );
if (input(PIN_C1)) q++;
output_low(PIN_C2); //clk = 0;
}
```

```
for (i=0;i<3;i++)

{

output_high(PIN_C2); //clk = 1;

q = q ^ 0x00800000;

output_low(PIN_C2); //clk = 0;

}

t = t + q;

}

t = t / 20;

v = t * 5000 / 16777215.0;

printf (lcd_data,"%g",v);

printf ("%g",v);

delay_ms(500);

lcd_cmd (0x01);

}

}
```

LCD_4BIT.c

```
#define LCD_EN 0x20

#define LCD_RS 0x10


void lcd_reset()

{

 output_b(0x5F);

 delay_ms(200);

 output_b(0x03+LCD_EN);

 output_b(0x03);

 delay_ms(100);

 output_b(0x03+LCD_EN);

 output_b(0x03);

 delay_ms(10);

 output_b(0x03+LCD_EN);

 output_b(0x03);
```

```
 delay_ms(10);

 output_b(0x02+LCD_EN);

 output_b(0x02);

 delay_ms(100);

 }

void lcd_cmd (int cmd)

 {

 output_b(((cmd >> 4) & 0x0F)|LCD_EN);

 output_b(((cmd >> 4) & 0x0F));

 output_b((cmd & 0x0F)|LCD_EN);

 output_b((cmd & 0x0F));

 delay_ms(10);

 }



void lcd_init ()

 {

 lcd_reset(); // Call LCD reset
```

```
 lcd_cmd(0x28); // 4-bit mode - 2 line - 5x7 font.

 lcd_cmd(0x28); // 4-bit mode - 2 line - 5x7 font.

 lcd_cmd(0x28); // 4-bit mode - 2 line - 5x7 font.

 lcd_cmd(0x0C); // Display on cursor blink.

 lcd_cmd(0x06); // Automatic Increment - No Display shift.

 lcd_cmd(0x80); // Address DDRAM with 0 offset 80h.

 }


void lcd_data (int dat)

 {

 output_b((((dat >> 4) & 0x0F)|LCD_EN|LCD_RS));

 output_b((((dat >> 4) & 0x0F)|LCD_RS));

 output_b(((dat & 0x0F)|LCD_EN|LCD_RS));

 output_b(((dat & 0x0F)|LCD_RS));

 delay_ms(10);

 }
```

4 RESULTS AND DISCUSSION

4.1 Purpose

In National Geophysical Research Institute, to determine the UCS the rock mechanics department make use of Universal Testing Machine (UTM) for applying huge amount of pressure. Currently, they are able to measure only the breaking point of the rock samples. We made a prototype system for the measurement of the tensile and compressive strength of rock samples by providing an interface between the load cell and PIC microcontroller. The data generated by the load cell is sent to the PIC microcontroller through ADC which is then displayed on LCD, subsequently the data is transferred to computer through serial communication for storage.

We have experimented with three rock samples which are massive basalt, Vesicular basalt and granite rock. Table 1 gives the results of the experiment conducted. The following steps were followed in order to obtain the results-

We connected our circuit to the Load Cell of Universal Testing Machine (UTM) of the rock mechanics department in order to measure the uni-compressive strain.

Experiment 1 – First experiment was conducted with granite rock sample with length as 5.944cm and diameter as 2.922. The measured value of Bridge offset was 365.5 μV.

Experiment 2 – The second experiment was conducted with massive basalt rock sample with length as 7.482 cm and diameter as 2.988. The measured value of Bridge offset was 365.2 μV.

Experiment 3 – The third experiment was conducted with vesicular basalt rock sample with length as 7.362 cm and diameter as 2.990. The measured value of Bridge offset was 359.8 μV.

For all the above experiments the Conversion factor was calculated as 22. Each experiment consists of three columns. The first column is the output of the load cell. The second column represent the actual axial load which is shown by the UTM display. The third column represents the calculated value of load is the measured using the designed circuit. From the results, as shown in Table 1 it is cleared that the designed prototype model shows the optimal results with an approximate error for Granite, Massive Basalt and Vesicular Basalt are 0.0109

%, 0.0353% and 0.051141 % respectively. The data is successfully transferred to the computer for further processing and storage purpose.

Experiment Description : Experiment, 10 Ton range UTM
Mode of Experiment : Uni-axial Compressive Test

	Sample : Granite Length (cm): 5.944 Diameter(cm): 2.922 Bridge Offsets: 362.5 µV Conversion Factor: 22			Sample : Massive Basalt Length (cm): 7.482 Diameter(cm): 2.988 Bridge Offsets: 365.2 µV Conversion Factor: 22			Sample : Vesicular Basalt Length (cm): 7.362 Diameter(cm): 2.990 Bridge Offsets: 359.8 µV Conversion Factor: 22		
Sl. No.	Output Load Cell	Axial Load	Calculated Load	Output Load Cell	Axial Load	Calculated Load	Output Load Cell	Axial Load	Calculated Load
	(µV)	(kg)	(kg)	(µV)	(kg)	(kg)	(µV)	(kg)	(kg)
1	377.4	327.3	327.8	386.4	468.4	466.4	366.4	144.4	145.2
2	385.3	502	501.6	424	1295.2	1293.6	383.7	525.1	525.8
3	395.6	728.9	728.2	442.9	1711.2	1709.4	388.8	637.4	638
4	409.8	1039.6	1040.6	462.5	2142.5	2140.6	392.6	721.4	721.6
5	423.4	1338.6	1339.8	484.2	2619.1	2618	429.4	1529.2	1531.2
6	445.2	1819	1819.4	502.4	3019.6	3018.4	474.7	2526.6	2527.8
7	470.2	2369.8	2369.4	529.1	3606.2	3605.8	495.1	2975.6	2976.6
8	491.9	2846.9	2846.8	546.1	3980.4	3979.8	524	3610.3	3612.4
9	509	3222.2	3223	565.7	4412.9	4411	545.2	4077.9	4078.8
10	531.3	3713.6	3713.6	588.3	4909	4908.2	568.3	4585.3	4587
11	547.4	4067.7	4067.8	623.6	5686	5684.8	587.8	5015.7	5016
12	564.3	4438.8	4439.6	638.5	6013.6	6012.6	608.8	5476.5	5478
13	583.9	4871.2	4870.8	657	6421	6419.6	622.5	5778.3	5779.4
14	594.7	5108.4	5108.4	681.6	6960.9	6960.8	641	6186.4	6186.4
15	611.7	5482.7	5482.4	712.6	7643.5	7642.8	649.8	6379.6	6380
16	622.5	5718.7	5720	732.3	8076.3	8076.2	664.4	6700.7	6701.2
17	635.5	6005	6006	752	8510.5	8509.6	676.3	6962.2	6963
18	654.8	6429.7	6430.6	779.9	9125.3	9123.4	691.8	7303	7304
19	670	6765.4	6765	808.2	9746.5	9746	697.9	7436.7	7438.2
20	681.2	7010.1	7011.4	823.8	10090.9	10089.2	704.7	7585.8	7587.8
21	693.4	7278.9	7279.8	848.5	10632.9	10632.6	710.7	7718.3	7719.8
22	700.7	7440.5	7440.4	869.2	11088.7	11088	721.2	7948.7	7950.8
23	708.9	7620.3	7620.8	888.8	11520	11519.2	724.5	8021.6	8023.4
24	725.5	7985.1	7986	922.9	12270.9	12269.4	742.6	8421.2	8421.6
25	735.5	8205.1	8206	935.8	12554.6	12553.2	756.9	8734.6	8736.2
26	745.3	8422.2	8421.6	960.1	13089.9	13087.8	770.8	9041.2	9042
27	765.4	8863.8	8863.8	977.5	13472	13470.6	776.2	9160.4	9160.8
28		Breaking Point		1012.1	14233.8	14231.8		Breaking Point	
29		% Error	-0.0109	1037.3	14787.2	14786.2		% Error	0.0511
30				1052.2	15114.3	15114			
31				1107.7	16335.9	16335			
32				1146.4	17186.6	17186.4			
33					Breaking Point				
					% Error	-0.0353			

TABLE -1 EXPERIMENT DATA

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Fig 9 **EXPERIMENT DATA**

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In National Geophysical Research Institute, to determine the Uni-Compressive Strain of the rock samples, The Rock Mechanics Department make use of Universal Testing Machine (UTM).A large amount of load is applied by the UTM. Currently, they are able to measure only the breaking point of the rock samples and are only able to take reading from UTM dial gauge. Our main motive was to overcome the following challenges mentioned above. Hence, we made a prototype system for the measurement of the uni-compressive strain and breaking point of the rock samples by providing an interface between the load cell and PIC microcontroller. The signal generated by the load cell is sent to the PIC microcontroller through ADC which is then displayed on LCD, subsequently the data is transferred to computer through serial communication for processing and storage. The experimented have been conducted using three rock samples namely massive basalt, Vesicular basalt and granite rock. In order to measure the accuracy of the proposed prototype system, we compared the calculated load value with the results obtained by the UTM machine. The designed prototype model shows the optimal results with an error for Granite, Massive Basalt and Vesicular Basalt rock samples as -0.0109 %, -0.0353% and 0.051141 % respectively. The data is successfully transferred to the computer for the storage purpose and hence can be used for real-time processing and data analysis in order to make improvements. Through this experiment we got the practical knowledge about the working of the UTM machine, learnt to make PCB design and to work with various electronic components and sensors.

5.2 Recommendations

Further the project can be extended. Hence, we would like to reccommend certain things such as the whole UTM machine can be automated by implementating the prototype system and the transfered data can be used for the real-time processing. Machine learning can come into action for further analysis in order to know how much the model is good and how it can be improved.

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