An Experimental Approach for Prognosis of Residual Strength of Steel by TCS3200 Color Sensor

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Abstract **- Corrosion is inevitable in reinforced structures unless constructed with proper materials and regular maintenance. Due to various reasons, corrosion occurs in the steel rod, which will damage the structure and degrade the life of the structures. In repairing the structures which was affected by the corrosion, first need to access the residual Strength of the steel. Only after assessing the Strength of the steel will, it be decided whether go with any repairing technique or any other decision. To find the residual Strength of existing steel rods, a technique is proposed to deduct the corrosion by using the colour sensor. The technique has implemented by using various diameter of steel rod with the size of 8mm, 10mm and 12mm were taken and it was corroded up to 10% rate of corrosion by accelerated corrosion with the help of galvanostatic processes by adding 5% of NaCl solution and by supply of 12V DC power. Each colour has their own frequency depends on their intensity. So, the corroded steel rod will change their colour frequency depending upon their rate of corrosion. By having the advantage of these, frequency has recorded with the help of colour sensor and Arduino setup with the regular interval. As increase of corrosion, the residual strength of steel rod also will change and it starts to degrade its Strength during the corrosion. The loss of Strength of steel rod has obtained at the regular interval by using Conventional Method with the help of Universal testing machine. The predicted equation has been developed for various diameter of steel rod recorded frequency and tensile strength. To validate the prediction equation, the steel rods were corroded up to 15% and the tensile strength of the steel rod was compared with the predicted equation with the help of colour frequency. The final results show that, the residual Strength of steel rod obtained from the conventional method and predicted equation shows that both vales are nearby and it is with in the acceptable limit.**

Keywords **– Arduino, Corrosion, Color sensor, Frequency , Monitoring,Residual Strength and Steel rod.**

1. INTRODUCTION

Concrete and reinforcement steel are essential building materials widely used in composite construction due to their advantages TattukollaKiran, N.Anand, Mervin Ealiyas Mathewsd (2022). Corrosion of reinforcement is one of the major durability challenges which leads to a reduction in the design life of reinforced concrete. Due to an increasing demand for longer service lives of infrastructure (typically 100–120 years) and the high cost involved in building and maintaining it, the repair of concrete structures has become extremely important rpit Goyal, Eshmaiel Ganjian, Homayoon Pouya (2018). Corrosion is considered to initiate when the chloride concentration around the reinforcement reaches a threshold to cause dissolution of the protective film. When the corrosion of steel bars develops significantly, it not only affects the structural serviceability by cracking or even spalling of the concrete cover but also has an impact on the structural safety by decreasing the load-bearing capacity of reinforced concrete members, which is of great concern to both owners and users of the structural building. Corrosion is the degradation of materials usually metal owing to chemical reaction with the environment which result in a functional failure of component. Corrosion is a reverse extractive metallurgy, which depends on the concentration of environment, stress, erosion and the temperature. It causes major economic losses ranges from 1% to 5% of GNP per year for any nations. In addition, corrosion not only increases the costs of component but it also responsible for life losses and safety hazard (S. HarsimranK. Santosh1K. Rakesh (2021). Corrosion of reinforcing steel is the main reason for the premature deterioration of concrete structures. The basic problem for the deterioration of reinforced concrete due to corrosion is not only that the

reinforcing steel itself is reduced in mechanical strength, but also the products of corrosion exert stresses within the concrete that cannot be supported by the limited plastic deformation of the concrete Abul K. Azad, Shamsad Ahmad, and Syed A. Azhe (2007). To find out the corrosion, nowdays sensors are used to find the residual strength of steel by frequency and colour. To measure the various colours of a material the Arduino is used for an intelligent colour sensing system that an measure the colours of a material Complementary Metal Oxide Semiconductor (CMOS) colour sensor. The important a part of the setup is Arduino micro-controller Gawthami, Humrish.k, Prem.p, Tony Antony Augustine (2018). The Arduino Board act as a brain of the colour sensing system. this will be useful to know how the new building looks in various colours and work according to it to avoid creating a lot of mess. Intelligent Colour Sensing (ICS) system for wall colour detection is developed ICS system needs a web and Wi-Fi for detection of colour levels.The rod may artificially corroded by an electrochemical accelerated corrosion technique using chloride solution (Xiong Yan et al.2017).This processes is carried out for several days were the steel totally corroded to lost its whole Strength. While the rod corrodes, the colour will change accordingly in the rod depends on the intensity and light emitted from the corroded rod. The corroded steel bars are tested with the color sensor which will gives the difference in frequency with the original steel rod. The spectrum of the rusted color is statistically determined in the Red-Green-Blue (RGB) color space (Chen et al., 2009). The colour sensor receives the frequency of the corroded steel bar and reflect back the of the steel bar varies with different frequencies. To predict the residual strength of the steel rod, the sensor techniques is used in this research.

2. MATERIALS REQUIRED

Color sensor, Arduino Board, Steel Rod, Stainless Steel, Dual DC power supply, Sodium Chloride., Distilled Water, Corrosion induced tank and wires.

2.1 COLOR SENSOR

The Colour sensor is the photoelectric gadgets which could emit light and locate the colour of contemplated light from an item. These sensors can locate the depth of light reflected from an item and differentiates the number one shades like red, blue, and green. These also are referred to as colour detectors. Colours sensors can illuminate the item with huge wavelength, light ratio, and decide the light intensity of the colours (red, blue, green, and white). The ratio of intensity of the light determines the quantity of light contemplated and absorbed with the aid of using the item.

2.2 WORKING PRINCIPLE OF COLOUR SENSORS

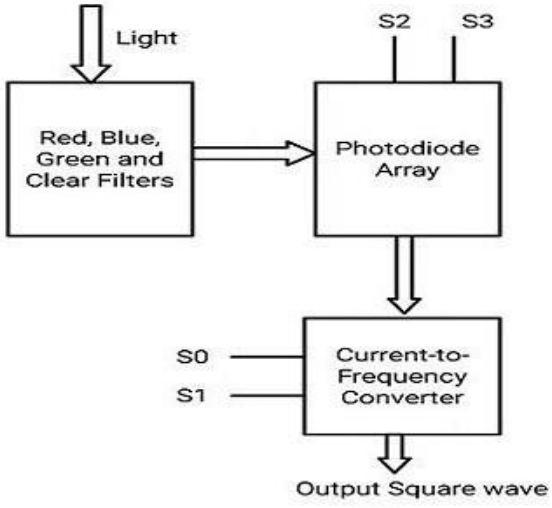
As we recognize that colorings are the maximum essential attributes to apprehend and compare the residences of an item or material. So, those sensors are the detectors used to locate the coloration of an item while subjected to light and additionally rejects the undesirable UV light and infrared light. Generally, sensors at the precept of diffuse generation. These are employed in electronics, optics and, software program generation to feel the huge variety of colorings. When white light is illuminated at the target, then the sensor is activated with three filters, that have three distinct wavelengths and determines the coloration of the target with admire to the RGB scale.

In the case of fibre optics, coloration sensors work at the precept of overall inner reflection. The quantity of light transmitted and pondered from the focused item relies upon at the optical glass fibres. When the white light is illuminated at the focused item through optical fibre, For example, the TCS3200 coloration sensor makes use of 3 filters for 3 colourings to investigate the colour pondered through the item. Another filter is for clear, this means that no filter. The form of filter (red filter, green filter, blue filter, and no filter) is chosen primarily based totally at the photodiode pins S2 and S3 as proven withinside the figure. This sensor offers the output rectangular wave with a 50% duty cycle. The converter is used to convert the light depth and pondered coloration into frequency. The frequency of the output is without delay proportional to the light depth and relies upon at the pins cutting-edge to frequency converter pins S0 and S1 i.e., high/low. From the received output, we are able to manage the frequency of the mild for 100%, 20%, and 2%. This output rectangular may be given to a microcontroller without delay.

2.3 TCS 3200 COLOUR SENSOR MODULE

TCS3200 chip is designed to locate the colour of light incident on it. It has an array of photodiode (a matrix of 8x8, so a complete sixty-four sensors). These

photodiodes are protected with 4 sort of filters. Sixteen sensors have RED filter over them hence can degree most effective the element of red with inside the incident light. Likewise other 16 have GREEN filter and 16 have BLUE filter. As you must realize that any seen shade may be broken into 3 number of primary colours. So those 3 sorts of filtered sensors allow degree the weightage of every of number primary colours in incident light. The rest sixteen sensors have clean filter. TCS3200 converts the depth of incident radiation into frequency. The output waveform is a 50% duty cycle square wave. You can use the timer of a MCU to degree length of pulse and hence get the frequency. The output of TCS3200 is to be had in single line.



3.EXPRIMENTAL INVESTIGATION COLOR SENSOR

The Color sensor is the photoelectric gadgets which could emit light and locate the color of contemplated light from an item. These sensors can locate the depth of light reflected from an item and differentiates the number one shades like red, blue, and green. These also are referred to as color detectors. Fig 1 shows the image of color sensor.

Fig 1 color sensor

Colors sensors can illuminate the item with huge wavelength, light ratio, and decide the light intensity of the colors (red, blue, green, and white). The ratio of intensity of the light determines the quantity of light contemplated and absorbed with the aid of using the item.

3.1 ARDUINO BOARD

Arduino UNO is a open- supply microcontroller board that may be included into loads of digital tasks. This board may be interfaced with different Arduino forums, Arduino shields, and Raspberry Pi forums and may manage relays, LEDs, servos, and automobiles as an output. Arduino UNO capabilities AVR microcontroller Atmega328, 6 analogues enter pins, and 14 virtual I/O pins out of which 6 are used as PWM output.

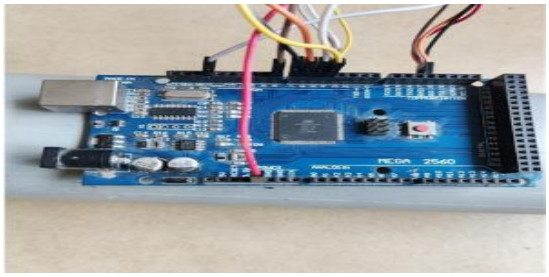


Fig 2 Arduino mega board

This board carries a USB interface i.e. USB cable is used to attach the board with the laptop and Arduino IDE (Integrated Development Environment) software program is used to program the board. The unit comes with 32KB flash reminiscence this is used to keep the quantity of commands whilst the SRAM is 2KB and EEPROM is 1KB. The running voltage of the unit is 5V which tasks the microcontroller at the board and its related circuitry operates at 5V whilst the enter voltage degrees among 6V to 20V and the endorsed enter voltage degrees from 7V to 12V.fig 2 s

3.2 SENSOR SETUP

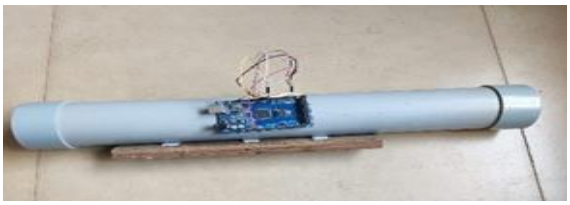


Fig 4 Sensor Setup side view

The color sensor is connected to the Arduino board with the help of wire. The Arduino board which is

coded with the above coding is connected with the power system. the color sensor is placed on the pipe like circular chamber where the steel rod of 0.5m length with various diameter are is placed. The chamber is closed on both sides in order to not allow the atmospheric light to fall on the specimen. Which helps the sensor to focus only on the specimen without any distraction of light from the atmosphere.as shown in fig.3 &4

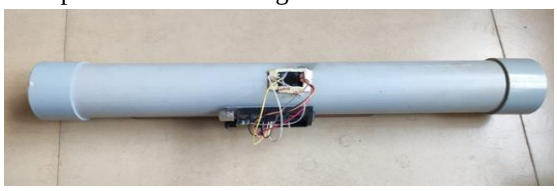


Fig 3 Sensor setup top view

3.3 STEEL RODS

Steel bar used as a tension device in reinforced concrete and reinforced masonry structures to strengthen and aid the concrete under tension. Concrete is strong under compression, but has low tensile Strength. Steel rod is one of the structural member of the building which with stand the load of the beams and columns. High yield steel reinforcement has a characteristic yield strength of 500 N/mm2 and is designated as Grade 500 in BS 4449, Specification for carbon steel bars for the reinforcement of concrete. It is supplied as deformed round bars. Standard diameters are from 8 mm to 40 mm.in this study only 10mm,12mm and 16mm diameter bars of 0.5 m length is used. here we us 15 nos of each dia bars are taken for accelerated corrosion.

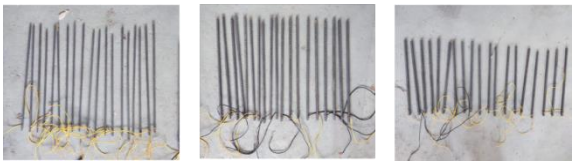


Fig 5 Steel rod of 10mm,12mm and 16mm diameter

3.4 ACCELARATED CORROSION

Accelerated corrosion tests provides the possibility to expose materials under controlled and stressed conditions to test their corrosion resistance. One advantage with accelerated corrosion tests are shorter exposure times compared to outdoor exposures. This accelerated corrosion test is achieved by galvanostatic method. By this method steel will corrodes more effectively and increase the speed of corrosion double the time than normal natural corrosion. In this the steel rod of 15nos on each diameter if 10mm,12mm,16mm with constant length of 0.5 m is soaked in a sodium chloride solution of 5% concentration. The dual power DC power supply with voltage of 12volt is connected to the one end of the rods which is positive and the other end of the rod is connected to the stainless steel which act as negative and here 1k resister is connected between the Dc power supply and rod in order to avoid the direct sorting of current. When the current passes through the steel rod it starts to corrode and the days by day degree of corrosion increased. when the current passes through the steel rod immersed in sodium chloride solution the protective film surround the steel rod will diffuse and it starts to corrode this corrosion will change the color of the steel rod.

Fig 6 Accelerated corrosion setup

3.5 FREQUENCY MEASUREMENT

The sample (8mm,10mm,16mm) after 3 days corrosion is dried and tested with the color senser setup and the frequency with respect to the colour of the corroded steel is measured with the help of colour and the values are noted.

Fig 7 Frequency Testing

3.6 UNIVERSAL TESTING MACHINE

The physical and tensile strength properties of steel is measured by using universal testing machine. Each and every corroded rod is tested to get the ultimate Strength of the rod. accordingly, the Strength of the steel rod will decreases with increase in degree corrosion. The tensile Strength is carried out daily until the steel lost its whole Strength.

Fig 8 Universal testing machine

4.RESULT AND DISCUSSION

FOR 10 MM DIAMETER BAR

Table1.Test results for10mm diameter bar

S.no	Dia of bar in mm^2	Initial cross sectional area of steel rod in mm^2	Final cross section mm^2	Reduction in cross sectional area after corrosion in mm^2	Distance from sensor (mm)	Rate of corrosion in percentage	Frequency (Hz)	Ultimate Stress (N/mm^2)
1	10	78.53	0.00	0.00	66.2	0.00	191	467.86
2	10	78.53	77.84	0.69	66.24	0.88	196	460.41
3	10	78.53	76.60	1.93	66.32	2.46	202	456.27
4	10	78.53	75.91	2.62	66.37	3.33	209	453.37
5	10	78.53	75.43	3.10	66.40	3.95	216	447.16
6	10	78.53	74.40	4.13	66.47	5.26	223	445.09
7	10	78.53	74.05	4.48	66.49	5.70	232	440.95
8	10	78.53	73.36	5.17	66.54	6.58	248	438.88
9	10	78.53	73.02	5.51	66.56	7.02	260	434.74
10	10	78.53	72.33	6.20	66.60	7.89	272	433.91
11	10	78.53	72.19	6.34	66.61	8.07	281	430.60

Graph is plotted between frequency and ultimate Strength for 10 mm dia bar from the obtained results and linear equation is formed.

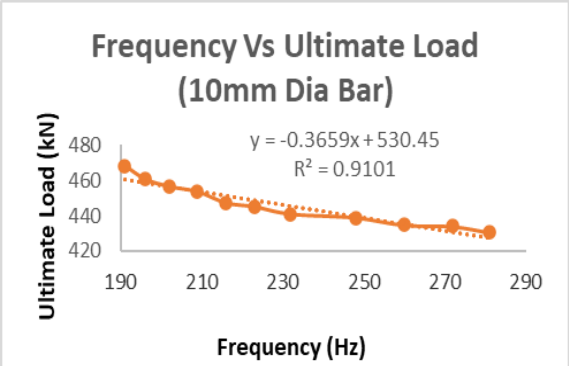


Fig 9. Frequency Vs Ultimate Load (10mm Dia Bar)

Graph is plotted between frequency and Rate of corrosion for 10 mm dia bar from the obtained results and linear equation is formed.

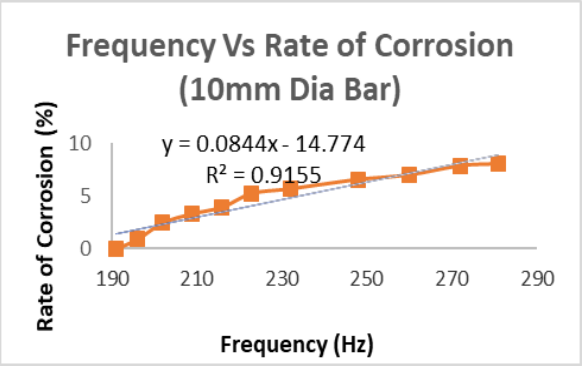


Fig 10. Frequency Vs Rate of corrosion (10mm Dia Bar)

FOR 12MM DIAMETER BAR

Table 2. Test results for 12mm diameter bar

S.no	Dia of bar in mm^2	Initial cross sectional area of steel rod in mm^2	Final cross section mm^2	Reduction in cross sectional area after corrosion in mm^2	Distance from sensor (mm)	Rate of corrosion in percentage	Frequency (Hz)	Ultimate Stress (N/mm^2)
1	12	113.09	113.09	0.00	64.2	0.00	251	681.15
2	12	113.09	111.80	1.29	64.27	1.14	265	671.56
3	12	113.09	110.23	2.86	64.35	2.53	271	667.20
4	12	113.09	109.51	3.58	64.39	3.16	282	665.45
5	12	113.09	109.22	3.87	64.41	3.42	291	663.71

6	12	113.09	108.94	4.15	64.42	3.67	297	654.11
7	12	113.09	107.36	5.73	64.51	5.06	313	652.37
8	12	113.09	107.08	6.01	64.52	5.32	321	651.50
9	12	113.09	106.93	6.16	64.53	5.44	328	645.39
10	12	113.09	105.93	7.16	64.59	6.33	347	644.52
11	12	113.09	105.79	7.30	64.59	6.46	361	637.54

Graph is plotted between frequency and ultimate Strength for 12 mm dia bar from the obtained results and linear equation is formed.

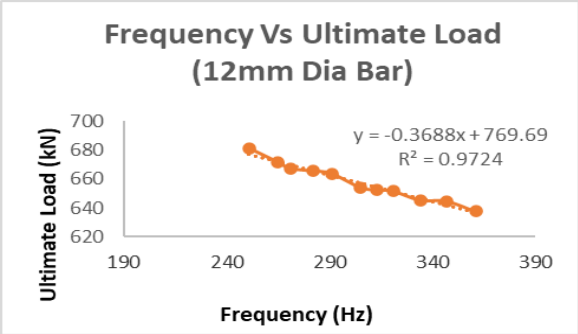


Fig 11. Frequency Vs Ultimate Load (12mm Dia Bar)

Graph is plotted between frequency and Rate of corrosion for 12 mm dia bar from the obtained results and linear equation is formed.

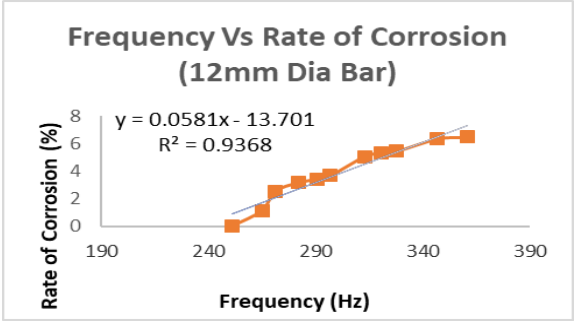


Fig 12. Frequency Vs Rate of corrosion (12mm Dia Bar)

FOR 16MM DIAMETER BAR

Table 3. Test results for 16mm diameter bar

S.no	Dia of bar in mm^2	Initial cross sectional area of steel rod in mm^2	Final cross section mm^2	Reduction in cross sectional area after corrosion in mm^2	Distance from sensor (mm)	Rate of corrosion in percentage	Frequency (Hz)	Ultimate Stress (N/mm^2)
1	16	201.06	201.06	0.00	60.2	0.00	284	707.15
2	16	201.06	199.69	1.37	60.25	0.68	296	703.91
3	16	201.06	198.78	2.28	60.29	1.14	312	697.44
4	16	201.06	196.95	4.11	60.36	2.05	335	692.58
5	16	201.06	195.58	5.48	60.42	2.73	342	687.73
6	16	201.06	194.21	6.85	60.48	3.41	352	686.11
7	16	201.06	193.75	7.31	60.49	3.64	369	684.49
8	16	201.06	193.29	7.77	60.51	3.86	382	681.25
9	16	201.06	192.38	8.68	60.55	4.32	395	679.64
10	16	201.06	191.92	9.14	60.57	4.55	405	674.78
11	16	201.06	190.55	10.51	60.62	5.23	412	674.78

Graph is plotted between frequency and ultimate Strength for 16 mm dia bar from the obtained results and linear equation is formed.

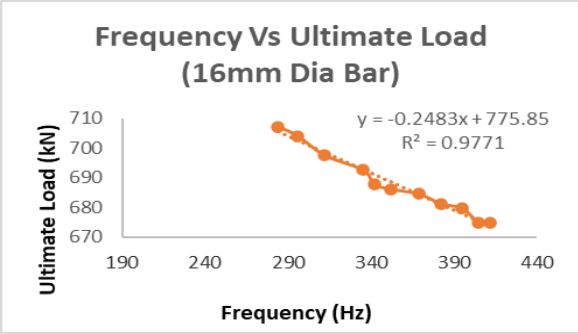


Fig 13. Frequency Vs Ultimate Load (16mm Dia Bar)

Graph is plotted between frequency and Rate of corrosion for 16 mm dia bar from the obtained results and linear equation is formed.

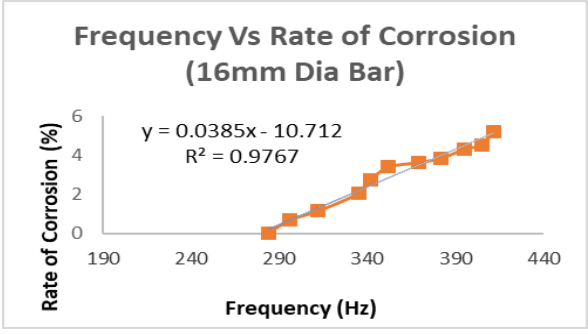


Fig 14. Frequency Vs Rate of Corrosion (16mm Dia Bar)

PREDICTED EQUATION

Table 4 Predicted equation for 10mm,12mm and 16mm diameter rod

S.no	Dia of Steel rod	Description		
		Parameters	Predicted Equation	R^2 Value
1	10 mm	Ultimate Load	-0.3659x + 530.45	0.9101
2		Rate of Corrosion	0.0844x - 14.774	0.9155
3	12 mm	Ultimate Load	-0.3688x + 769.69	0.9724
4		Rate of Corrosion	0.0573x - 13.54	0.9346
5	16 mm	Ultimate Load	-0.2483x + 775.85	0.9771
6		Rate of Corrosion	0.0385x - 10.712	0.9767

VALIDATION

Table 5 Validation table for ultimate load

S.no	Dia of Steel Rod	Frequency	Ultimate Load by testing	Ultimate Load by Predicted Equation	Difference in value
1	10 mm	297	428.53	421.78	6.75
2		305	424.39	418.85	5.54
3		310	422.32	417.02	5.30
4		316	420.25	414.83	5.42
5		320	417.63	413.36	4.27
6	12 mm	361	635.8	629.91	5.89
7		383	632.31	625.49	4.82
8		391	623.59	617.74	5.85
9		412	619.23	614.43	4.80
10		421	612.62	617.74	-5.12
11	16 mm	412	671.55	673.55	-2.00
12		423	668.31	670.82	-2.51
13		435	665.07	667.84	-2.77
14		453	660.22	663.37	-3.15
15		457	656.98	662.38	-5.40

Graph is plotted between frequency and ultimate load by testing and ultimate load by predicted equation for 10 mm diameter bar.

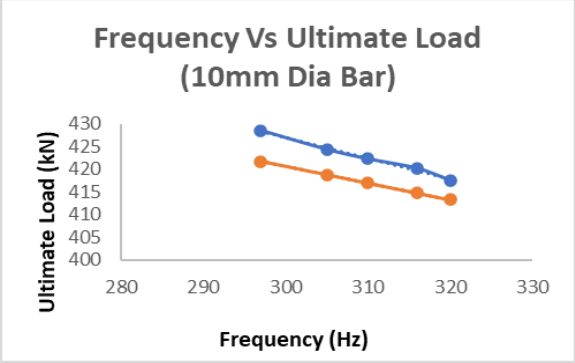


Fig 15. Validation of Frequency Vs Ultimate Load (10mm Dia Bar)

Graph is plotted between frequency and ultimate load by testing and ultimate load by predicted equation for 12 mm diameter bar.

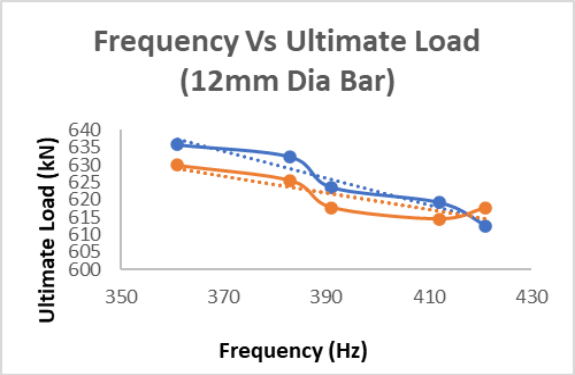


Fig 16. Validation of Frequency Vs Ultimate Load (12mm Dia Bar)

Graph is plotted between frequency and ultimate load by testing and ultimate load by predicted equation for 16 mm diameter bar.

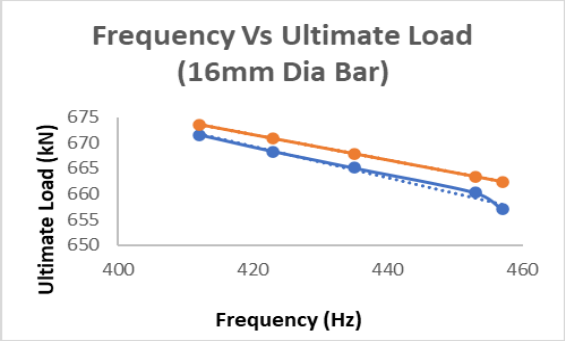


Fig 17. Validation of Frequency Vs Ultimate Load (16mm Dia Bar)

Table 5 Validation table for Rate of corrosion

S.no	Dia of Steel Rod	Frequency	Rate of Corrosion by testing	Rate of Corrosion by Predicted Equation	Difference in value
1	10 mm	297	8.77	10.29	-1.52
2		305	9.21	10.97	-1.76
3		310	10.09	11.39	-1.30
4		316	10.53	11.90	-1.37
5		320	10.96	12.23	-1.27
6	12 mm	361	7.47	7.15	0.32
7		379	7.72	8.18	-0.46
8		391	8.23	8.86	-0.64
9		412	9.49	10.07	-0.57
10		421	10.13	10.58	-0.46
11	16 mm	412	5.68	5.15	0.53
12		423	6.14	5.57	0.56
13		435	6.59	6.04	0.56
14		453	7.27	6.73	0.54
15		457	7.73	6.88	0.84

Graph is plotted between frequency and Rate of corrosion by testing and Rate of corrosion by predicted equation for 10 mm diameter bar.

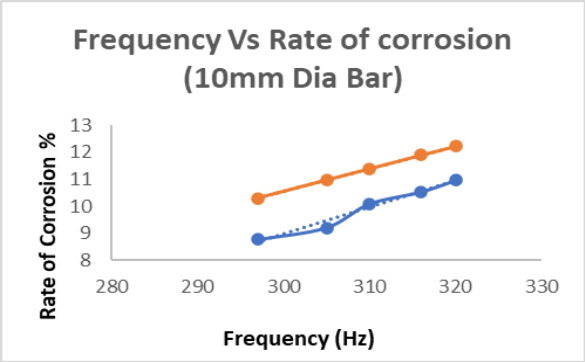


Fig 18. Validation of Frequency Vs Rate of corrosion (10mm Dia Bar)

Graph is plotted between frequency and Rate of corrosion by testing and Rate of corrosion by predicted equation for 12 mm diameter bar.

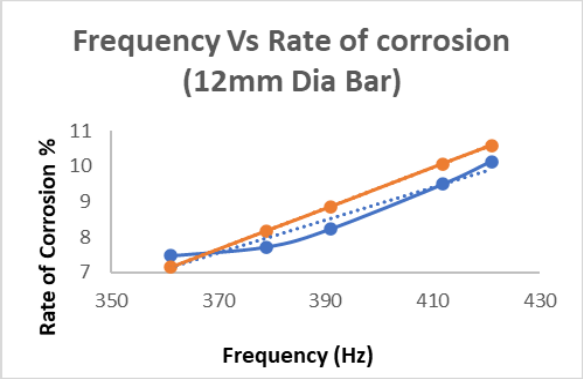


Fig 19. Validation of Frequency Vs Rate of corrosion (12mm Dia Bar)

Graph is plotted between frequency and Rate of corrosion by testing and Rate of corrosion by predicted equation for 16 mm diameter bar.

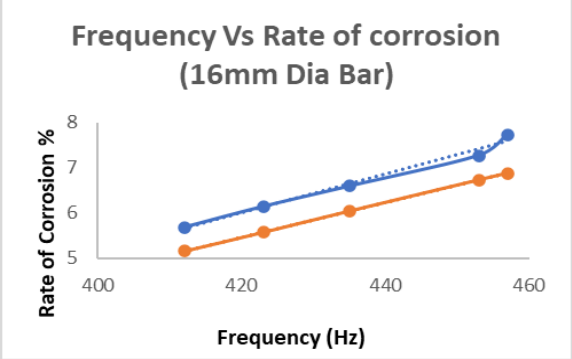


Fig 20 Validation of Frequency Vs Rate of corrosion (16mm Dia Bar)

4 CONCLUSION

- By these processes we can eliminate the manual testing of corrosion.
- We can able to find the residual strength of the reinforcement without destroy the building.
- It is the onsite processes that can be able to processes throughout the world.
- We can easily determine the strength of the steel within the fraction of second.
- determine the FREQUENCY of the steel rod in the various degree of corrosion.
- It is highly helpful for the renovation work of the building.

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