Semiconductor Optoelectronics
ISSN: 1001-5868

INVESTIGATION OF EPOXY GRANITE MATERIAL AS AN INSULATED TOOL HOLDER FOR WIRE ELECTRIC DISCHARGE MACHINE

K Gurav
1University Road, Ganeshkhind, Pune University, Pune 411007, India

Dr. V M Kale
Department of Mechanical Engineering, Rajarshi Shahu College of Engineering, Tathawade, Pimpri-Chinchwad 411033, India
*Author for correspondence
Short title: Investigation of Epoxy Granite material

Abstract - Precision of machining is influenced by stiffness, long term thermal stability, damping properties of structural material used for machine tool. wire electric discharge machine (WEDM) is a special form of cutting machine in which current carrying wire is a cutting tool which is passed through an insulator. In this study an insulated tool holder of wire electric discharge machine is manufactured using epoxy granite. This epoxy granite insulator component is tested for various properties such as Electrical Insulation, Density, Water absorption and Flexural strength; tested using Megger's test setup, Density and Water absorption setup and Flexural strength setup respectively and the results are obtained. The results are compared with the epoxy glass component and conclusions are derived. The novelty of the present work is the design of epoxy granite material as isolated utensil in case of manufacturing.
Keywords - Epoxy granite; WEDM; Insulated Tool holder; Insulators; Manufacturing; Flexural Strength; Megger's test setup.

Introduction:

Insulators are materials that do not allow the flow of electrons, because of very large energy band gap between their valence band and the conduction band. They do not let electrons flow very easily from one to another, and require significantly high amount of energy to conduct. Thus, Insulators do not conduct and can be used to resist the current flowing through conductors, by covering them. Human body can conduct electricity but is not pleasant to do so. The function of our heart can be disrupted by strong electrical shock and the current can cause burns. Hence, we need shields from the conductors that carry electricity. These shields are insulators which have high resistance to electrical current. There are three different types of insulating materials namely solid insulators, liquid insulators and gaseous insulators. Gaseous insulators are used in switch gears whereas liquid insulators in transformers as transformer oil. Solid insulators are widely used and the various materials used are mentioned below.

1.1 Solid materials used as insulators

Solid materials used as insulators are glass, mica, porcelain and various polymers. These materials are explained in detail below.

Porcelain - Porcelain insulators are made from clay, quartz or alumina and feldspar, and are covered

with a smooth glaze to shed water. Insulators made from porcelain rich in alumina are used where high mechanical strength is a criterion. [1]

Glass – Glass is a mixture of silica, soda ash and limestone. Glass is a higher dielectric strength insulator but the moisture condensation causes deposition of air dust allowing leakage of current.

Mica – This is a good stable material even when exposed to the elements. It is a good thermal conductor while being an insulator.

Polymers - Polymer insulators have two parts: one is glass epoxy rod shaped core and other is silicone rubber or EPDM (Ethylene Propylene Diane Monomer) made weather sheds. Rod shaped core is covered by weather sheds [2]. Weather sheds protect the insulator core from out-side environment. As it is made of two parts, core and weather sheds, polymer insulator is also called composite insulator. The rod-shaped core is fixed with hop dip galvanized cast steel made end fittings in both sides. But there are certain disadvantages such as moisture which enters the core if there is any unwanted gap between the core and weather sheds can cause electrical failure of the insulator. Another disadvantage is, they have post type polymeric insulators melt and bend in bush fire areas. All these materials have certain advantages and disadvantages. To overcome these disadvantages a new material can be proposed which is a mixture of granite powder and epoxy resin an epoxy granite composite. Epoxy granite material is an aggregate of crushed granite particles mixed with formulated epoxy resin. Epoxy Granite is a material that possess the properties that an insulator should have such as its mechanical strength to carry tension and weight of the conductors, it has high dielectric strength to withstand voltage stressed, it is free from other impurities, and the most important is its less porosity. Good chemical resistance, ease of manufacturing, electrical resistance, high strength to weight ratio, low thermal conductivity, non-magnetic, low water absorption which makes epoxy granite more preferable material than other conventional materials. [3].

1.2 Wire electric discharge machining:

Electrical discharge wire cutting, (Figure 1) is a EDM where the cutting tool is in the form of wire. The tensioned wire travels from a take-off spool to another while being guided by an insulator [4]. The current is passed through the wire electrode that cuts the work piece. After cutting the work piece, from the bottom spool, the wire is passed out through the cantilever arm. This process is widely used for the manufacturing of punches, dies, and stripper plates.

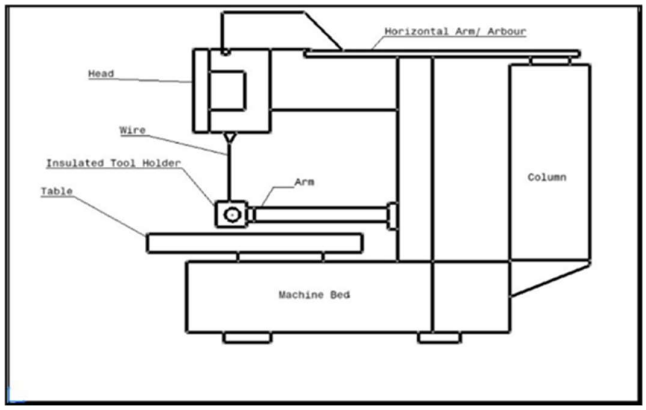

Figure 1. Schematic Diagram of typical electrical discharge wire cutting machine.

In the insulated tool holder, brass plate is embedded and each side faces of the brass plate have a tapping to which the wires are joined, where the positive charge is passed to the work piece and the negative charge is passed to the wire electrode. The current resistive material which holds the brass plate between itself restricts the outflow causing high damage to the parts of the insulator.

In this article, study is done on epoxy glass insulator with the proposed epoxy granite as a current resistive material along with properties such as vibration, and mechanical strength. The insulator of the wire electric discharge machine is made-up of epoxy granite material as an insulating material that covers a brass plate which acts as a current conductive material through which the wire is guided that cuts the material.

SPECIMEN PREPARATION

Indian Black Granite with compressive strength of 2700 kg/cm2 to 3000 kg/cm2 is selected to prepare granular. According to ASTM – C35, a test specimen size of 300x50x50 mm is decided [5].

2.1 Aggregate and epoxy selection: Epoxy granite is granite granules and epoxy mixed in certain proportion. Mechanical properties of Epoxy granite are influenced by voids if any inside the material. Generally, voids are formed because of the irregular shapes of granules and improper compaction techniques. Granite granules are made using crushing operation. After granite crushing different sizes and shapes of granules are obtained which are segregated in range of sizes as specified in Table 1. While making Epoxy granite different sized granules with different volume or weight can be considered. Best combination gives a high dense mixture. Higher density of the mixture results in minimum void content and better mechanical properties. Bigger size aggregate in high proportion gives strength to the structure whereas medium and fine size aggregates need to be used in small quantity because of the higher consumption of epoxy. Here we use small size aggregates as larger size aggregates if used they would not easily pass through the brass plate and rest at the bottom. A bigger size aggregate leads to porous insulator. Hence filler size aggregates are bonded with epoxy. The epoxy mixture added here is about 14-15% due to small size aggregates.

Table 1. Size variation of granules:

8-11 mm	4-8 mm	1-3 mm	0.1-0.3 mm	Total
40	30	20	10	100
30	25	25	20	100
20	20	30	30	100
10	15	35	40	100

2.2 Vibration frequency: The extent to which an aggregate can be compacted to produce a minimum void content is dependent on the particle size distribution and the frequency of vibration during compaction process. Proper compaction leads to perfect contact between aggregate particles which leads to minimization of component deformation and creeping characteristics. Natural frequency of well graded granite particles is around 40 - 50 Hertz. In this study, a frequency of 50 hertz was maintained during compaction process.

2.3 Specimen preparation procedure: The specimen of required size and shape is made as per the design of the mould. The aggregate and epoxy are mixed as per the required ratio with the help of stirrer. The mould (Figure 2) is vibrated at a 45Hz-60Hz frequency after pouring the mixture in the mould and proper compaction of the mixture is obtained. Generally, the curing time for the mixture is 24 hours.

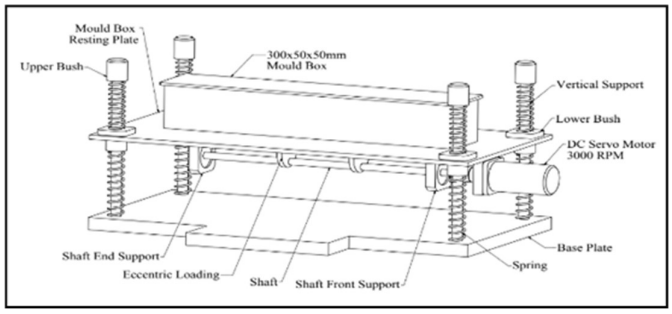

Figure 2. Mould box with vibration table.

PROPERTIES TESTING:

For an insulator it should fulfill properties such as electrical resistance, high strength, lower water absorption. Here, the attempt is to find out the maximum density of the dry mixture of different granular sizes of granite in different weight combinations, Epoxy content and vibration frequencies are the variables studied. It also aims to simplify the selection of granite granular weight combinations to maximize the density and subsequent material properties. Hence following test are conducted in order to conform the requirements.

3.1 Density Test

Density is the degree of compactness of a substance. A ratio between mass and volume or mass per unit volume. Different materials have different densities, and density may be relevant to buoyancy, purity and packing. To simplify comparisons of density across different systems of units, it is sometimes replaced by the dimensionless quantity "relative density" or "specific gravity", i.e., the ratio of density of the material to that of a standard material, usually water. Epoxy granite is a low-density material. Density of different specimens of Epoxy granite vary because of the varying sizes of the aggregates and the weight percentage in the mixture [6]. For the calculation of density of epoxy granite, the actual dimensions of the specimen prepared is taken. Following the dimension measurement weight of the specimen is measured. Volume is calculated from the actual dimensions and we obtain the density of the specimen. Table 2 shows the density test of epoxy granite specimen.

Table 2. Densities of specimen:

Specimen No.	Density (gm/cm^3)
1	2.33
2	2.29
3	2.37
4	2.54
5	2.44
6	2.29
7	2.3
8	2.44
9	2.16
10	2.37
11	2.4
12	2.4

3.2 Water absorption test

Water absorption is the ability of porous materials to retain a certain amount of liquid (water) in their air spaces, which is a key property when it comes to the resistance of the product in the environment.

Water absorption gives an idea of strength of aggregate. Aggregates having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness tests [6]. In this test specimens are soaked in water for 24 hours under 25℃ and the weight before and after soaking the specimen are analyzed to obtain the amount of water absorption, in Table 3. Figure 3 shows the weight machine, Figure 4 shows the specimen before and after the water absorption test and Figure 5 shows the specimen sub-merged in water.

Table 3. Water absorption Test results:

Specimen	Weight (Kg)		Percentage of water absorbed
	Before	After	
1	0.749	0.773	3.204
2	0.765	0.77	0.654
3	0.8	0.803	0.375
4	0.901	0.909	0.888
5	0.871	0.874	0.344
6	0.997	1.001	0.401

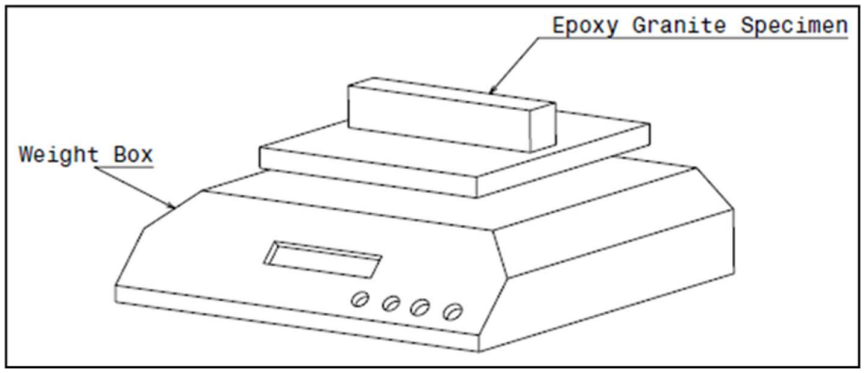

Figure 3. Weights of Specimen:

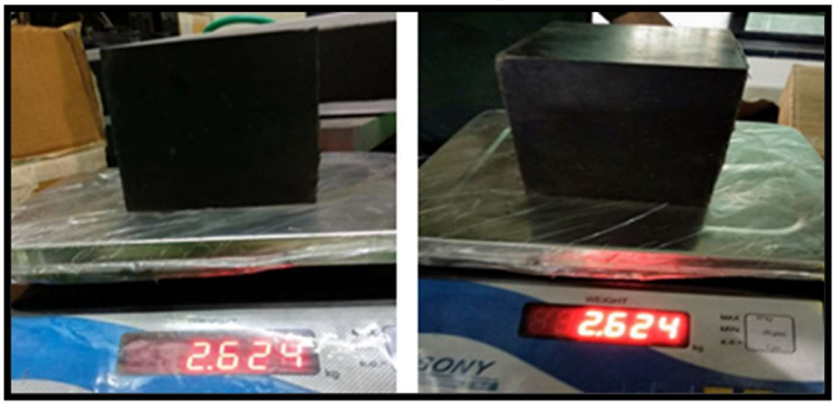

Figure 4. Before and after water absorption test weight of epoxy granite specimen:

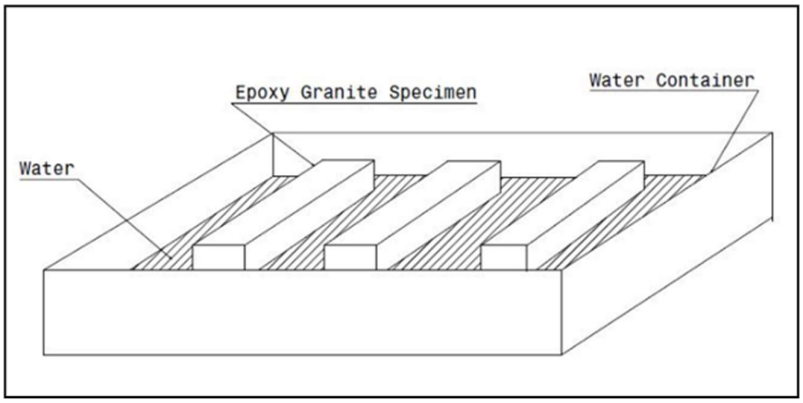

Figure 5. Specimen sub-merged in water

The percentage of water absorption for each of the samples is evaluated using the equation given below

Water absorption (%) = [(B-A)/A] x 100 (1)

Where,

A= Oven dry weight of specimen.

B= Surface Saturated dry (SSD) weight of specimen.

3.3 Flexural strength test:

The test was conducted in compliance with standard C-580 to evaluate the Flexural Strength and material characteristics of the Epoxy Granite. The specimens of granite were prepared as per standard [7] and 12 number of specimens with varying composition of Epoxy and Aggregate percentage were tested, shown in Figure 6. The specimen dimensions to be tested were 300x50x50 mm. The specimens were tested in a Simply supported manner on the UTM machine, the results obtained (Table 4) and the specimen with good flexural strength was further tested on the Set-up for the Cantilever beam. Loads of 1,3 & 8 kg were applied while loading and unloading of 3 cycles each. The specimen showed some amount of deflection which was noted. By using standard Flexural Strength Formula, the Modulus of Elasticity was calculated.

A Graph was plotted, Figure 12 of load versus deflection and the equation of the curves formed were clearly exhibiting the validation of the experimental setup and repeatability of the values.

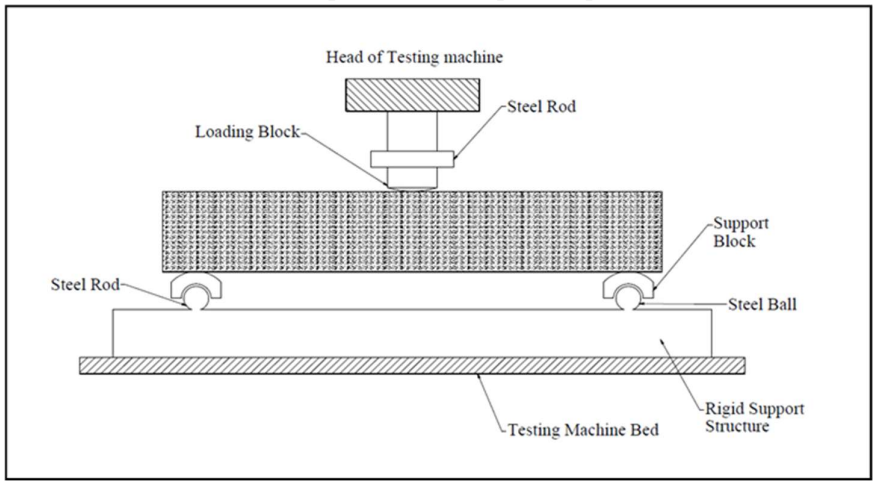

Figure 6. Flexural strength testing set-up

Table 4. Densities and max. load of specimen:

Specimen No.	Density (gm/cm^3)	Max load (KN)
1	2.33	4.8
2	2.29	2.73
3	2.37	6.1
4	2.54	7.95
5	2.44	8
6	2.29	3.99
7	2.3	4.35
8	2.44	7.14
9	2.16	1.86
10	2.37	4.7

3.4 Electrical Insulation:

For testing Electrical insulation of material, Megger Insulation Test is used in compliance with the standard. High Voltage Testing set of 5KV is used. The figure shows schematic diagram for the test. Connect the circuit as described in schematic Figure 7. Press the button on megger, the megger will generate the current. Gradually increase the voltage from 1 KV to 5 KV and note down the readings of current passed. Table 5 shows the amount of current passed throughout the specimen while conductance of the test.

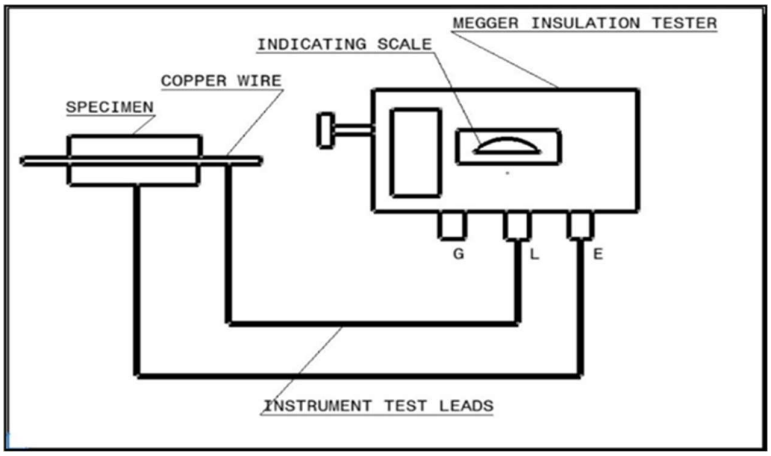

Figure 7. Megger's test set-up:

Table 5. Megger's Test result on all specimen

Voltage Applied (kV)	Current Passed (mA)
1	0
2	0
3	0
4	0
5	0

4. DESIGN AND DEVELOPMENT OF INSULATED TOOL HOLDER

As per the conductance of test it clearly exhibits suitability and usability of the material for our insulator tool holder. Hence, we proceed with design and development of insulated tool holder.

4.1 Development of insulated tool holder

For the manufacturing of insulator, the entire design of the wire electric discharge machine was studied and the required dimensions of the insulator unit were obtained. Using the dimensions obtained from the study three Dimension CAD model was prepared in a software. For this CAD model a mould is designed. In this mould a mixture of epoxy granite is casted. This designed mould is manufactured as per the CAD drawings plotted. Epoxy granite insulator is prepared by mixing and setting the mixture in the mould as per the design requirements. After solidification this insulator is machined for making the holes of required sizes. The component prepared is tested on the wire electric discharge machine and the results were obtained. The properties calculated are current resistance, damping ratio, chemical resistance, high strength to weight ratio and water absorption.

4.2 Mould design of insulated tool holder

The mixture of epoxy granite is to be casted for which a mould is designed as per the required dimensions of the insulator. This designed mould is manufactured as per the drawings provided. The design and manufacturing phase depend on factors whether the brass plate is perpendicular with respect to the L bracket for proper location of brass plate. Figure 8 shows the CAD model design for the brass plate assembly and figure 8 shows the CAD model design for mould assembly.

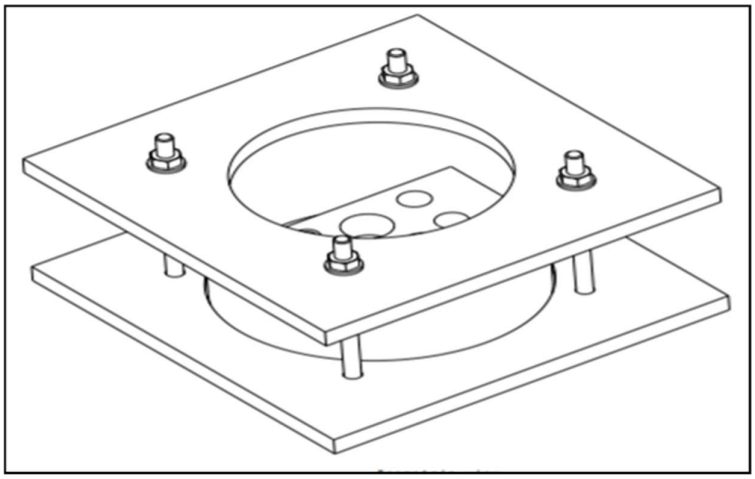

Figure 8. Mould assembly

The mould consists of eight different components which are assembled to form the mould. The mould consists of a PVC pipe, top plate, bottom plate, horizontal and vertical brass plate assembly, L plate, screws and bolts. The PVC pipe has a height of 64 mm with external diameter 114 mm and thickness 2 mm.

4.3 Machining of granite insulator:

Outer diameter turning operation of the raw moulded epoxy granite is carried out. An ‘O’ ring slot is prepared on the moulded part. Milling of the top and bottom face is the next operation performed during the machining. Drilling holes are made and finally both the side faces are grinded as per requirements. Figure 9 and 10 show the tool holder before and after machining.

Figure 9. Tool holder specimen before machining:

Figure 10. Tool holder specimen after machining

5. RESULT AND DISCUSSION:

The specimens are tested for the above-mentioned tests and the results were obtained and noted. Four samples are prepared with different aggregate sizes and epoxy percentages and the tests are conducted. The best sample is selected based on the comparison with epoxy glass properties.

5.1 Density:

Four samples are tested and their densities are calculated using the density test and it was observed that specimen 4 had the highest density amongst all, giving us the composition of 30-25-25-20 being most superior.

5.2 Water absorption test:

Test Clearly exhibits that with increase in Density, porosity of the specimen decreases and hence water absorption capacity also reduces, same is shown in figure 11.

Specimen e with aggregate of 30-25-25-20 with epoxy content of 16% is exhibiting better water absorption and comparatively superior density amongst other.

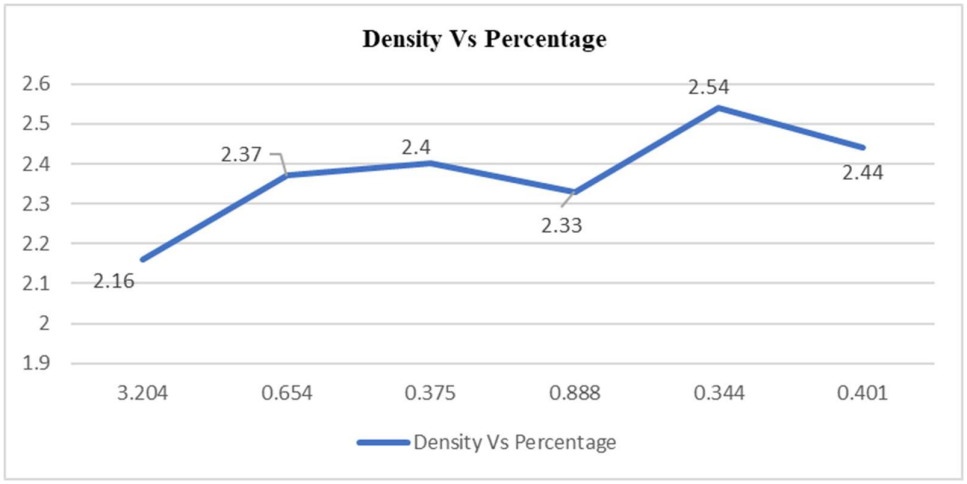

Figure 11. Density vs. Percentage

5.3Flexural Strength Test:

As per the conductance of Cantilever and Simply supported beam testing, specimen having an Aggregate percentage of (30-25-25-20) and Epoxy type (E1) content of 16% and 20% Epoxy resin and Vibrating frequency of 60Hz gave better properties such as maximum density and maximum loading carrying capacity. We can go for 16% of epoxy resin content as there is not much difference in the properties and being more economical to use it at the same time. This specimen has the potential to satisfy our end purpose and application.

Hence, from the results in Figure 12, it is reflecting that density has a direct relation with maximum load and density is directly proportional to the maximum load. Also, modulus of rupture is directly proportional to maximum load. Hence, density is directly proportional to the modulus of rupture, and is shown in Figure 13.

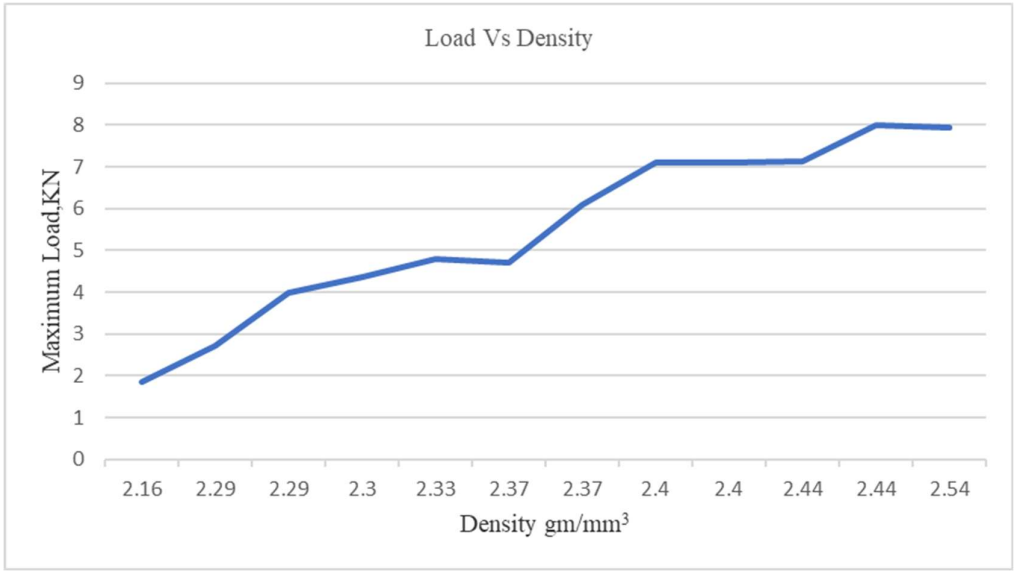

Figure 12. Load vs. Density

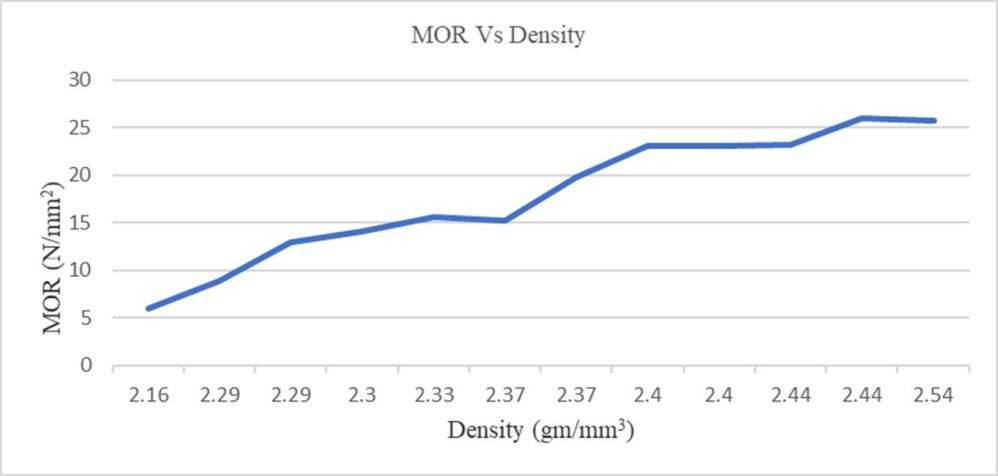

Figure 13. MOR vs. Density

MOR= 3FL / 2bd^2 (2)

MOR= modulus of rupture, N/mm2
F = load at a given point on the load deflection curve, N
L = Support span, mm
b = Width of test beam, mm
d= Depth or thickness of tested beam, mm

5.4 Electrical Insulation test:

Megger Electrical Insulation test clearly indicates the satisfactory results and depicts Epoxy granite as proficient insulator.
At Actual this part is manufactured and tested on Wire Electric Discharge Machine and it is observed that it satisfies the purpose for the same.

Theoretical implications

Our research also has the methodological implication as it contributes to the literature by providing the measures of investigation of epoxy granite material. It provides the antecedents influencing the compare with other material as glass component. the insights on this study approach and usage of various further research work derived.

Limitations and Future scope

This study does have some limitations that need to be considered when interpreting the results. However, All the experiment practically, reliability and credibility were the various measures of trust worthiness as considered in this study. Hence there can be more parameters on it. this research focus on other parameters also. Future research may examine whether the trust in experiment by the other parameters. These results are limited in this study approach be generalized, hence giving scope for further research in other regions.

6. CONCLUSIONS:

Composition of aggregate 30-25-25-20, 16% Epoxy resin and vibration frequency of 60Hz gives highest density.

Flexural Strength of Epoxy granite material states density is directly proportional to the flexural strength.

As density increases water Absorption property of material decreases.
Epoxy Granite Specimen depicts satisfactory results as an insulator in Megger's test.

CONFLICT OF INTEREST –NIL

SOURCE OF SUPPORT -NONE

7. REFERENCES:

[1] Mukherjee S 2013 The Sci. of Clays: App. in Ind. Engg. and Env., 15 221
[2] Sourabh Kumar and Prof. Anil Kumar 2016 Int. J. for scientific research & Development, 05 172
[3] Kailas G, V. M. Kale, Akash S. 2020 Study of Epoxy Granite Properties using Indian Origin Granite Bulletin of Engineering 13 97
[4] Chang Sup Lee, Je Hoon Oh, Dai Gil Lee, Jin Ho Choi 2001 Journal of Material Processing Tech. 113 172
[5] ASTM C 35 Standard Specification for Inorganic Aggregates for Use in Gypsum Plaster 1
[6] Subhash C, Rama M, Sai M, Harsha B and Rama S 2017 Development of Granite Powder Reinforced Epoxy Composites Materials Today: Proceedings 5 13010
[7] ASTM C 580 – 02 Standard Test Method for Flexural Strength 3